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ABSTRACT

Pedagogical content knowledge has been shown to be important to the work of teachers. This paper assumes it should be incorporated into the curriculum of teacher preparation and explores when and how that might be done. Results from the literature are reported in order to raise issues needing to be resolved before this question can be answered satisfactorily. The preparation of teachers typically occurs in three stages: a liberal education together with acquisition of competence in subject matter, the professional study of education, and clinical experience in the schools. Some questions raised for discussion are: (1) to what extent does pedagogical content knowledge need to be taught at all? (2) what is the derivation of pedagogical content knowledge? (3) to what extent can teachers learn pedagogical content knowledge effectively in preservice academic settings versus inservice clinical settings? and (4) how can universities effectively teach pedagogical content knowledge? This paper neither exhausts the range of issues pertaining to when teachers should learn pedagogical content knowledge nor resolves any of them. Rather, it simply points out that this is an important area which has yet to be explored, indicates the complexity involved in trying to formulate an answer, and suggests some of the kinds of investigations that might help practitioners make better decisions regarding this aspect of teacher education. (LL)

WHEN SHOULD TEACHERS LEARN PEDAGOGICAL CONTENT KNOWLEDGE?

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Pedagogical content knowledge has been shown to be important to the work of teachers. This paper assumes it should be incorporated into the curriculum of teacher preparation and explores when and how that might be done. Results from the literature are reported in order to raise issues needing to be resolved before this question can be answered satisfactorily.

The preparation of teachers typically occurs in three stages: a liberal education together with acquisition of competence in subject matter, the professional study of education, and clinical experience in the schools. In the first stage teachers accumulate subject matter knowledge, among other things; in the second stage they begin to acquire explicit knowledge of pedagogy and related areas; and in the third stage they synthesize, apply, and adapt these two forms of knowledge—of content and of pedagogy—in the course of practice teaching experiences. The third phase in fact continues beyond formal teacher education, as teachers learn more about students, schools, curriculum, methods, and even subject matter through their first few years of teaching.

Pedagogical content knowledge is the specialized knowledge that teachers develop regarding the teaching of particular subject matter. This kind of knowledge has been shown to be part of the repertoire of experienced teachers and to be important in their work (e.g., Carpenter, Fennema, Peterson, & Carey, 1988; Wineburg & Wilson, 1988). The simplest characterization of pedagogical content knowledge is that it is a sort of synthesis of subject matter knowledge and general pedagogical knowledge.[1] Consequently, pedagogical content knowledge could be taught explicitly at any or all of the three stages of teacher preparation described above, and it could be further developed during the early years of teaching.

This paper assumes that it is important that teachers acquire some degree of pedagogical content knowledge in whatever disciplines they teach. The question then arises, when should they learn it? This question has no simple answer at present, nor is this paper going to suggest one. Instead the paper will identify and discuss several issues that bear on the question and that need further investigation before an adequate answer can be proposed. Although many of the examples in this paper are from mathematics, the ideas discussed generalize to other content areas.

To what extent does pedagogical content knowledge need to be taught at all? This is not to say, "Is it important?" but rather, "To what extent will teachers naturally and spontaneously develop pedagogical content knowledge?" Some aspects of pedagogical content knowledge are

[1] General pedagogical knowledge is used here, as in much of the literature, to include knowledge of students and how they learn, of curriculum, of strategies for planning and management, and other content-independent aspects of teaching, as well as of pedagogy per se.

formulated without explicit instruction. One obvious example is a teacher's values regarding the subject matter, which includes such things as understanding of the semantic and syntactic structures described by Schwab (1978), attitudes about how useful or difficult the content is, and assumptions about what it means to know, say, mathematics (Ball, 1988b) or history (Wilson & Wineburg, 1988).

> When future teachers study the subject matter they will later teach to high school students, they are not just learning facts; they are acquiring a world view imbued with values. When teachers have forgotten many of the facts they learned in college, they will still remember value-laden impressions. These values shape the development of their pedagogical content knowledge and their interpretation of the texts they teach high school students. (Gudmunsdottir, 1990, p. 47)

Furthermore, as Ball points out, these values are mostly implicit, forged from years spent in classrooms and in the larger culture.

Although beginning teachers may have formulated values regarding the subject matter, values that will influence significantly how they teach it, these values may or may not be appropriate. For instance, many prospective teachers, especially at the elementary school level, view mathematics as a fairly arbitrary set of rules that are handed down from on high, and see learning mathematics as nothing more than memorizing how and when to apply those rules. This is an inaccurate and extremely limiting perspective, antithetical to modern principles of mathematics education (e.g., National Council of Teachers of Mathematics, 1989). This state of affairs implies the need for future teachers to explore and challenge their implicit values regarding subject matter sometime in their formal preparation for teaching.

The same difficulty arises in more tangible areas than values. Lortie (1975) pointed out the powerful influence that simply sitting in math or history classes through years and years of schooling can exert on a new teacher's own pedagogical choices. In the case of mathematics, much K-12 teaching relies heavily on drill and practice of largely rote procedures—that is, the pedagogical technique in the schools mirrors the reigning values about mathematics itself. As "apprentice observers," prospective teachers thus internalize a very limited view of how mathematics is taught.

In general, whatever pedagogical content knowledge future teachers may have absorbed before they enter university-level coursework needs to be examined and reworked. But the question heading this section arises again at the university: To what extent will teachers construct or revise pedagogical content knowledge on their own, without explicit college instruction, by synthesizing ideas from their subject matter knowledge and their studies of generic curriculum and pedagogy? One means of exploring this question is at hand. Teacher education programs vary widely in the degree to which their curricula emphasize content-specific matters, from not at all to a great deal. Selecting programs from each extreme and comparing their graduates' understanding and use of pedagogical content knowledge, both in their beginning teaching experiences and a few years later, would tell us something about the role of explicit instruction in this area. There is already clear evidence that some beginning teachers do in fact invent pedagogical content knowledge (e.g., Wilson, Shulman & Richert, 1987), but further investigation can help determine how many teachers do so, how much such knowledge they develop, and under what circumstances.

What is the derivation of pedagogical content knowledge? The prototypical view of pedagogical content knowledge is that it results from the transformation of subject matter knowledge into forms which facilitate the learning of that subject matter. Shulman (1986), for instance, described it as "the most useful forms of representation of [subject matter] ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9), together with an understanding of how learners perceive or misperceive the ideas. Ball (1988a) reiterated this approach in her work with preservice elementary teachers in mathematics, declaring "'forms of representation' ... to be the crucial *substance* of pedagogical content knowledge" (p. 298). This view of pedagogical content knowledge corresponds to what Dewey (1969) referred to as "psychologizing" the subject matter.

Marks (1990a; 1990b) acknowledged and illustrated this derivation of pedagogical content knowledge, labeling it *interpretation* of content. An example from mathematics is the ability to sketch half a dozen different kinds of pictures or diagrams representing the concept of "function"

and to discuss the strengths and weaknesses of each for representing that concept. Marks, however, went on to demonstrate that pedagogical content knowledge can grow out of general pedagogical knowledge in the process of applying it to the teaching of particular content; he called this derivation the *specification* of knowledge of general pedagogy. A mathematical example is the ability to generate an appropriate sequence of questions to guide a student toward discovering the relationship between diameter and circumference in a circle. Marks also showed that pedagogical content knowledge can derive from a *synthesis* of knowledge of general pedagogy and subject matter, without being clearly traceable to either form, and from an *extension* of existing pedagogical content knowledge.

These various derivations spring from different sources, represent different cognitive processes, and suggest different settings. In order to make wise choices about where and how to focus the curriculum of teacher education, we need to understand to what extent each of these derivations is important.

If interpretation of subject matter in representational forms is the predominant way that pedagogical content knowledge is formed, as some researchers seem to assume, then such knowledge needs to either build on an established base of content knowledge or else be developed as part and parcel of that content. In either case a student may need little or no background in educational foundations or professional studies in order to learn to represent the subject matter in a rich variety of ways. Let's revisit the mathematical example given above: the ability to produce quickly a half-dozen different kinds of diagrams and symbolic forms describing a given function and to discuss how they are related. These representations include such things as a function machine (a "black box" with an inlet and an outlet), an arrow diagram pairing inputs with outputs, a table of values, a set of ordered pairs, a coordinate graph, an algebraic equation, and a verbal description. Note that a mathematics student requires no awareness of cognitive learning theory, curriculum, or lesson planning to be able to generate and discuss these representations. Virtually all students are familiar with most of these forms even before reaching college and can perform various manipulations with them. Yet the crucial aspect of this chunk of knowledge from the

perspective of someday teaching it to kids is the understanding of how these forms are related to one another—say, an equation and its graph—and of the particular aspects of the concept (function) that each form represents effectively, or in some cases misrepresents. These more conceptual components of knowledge about functions could be taught at the same time as the more standard manipulations, though they seldom are. Instead, when they appear at all they are usually found in university math textbooks for elementary teachers (e.g., Billstein, Libeskind & Lott, 1990; Krause, 1987); many secondary math teachers may never see or hear such ideas discussed.

The previous example raises two important issues. First, should prospective teachers study in their academic coursework the content they will actually teach somewhere in the K-12 schools? In fact, elementary mathematics and reading may be the only areas of the K-12 curriculum in which this routinely occurs. In other areas future teachers usually sample rather than cover the content, often at a much more advanced and abstract level. For example, an elementary teacher's science coursework might consist of one course each in botany, oceanography, and mechanics. Is it reasonable to expect that a teacher can adapt what she knows about university-level botany (all those Latin names!) to prepare herself to teach biology to second-graders, or sixth-graders? In some extreme cases teachers have virtually no background in the content they will teach; a high school social studies (read U. S. history) teacher might have one college course in European history and a major in anthropology. Is this a reasonable preparation in subject matter? Even in mathematics, most secondary teachers with math majors haven't seen Euclidean geometry since they themselves were in high school. Is this adequate? These are not rhetorical questions, but empirical ones, and so far as I know the answers are not evident. They may in fact differ from one content area or grade level to another.

The second issue raised by the mathematics example is, supposing that pre-service teachers do in fact study the content they will later teach, should pedagogical aspects or transformations of the content be incorporated at the same time or should they be postponed to later coursework, such as instructional methods courses? A partial answer was given earlier in this paper; such things as values regarding the subject matter and the modeling of pedagogical methods become automatically

part of what students learn in content courses. When there is a choice, the answer may be partly pragmatic: which choice results in greater consistency, or makes better use of time? But the issue reaches deeper: Is pedagogical content knowledge a sort of overlay, a way of extending "real" subject matter knowledge to the application of classroom teaching, or is it more an intrinsic part of subject matter knowledge itself? On one hand, Aristotle felt that the greatest indicator of knowledge of a discipline was the ability, not to practice it, but to teach it (Shulman, 1986). Also, the kinds of conceptual ideas implicit in the present discussion of pedagogical content knowledge, together with the judicious use of representations for conveying these ideas, fit nicely with the view of "knowledge" described by modern cognitive psychology (e.g., Resnick & Ford, 1981). On the other hand, the very emergence of pedagogical content knowledge as an entity in the past few years suggests that it is distinct from subject matter knowledge. To what extent can or should these two sisters in the family of knowledge be kept apart, or bound together, in the curriculum of teacher education? This is a central question, and it will surface again later in this paper.

The discussion in this section so far has focused on pedagogical content knowledge as "interpreted" from subject matter knowledge. In contrast, if pedagogical content knowledge is formed primarily through "specification" of knowledge of general pedagogy, then the requisite knowledge base is of educational foundations, principles, and techniques, which can then be applied to specific subject matter contexts as they arise. This case implies a very different order of development. Undergraduate subject matter courses would then be largely inappropriate venues for teaching pedagogical content knowledge, which should be postponed until students have completed at least some professional coursework in education. The primary sites for acquiring pedagogical content knowledge would presumably be subject-specific curriculum and methods courses, most likely after students had already studied such things as learning theory and instructional planning in a generic context, and clinical teaching settings.

This second derivation corresponds to the view of teaching, and learning to teach, that dominated instructional research in the 1960's and 70's: an emphasis on teacher behaviors (and later on teacher thinking) that is essentially independent of the content being taught, and that

consequently can be applied easily to any subject area. While that research program produced some worthwhile results, it has also been criticized as incomplete precisely because of its blindness to subject matter (Shulman, 1986). Perhaps further investigation into this way of formulating pedagogical content knowledge will help correct that deficiency.

Rather than simply conjecturing which is the more important derivation of pedagogical content knowledge, we might be wise to reformulate the issue. We need, first of all, more fully developed examples of pedagogical content knowledge in various disciplines and at diverse grade levels. Then we could analyze these to determine which aspects of this form of knowledge derive mainly from subject matter and which from the perspective of general pedagogy. Each of these aspects of pedagogical content knowledge could then be nurtured in appropriate settings and at propitious times.

To what extent can teachers learn pedagogical content knowledge effectively in pre-service, academic settings versus in-service, clinical settings? One of the characteristic features of pedagogical content knowledge—in contrast to other, more general forms of pedagogical knowledge—is that it is highly contextualized. By definition, that knowledge specifically useful for teaching elementary mathematics is different from that for teaching secondary mathematics or elementary English. As a rule, highly context-sensitive phenomena tend to make more sense when viewed in their natural context. This argues that pedagogical content knowledge is best developed in clinical settings, from student teaching on into novice teaching. Accordingly, as mentioned earlier, several beginning teachers documented in case studies have demonstrated an ability to generate appropriate representational forms or adapt their native views of content to fit the needs of their own particular students (Wilson, Shulman & Richert, 1987).

Two drawbacks to this approach are apparent, nowever. First, formal student teaching is usually accompanied by little university coursework, and subsequent teaching is tied to none. What overworked neophyte teachers manage to pick up or figure out on their own is probably minimal compared to what they might learn under deliberate instruction, regardless of the setting. Second, most of the secondary mathematics teachers in the case study research showed very little

evidence of developing pedagogical content knowledge during their student teaching or their first year of full-time teaching (Steinberg, Haymore & Marks, 1985; Marks, 1990). Indeed, two of the eight elementary teachers Marks (1990) studied extensively demonstrated remarkably scant pedagogical content knowledge in mathematics, although they had been teaching for 30 and 18 years respectively! In other words, the spontaneous development of pedagogical content knowledge in clinical practice appears to be a hit-or-miss affair. This doesn't diminish the potential value of the clinical setting, but it does suggest that some form of deliberate instruction is desirable. This could come from resident teachers or other clinical supervisors, from accompanying university coursework, or both.

The question of which type of setting, academic or clinical, is more effective could also be rephrased along the same lines as the previous question, namely, "Which aspects of pedagogical content knowledge are best learned in each setting, and how?" Further research along these lines would be useful.

How can universities effectively teach pedagogical content knowledge? Once again, no clear answer will be proposed here. However, several issues bear directly on the answer, and these will be discussed briefly.

An earlier section of this paper described two different derivations of pedagogical content knowledge, one based on subject matter knowledge and the other on general pedagogical knowledge. The former implies that instruction in pedagogical content knowledge should either accompany or build on substantial knowledge of content. In fact there is some evidence that without such content knowledge teachers do not develop much content-specific pedagogical knowledge either. The math teachers in the case studies cited above showed a very consistent pattern in this respect. Of the four secondary teachers studied by Steinberg, Haymore and Marks (1985), the one with an extremely advanced knowledge of mathematics (an A.B.D.) displayed by far the most pedagogical content knowledge in his interviews and his teaching; the one with very little knowledge of mathematics (an Italian major) displayed almost none at all, and virtually no growth through two years of teaching; and the remaining two fell in between on both measures.

Of the eight elementary teachers investigated by Marks (1990), the two veteran teachers who showed scant pedagogical content knowledge in math were also the two who had little understanding of mathematics per se. The other six teachers all knew mathematics well and also demonstrated a great deal of pedagogical content knowledge—including two who were only student teachers! These results suggest that a substantial knowledge of the subject matter itself may be a pre- or co-requisite to teachers' learning pedagogical content knowledge in that domain. While this makes intuitive sense, it would be useful to have corroborative data from fields other than mathematics before attempting to generalize.

Even if we assume that adequate subject matter knowledge is requisite, several questions remain. First, should pedagogical content knowledge be taught at the same time as the academic content, within the same course, or later, in another course? If in another course, should it be a content course—e.g., mathematics—or an education methods course? The former implies a view of pedagogical content knowledge as intrinsic to the content itself, a perspective which this paper has already demonstrated as legitimate, but the alternative view is also legitimate. This is another area where carefully designed research could help teacher educators make wise curricular and instructional choices.

Second, if pedagogical content knowledge is taught in content courses in the academic disciplines, should these be separate courses or sections designated for teachers, in parallel with but separate from similar courses for non-teachers, or should they just be the way this content is taught for all students? This is based on some of the same considerations as the previous question, but the implications are different. One argument might be that pedagogical content knowledge, especially the creation and use of various representations for subject matter concepts, is not only intrinsic to the concepts themselves but also very useful for coming to understand them, and so it ought to be a part of the course for anyone who takes it. A counterargument might be that this perspective on the content is, by definition, specifically relevant to teaching it, and so it ought to be reserved for future teachers as a sort of professional specialization. In the latter case, even though the justification for maintaining separate courses or sections is based on professional perspectives,

there is a real danger that the campus community will see such a choice as the ghettoization of education, that is, the provision of separate-but-not-equal, probably sub-standard courses for teachers. This is admittedly an unfair characterization, but sadly, it is also a popular one. In any case, this is another decision to be made with little empirical guidance from educational research.

Another pragmatic set of questions arises if universities decide that pedagogical content knowledge ought to be developed within the courses in the discipline itself. These questions concern the ability of the disciplinary faculty to provide this kind of instruction. Can university mathematics or history or English professors incorporate pedagogical content knowledge pertinent to elementary, middle, and secondary schools into their math, history, or English courses? Do they know how? Are they willing to do so? What conditions would need to prevail? What kind of support might be needed? These are far from trivial questions. Clearly, local conditions within a given university are important determinants of what answers may be reasonable. But the questions also point to larger issues within the profession of teacher education: What kinds of faculty members are appropriate for preparing students to teach subject matter effectively? In what ways do our current university administrative structures facilitate and/or impede this process, and how might they be improved? What kinds of attitudes make our jobs more difficult in this respect, and what might help to change them? These and similar questions could benefit from policy-oriented studies focusing on the relationship between teacher education and the content disciplines within colleges and universities.

Conclusion

This paper does not pretend either to exhaust the range of issues pertaining to when teachers should learn pedagogical content knowledge, or to resolve any of them. Its purpose has been merely to point out that this is an important question which hasn't been explored (or maybe even asked) yet, to indicate the complexity involved in trying to formulate an answer, and to suggest some of the kinds of investigations that might help us make better decisions regarding this aspect of teacher education.

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