

4. NATURE, SOURCES, AND DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE FOR SCIENCE TEACHING

INTRODUCTION

“What shall I do with my students to help them understand this science concept? What materials are there to help me? What are my students likely to already know and what will be difficult for them? How best shall I evaluate what my students have learned?” These questions are common for every teacher, and central to describing the knowledge that distinguishes a teacher from a subject matter specialist. In this paper, we argue that such knowledge is described by the concept known as pedagogical content knowledge, and that this concept is critical to understanding effective science teaching. We describe pedagogical content knowledge as the *transformation* of several types of knowledge for teaching (including subject matter knowledge), and that as such it represents a unique domain of teacher knowledge. This chapter presents our conceptualization of pedagogical content knowledge and illustrates how this concept applies to understanding science education from the perspective of the teacher, the science teacher educator, and the science education researcher.

THEORETICAL FOUNDATIONS

Planning and teaching any subject is a highly complex cognitive activity in which the teacher must apply knowledge from multiple domains (Resnick, 1987; Leinhardt & Greeno, 1986; Wilson, Shulman, & Richert, 1988). Teachers with differentiated and integrated knowledge will have greater ability than those whose knowledge is limited and fragmented, to plan and enact lessons that help students develop deep and integrated understandings. Effective science teachers know how to best design and guide learning experiences, under particular conditions and constraints, to help diverse groups of students develop scientific knowledge and an understanding of the scientific enterprise.

These statements about the role of knowledge in teaching is supported by a body of research documenting that science teachers' knowledge and beliefs have a profound effect on all aspects of their teaching (e.g., Carlsen, 1991a, 1993; Dobey & Schafer, 1984; Hashweh, 1987; Nespor, 1987; Smith & Neale, 1991), as well as on how and what their students learn (Bellamy, 1990; Magnusson, 1991). Some of this research was framed by conceptualizations developed by Shulman and his

colleagues of the diverse knowledge domains that teachers use when planning and teaching (Grossman, 1990; Shulman 1986, 1987; Wilson, Shulman & Richert, 1988). A major contribution of this formulation of the knowledge base for teaching was its acknowledgment of the importance of subject-specific knowledge in effective teaching. A revolutionary feature of this work was the identification of a type of knowledge that was viewed as unique to the profession of teachers: pedagogical content knowledge.¹ Pedagogical content knowledge is a teacher's understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. We argue that pedagogical content knowledge, also known as content-specific or subject-specific pedagogical knowledge (e.g., McDiarmid, Ball, & Anderson, 1989), is integral to effective science teaching. Further, an understanding of this domain of knowledge and its influence on teachers' practice is necessary to foster the improvement of science teaching and science teacher education.

DEFINING PEDAGOGICAL CONTENT KNOWLEDGE

In our view, the defining feature of pedagogical content knowledge is its conceptualization as the result of a *transformation* of knowledge from other domains (Wilson, Shulman, & Richert, 1988). This idea is depicted graphically in Figure 1, which presents a model of the relationships among the domains of teacher knowledge that primarily has been informed by the work of Grossman (1990). The shaded boxes in the figure designate the major domains of knowledge for teaching.² The lines that link the domains of knowledge illustrate the relationship between pedagogical content knowledge and the other domains of knowledge for teaching. The terms on the lines and the arrows at the ends of lines describe the nature and direction of each relationship. Arrows at each end of a line indicate a reciprocal relationship between domains. The figure is intended to depict that pedagogical content knowledge is the result of a transformation of knowledge of subject matter, pedagogy, and context, but that the resulting knowledge can spur development of the base knowledge domains in turn. Grossman conceptualized pedagogical content knowledge as consisting of four components (shown in the figure to the sides of the box representing pedagogical content knowledge). Our conceptualization is very similar, with some modification and the addition of one component. We begin our discussion of the concept of pedagogical content knowledge for science teaching by defining and describing these components.

Components of Pedagogical Content Knowledge for Science Teaching

Building upon the work of Grossman (1990) and Tamir (1988), we conceptualize pedagogical content knowledge for science teaching as consisting of five compo-

nents: (a) orientations toward science teaching, (b) knowledge and beliefs about science curriculum, (c) knowledge and beliefs about students' understanding of specific science topics, (d) knowledge and beliefs about assessment in science, and (e) knowledge and beliefs about instructional strategies for teaching science. These components are shown in Figure 2.³ In this section, we provide conceptual descriptions and illustrative examples to define the specific knowledge that is represented by each component. In addition, we synthesize findings from research that has assessed teachers' pedagogical content knowledge and, where it has been examined, the impact of that knowledge on science teaching and learning.

Orientations Toward Teaching Science

This component of pedagogical content knowledge refers to teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. Grossman designated this component as consisting of knowledge of the purposes for teaching a subject at a particular grade level or the "overarching conceptions" of teaching a particular subject. Research in science education has referred to this component as "orientations toward science teaching and learning," (Anderson & Smith, 1987),⁴ which we prefer to Grossman's term. An orientation represents a general way of viewing or conceptualizing science teaching. The significance of this component is that these knowledge and beliefs serve as a "conceptual map" that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning (Borko & Putnam, 1996).

Orientations toward teaching science that have been identified in the literature are shown in Tables I and II.⁵ The orientations are generally organized according to the emphasis of the instruction, from purely process or content to those that emphasize both and fit the national standard of being inquiry-based. Each orientation has then been described with respect to two elements that are useful in defining and differentiating them: the goals of teaching science that a teacher with a particular orientation would have (Table I), and the typical characteristics of the instruction that would be conducted by a teacher with a particular orientation (Table II).

A comparison of the characteristics of instruction that follow from particular orientations reveals that some teaching strategies, such as the use of investigations, are characteristic of more than one orientation. This similarity indicates that it is not the use of a particular strategy but the *purpose* of employing it that distinguishes a teacher's orientation to teaching science. For example, teachers with a discovery, conceptual change, or guided inquiry orientation might each choose to have students investigate series and parallel circuits, but their planning and enactment of teaching relative to that goal would differ. The teacher with a "discovery" orientation might begin by giving his students batteries, bulbs, and wires, and proceed by having them follow their own ideas as the students find out what they can make

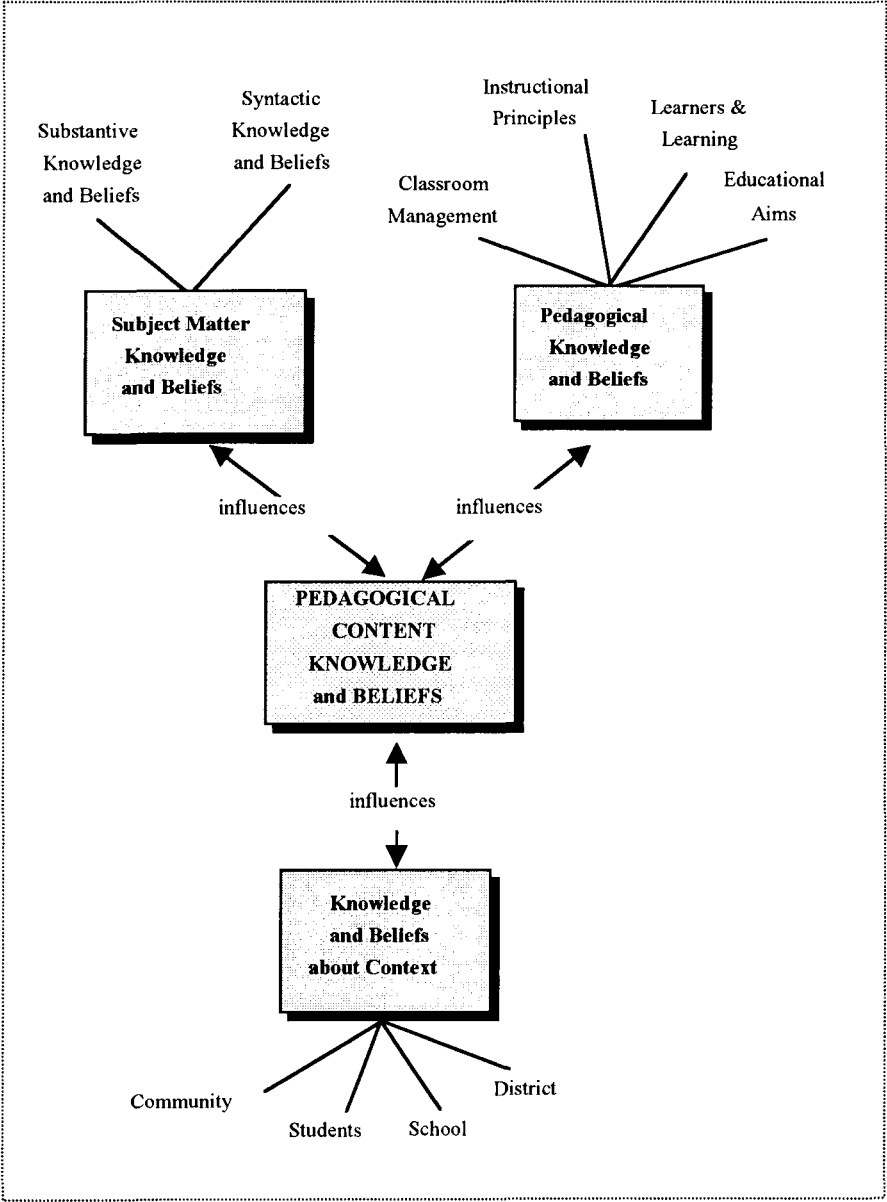


Figure 1. A model of the relationships among the domains of teacher knowledge.
[Modified from Grossman (1990)]

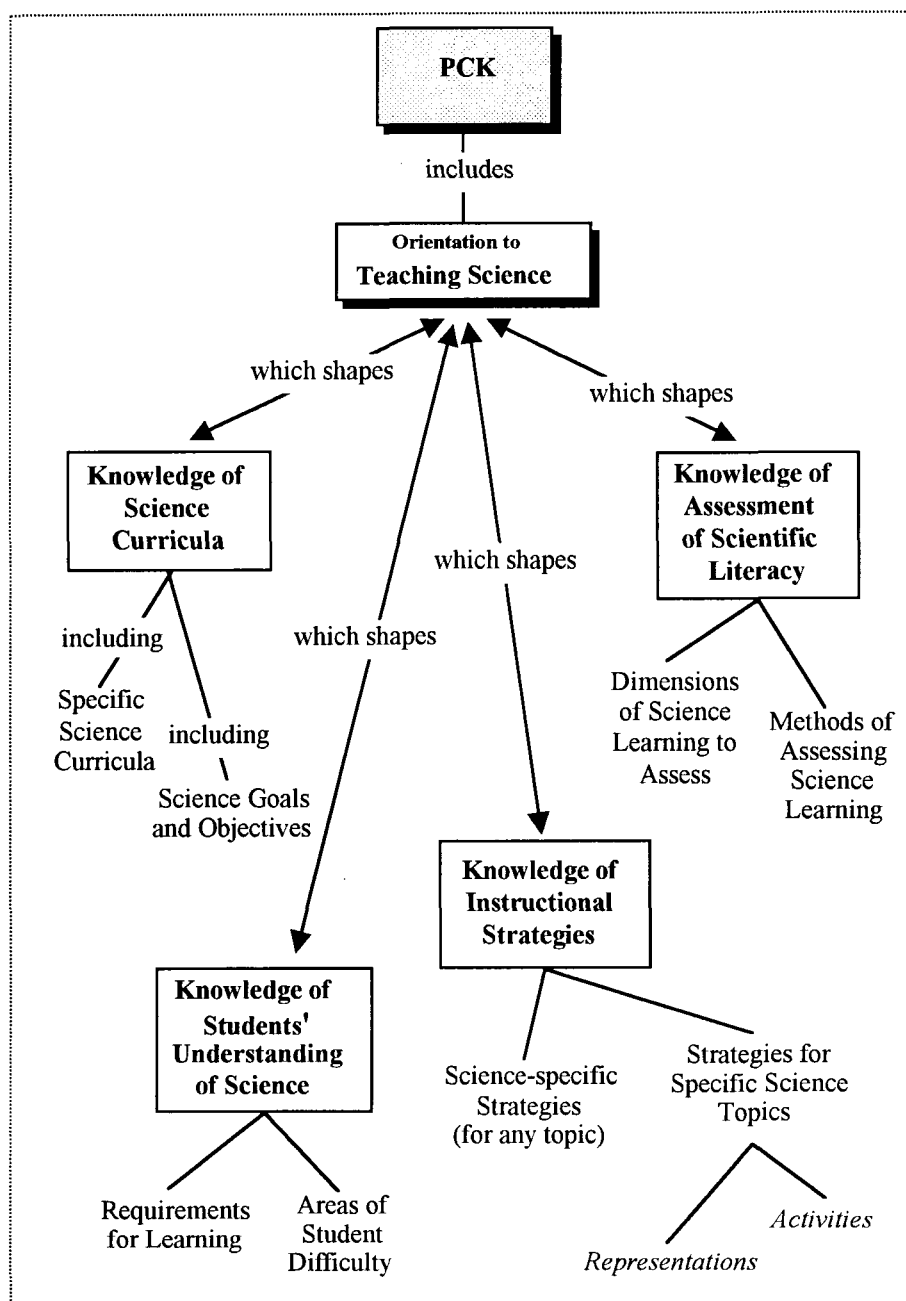


Figure 2. Components of pedagogical content knowledge for science teaching.

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