A Review of Teachers’ Pedagogical Content Knowledge and Subject Matter Knowledge for Teaching Earth System Concepts

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Abstract: During the last three decades, earth science has been re-conceptualized as an interdisciplinary discipline entitled Earth System Science (ESS), which is based on knowledge of the physical earth system and human impact on the earth. While there is increasing effort to teach earth as a system in K-12 education, teachers’ preparedness of to teach earth system is still in its infancy. This article focuses on reviewing the literature of teachers’ knowledge of earth systems and of how teachers’ knowledge of subject matter affects their teaching practice and pedagogical content knowledge (PCK). First, the study investigated a literature of PCK in general as well as in science teaching. Then this study discuss what teachers’ subject matter knowledge (SMK) is and what it means to be in teaching earth system science. Third, a literature of teachers’ knowledge of earth system was reviewed. Finally, a number of suggestions and implications are made as to what teacher education program should do to better prepare future teachers to teach earth systems.

Keywords: Subject matter knowledge, Teacher education, Teacher knowledge, Pedagogical content knowledge.

Introduction

Over the last two decades, scientists have recognized the necessity of studying the earth as an integrated system in order to explain complex and unpredictable natural phenomena. Consequently, knowledge of the physical earth system generated by traditional earth science disciplines was integrated to form a new discipline, Earth System Science (ESS), the concept of the earth as a set of systems (Johnson et al., 1997). However, there has been increasing concern about the K-12 Earth Science teaching and teachers’ understanding of earth as a system.

A recently published survey of Earth Science standards across the United States was pessimistic about the state standards of K-12 Earth Science education in the U.S. (Hoffman and Barstow, 2007). The report opens with a call to action in that “understanding Earth’s interconnected systems is crucial to the future of our nation and the world. Yet our nation’s schools have a mixed record of effective Earth science education” While the national standard documents (American Association for the Advancement of Science (AAAS, 1993) address “system” as one of the important themes in understanding scientific concepts, the standards (national as well as the state standards) do not directly present how to use a system-based approach to teach earth science (Hoffman and Barstow, 2007). Due to the lack of consensus on the central ideas of ESS and what teachers should teach about it, interpreting and addressing earth science knowledge using systems ideas has always been extra work for teachers in the classroom, curriculum developers, and assessment designers.

Knowing how to effectively teach particular ideas is impacted considerably by the nature of the teacher’s subject matter knowledge (Barnett and Hodson, 2001). In other words, Earth Science teachers need to possess earth systems knowledge as well as understand effective ways to teach this knowledge to support K-12 students in developing their own earth systems knowledge. Subject matter knowledge encompassed another crucial component of knowledge base for teaching (Shulman, 1986). The concept of “Pedagogical Content Knowledge (PCK)” has been introduced by Shulman to fill the gap between content and pedagogical knowledge (Veal et al., 2001). Shulman...
(1986) defined “Pedagogical Content Knowledge” (PCK) as “subject matter knowledge for teaching”. While researchers argue the importance of teachers’ subject matter knowledge for developing their PCK and classroom practice (Gess-Newsome and Lederman, 1993; Lederman et al., 1994), little research has been done about how much science teachers know about earth systems and how to assess science teachers’ conceptual understanding of earth systems. This literature review delineates the relationship between teachers’ topic-specific subject matter knowledge (knowledge of earth system) and their teaching practice. The literature reviewed in this paper includes both studies of teacher knowledge domain (specifically about PCK) and teachers’ subject matter knowledge (and its relationship with teaching practice). Based on the literature review, we also propose the important aspects that teacher educators need to consider for preparing teachers to teach topic-specific content knowledge.

This article follows three steps: first, we reviewed literature about PCK, in general. In this step, we described definitions of PCK from different studies. Then we reviewed literature of PCK in science education to understand the themes in the current research on teachers’ conceptual knowledge in a specific topic earth system knowledge and its relationship with their teaching practice. Finally, we suggest directions of teacher preparation about teachers’ subject matter knowledge for teaching earth system.

**Pedagogical Content Knowledge (PCK)**

What teachers know about the earth system is an important factor in determining how they teach it. We usually assume that teachers with strong content knowledge easily draw upon this knowledge in teaching situations. Most university-based teacher education programs are based on the assumption, or hope, that subject matter knowledge can inform knowing how to teach (Rovegno, 1992). However, what earth science teachers teach about earth systems is not always determined by what they know about earth system. Pre-service and novice teachers’ application of their content knowledge to the classroom situation were found to be difficult in many studies (Rovegno, 1992; Gess-Newsome and Lederman, 1993; Lederman et al., 1994; van Der-Valk and Broekman, 1999). This is because teachers’ selection of subject matter knowledge for teaching is not only affected by their content knowledge but also by other knowledge domains such as pedagogy knowledge, knowledge of the students, knowledge of the curriculum, and so on. In the early 1980s, Shulman and his colleagues argued that teaching effectiveness is much more related to the content the teacher is teaching, or domain-specific rather than general (Shulman, 1986, 1987). Shulman (1986) used the term, “the missing paradigm,” which indicates that the study of teaching has ignored the interaction between content knowledge and pedagogy. Teachers’ specific pedagogical practice cannot be separated from their content knowledge as well as their pedagogical knowledge. Shulman (1987) introduced the “knowledge base for teaching” which consisted of seven categories: content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners, knowledge of educational context, and knowledge of educational purposes. Shulman (1987) defined PCK as a unique form of teacher knowledge and the ways of representing and formulating subject matter that make it comprehensible to others and also, including an understanding of what makes the learning of specific topics easy or difficult.

In his earlier work, Shulman (1986) categorized PCK under the content knowledge domain but ultimately PCK plays an essential role in integrating pedagogical knowledge and curricular knowledge. Following Shulman’s (1986) ideas about PCK, other researchers developed their own categories of teacher knowledge (e.g. Borko and Putnam, 1996; Grossman, 1990; Adams and Krockover, 1997). Particularly, Adams and Krockover (1997) develop a framework for investigating teacher knowledge by synthesizing