Why Teachers' Science Content Knowledge Matters: A Summary of Studies

Professional learning opportunities for teachers of science have increasingly focused on deepening teachers' content knowledge. Based on a number of research studies identified in a large-scale literature review, teachers' science content knowledge makes a difference both in their professional practice and in their students' achievement. Additional information on how these studies were identified and reviewed, and a summary of the methodology, can be found at:

http://www.mspkmd.net/index.php?page=18_4a-3b1

Teachers' Science Content Knowledge InfluencesTheir Professional Practice

A systematic search of education research databases surfaced 11 studies examining the link between teacher science content knowledge and their teaching practice. (See Table 1.) Across the 11 studies, influences on instructional practice were investigated for three aspects of teacher knowledge: (1) disciplinary content knowledge,[1] (2) knowledge of the nature of science[2], and (3) knowledge of the goals/objectives of the curriculum and students' understanding of content.[3] Regardless of the type of knowledge or the characteristics of the teachers studied, the general conclusion of the studies is the same: teacher content knowledge matters. Teacher content knowledge appears to have a number of direct, and sometimes also indirect, influences on classroom practice.

Teachers' knowledge, whether it is about science content, the nature of science, or the goals of the science curriculum, appears to exert an influence on classroom practice, although a few of the relationships investigated in the studies were not supported by the empirical evidence. As a group, these studies are generally methodologically sound, though the majority involved small samples of teachers which might raise concerns about the robustness of findings due to sample biases.

The studies focusing on disciplinary content knowledge suggest that teachers with more content knowledge are more likely to teach in ways that research on learning suggests will help students construct knowledge, and develop science ideas conceptually. One study[4] reported that the way teachers organize their own knowledge affected how they taught content. A study of a professional development intervention for elementary teachers[5] found that increased content knowledge after the intervention was related to greater attention to student thinking, but another

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[1] Alonzo, 2002; Gess-Newsome & Lederman, 1995; Heller, Daehler, & Shinohara, 2003; Nehm & Schonfeld, 2007); Sanders, Borko, & Lockard, 1993.

[2] Brickhouse, 1990; Cunningham, 1998; Lederman, 1999; Nehm & Schonfeld, 2007; Roehrig & Luft, 2004.

[3] Henze, van Driel, & Verloop, 2008.

[4] Gess-Newsome & Lederman, 1995.

[5] Heller et al., 2003.

study[6] reported that variations in content knowledge about energy were unrelated to teachers' ability to accurately predict actual student performance on assessment items targeting misconceptions about the content.

Two studies[7] that investigated several specific instructional practices found that teachers with stronger content knowledge pose more questions, and are more likely to have students consider alternative explanations, propose more investigations, and pursue unanticipated inquiries compared to teachers with weaker content knowledge. These studies also found that teachers with weaker content knowledge tended to use more direct instruction, telling students the content rather than guiding their inquiries.

Another study[8] in this group found that teachers with weak content knowledge struggled to plan instruction that developed a conceptual storyline, in contrast to teachers with strong content knowledge. In a study[9] about novice teachers' goals for teaching about the origin of species, those with greater science content knowledge tended to prefer teaching only evolution in science class, while those with weaker content knowledge were more likely to report preferences for teaching both evolution and creation.

With regard to the nature of science, four studies[10] found that when teachers have an established view of the nature of science, regardless of what that view is, they tend to translate it into classroom instruction. That is, teachers' instruction portrays an image of the discipline of science consistent with their own view. Three of the studies found that teachers who saw science primarily as generative tended to do more inquiry activities so that students could generate knowledge. Those who saw science as a body of knowledge to be used to solve problems generally planned instruction in which students used science in this way. Two studies[11] found this mirroring to be true even among the first-year teachers they studied, in contrast to two other studies[12] that could not establish such a firm relationship among inexperienced teachers.

One study[13] investigated the relationship between secondary science teachers' instructional practice and their knowledge of: (a) the goals and objectives of the curriculum, and (b) students' understanding of science content ideas. Results indicated that teachers' knowledge of

[6] Diakidoy & Iordanou, 2003.

[7] Alonzo, 2002; Sanders et al., 1993.

[8] Sanders et al., 1993.

[9] Nehm & Schonfeld, 2007.

[10] Brickhouse, 1990; Cunningham, 1998; Lederman, 1999; Roehrig & Luft, 2004.

[11] Nehm & Schonfeld, 2007; Roehrig & Luft, 2004.

[12] Brickhouse, 1990; Cunningham, 1998.

[13] Henze et al., 2008.

instructional strategies for using models in space science instruction was consistent with their knowledge of goals of the curriculum and student understanding of content.

As a group, these 11 studies include strong elements of rigorous research design and implementation, primarily due to the wealth of data they collected and the extent of triangulation among data sources. However, most of the studies had small sample sizes, ranging from 3 to 14 teachers.[14] The ways that the dependent variable in these studies—classroom practice—was measured may have necessitated small sample sizes because the data collection methods were quite time-consuming and logistically complicated. While the sample sizes were small, the studies were based on broad and deep data collection. All of the studies used classroom observation to collect data on classroom practice. One study[15] included 15 observations of each of 5 teachers; another[16] was based on observations of 3 teachers for a minimum of 35 hours each. All of these studies also included data collected in other ways, such as interviews, questionnaires, and classroom artifacts (e.g., lesson plans and student work), to triangulate findings. The fact that the 2 of the 3 studies[17] with somewhat larger samples of 44 and 50 teachers reported similar findings regarding teachers' content knowledge and their instructional practice helps to alleviate concerns regarding the robustness of this relationship, although the other study[18] with a larger sample of 63 teachers did not find a relationship between content knowledge and prediction of student ideas.

Although eight of the studies[19] made it clear that findings are based on multiple data sources, it was not always as clear how the data were combined and analyzed, as several studies lacked such description.[20] If the findings were not so consistent across studies, the lack of detail provided about the analyses would cast more doubt on the conclusions. A similar argument can be made for the potential weakness of small sample size, which threatens generalizability. Again, the findings are consistent enough across settings to suggest that they may in fact be more broadly generalizable. However, 6 of the 8 studies examined teachers in the secondary grades, with only 2[21] focused on teachers in elementary schools. Consequently, the generalizability of findings to teachers at the elementary level is not strongly supported empirically.

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[14] Alonzo, 2002; Brickhouse, 1990; Cunningham, 1998; Gess-Newsome & Lederman, 1995; Heller et al., 2003; Lederman, 1999; Nehm & Schonfeld, 2007; Roehrig & Luft, 2004; Sanders et al., 1993.

[15] Gess-Newsome & Lederman, 1995.

[16] Brickhouse, 1990.

[17] Heller et al., 2003; Nehm & Schonfeld, 2007.

[18] Diakidoy & Iordanou, 2003.

[19] Alonzo, 2002; Brickhouse, 1999; Cunningham, 1998; Gess-Newsome & Lederman, 1995; Heller et al., 2003; Lederman, 1999; Roehrig & Luft, 2004; Sanders et al., 1993.

[20] Alonzo, 2002; Brickhouse, 1999; Heller et al., 2003; Lederman, 1999; Sanders et al., 1993.

[21] Alonzo, 2002.

Table 1. Studies Examining the Influence of Teachers' Science Content Knowledge on Professional Practice

			Content				Type(s) of Knowledge			Measures of Teacher Content Knowledge			
Name of Study	Number of Teachers	Grade Level	Earth Science	Life Science	Physical Science	Various Sciences	Disciplinary Content Knowledge	Ways of Knowing	Pedagogical Content Knowledge	Assessments	Interviews	Observations	Other approach
Evaluation of a model for supporting the development of elementary school teachers' science content Knowledge (Alonzo, 2002)	7	3			•		•	•		•	•		
Teachers' beliefs about the nature of science and their relationship to classroom practice. (Brickhouse, 1990)	3	6–12				•		•			•		
The effect of teachers' sociological understanding of science (SUS) on curricular innovation. (Cunningham, 1998)	6	9–12		•				•		•	•		•
Preservice teachers' and teachers' conceptions of energy and their ability to predict pupils' level of understanding (Diakidoy & Iordanou, 2003)	63 6	6–8			•		•			•			
Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. (Gess-Newsome & Lederman, 1995)	5	9–12		•			•				•	•	
Connecting all the pieces (Heller et al., 2003)	50	K–5			•		•			•	•		
Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe (Henze et al., 2008)	9	9–12	•				•	•			•		
Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. (Lederman, 1999)	5	9–12		•				•		•	•	•	
Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools? (Nehm & Schonfeld, 2007)	44	6–12		•			•	•		•			
Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. research report (Roehrig & Luft, 2004)	14	6–12				•		•		•	•		
Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. (Sanders et al., 1993)	3	9–12				•	•				•	•	•

Teachers' Science Content Knowledge is Related to Their Students' Learning

Three studies were identified that explored the relationship between teacher science content knowledge and student understanding. Information about these research studies is displayed in Table 2. One study investigated changes in students' understanding of heat energy and temperature, whereas the other two examined students' understanding of the nature of science.

Magnusson and colleagues[22] studied six eighth grade teachers randomly selected from a larger group participating in a workshop on microcomputer-based laboratory instruction. The teachers' disciplinary content knowledge and pedagogical content knowledge were assessed through interviews. Each teacher's knowledge was compared to the conceptual understandings of one of their students, also measured through interviews. The researchers found a relationship between teacher knowledge and changes in student knowledge, but only with regard to incorrect ideas, not correct ideas. That is, when a teacher held an incorrect idea, students were more likely to develop the same incorrect idea than if the teacher correctly understood the concept. The students of the two teachers with the most understanding of heat energy and temperature did not demonstrate the most learning over the unit of instruction, although the researchers found evidence of a small positive relationship between teachers' pedagogical content knowledge for the concepts of heat energy and temperature and their students' learning.

Lederman[23] conducted a multi-case study of five high school biology teachers to investigate the relationship of teachers' understanding of the nature of science and their students' understanding. No relationship between teachers' knowledge and students' understandings was identified. Regardless of the teachers' content understanding, the study found that the overwhelming majority of the participating students held ideas about the nature of science that were inconsistent with current thinking about the discipline. However, a study by Dogan and Abd-El-Khalick of a nationally representative sample of 378 grade 10 teachers and their students in Turkey[24] found that the teachers' views of the nature of science were virtually identical to those of their students on most items. Consistent with Lederman's study, though, was the finding that the majority of students, as well as teachers, held naïve or partially informed views of the nature of science.

Both the Magnusson and colleagues and Lederman studies used teacher and student interviews to assess content knowledge and appropriate methods for assessing the relationship between teacher content knowledge and student understanding. Lederman's study also included classroom observations, an open-ended questionnaire, and an analysis of instructional plans and materials to provide a stronger assessment of teachers' content knowledge. Magnusson and colleagues provided a particularly strong plan of analysis for qualitative data, which was thoroughly described. Each of these studies focused on a relatively small area of content knowledge, which allowed the researchers to probe many subtleties of understanding among both teachers and students while including several checks on validity and reliability. However, the small sample sizes in these studies limit claims regarding generalizability of the findings. Also, the Magnusson

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[22] Magnusson, Borko, Krajcik, & Layman, 1992.

[23] Lederman, 1999.

[24] Dogan & Abd-El-Khalick, 2008.

and colleagues study provided little descriptive or contextual information about the teachers and the settings in which they work to support inferences about generalizability of the findings to similar teachers. In contrast, the study by Dogan and Abd-El-Khalick was conducted on a large, representative sample of teachers and their students, using survey methodology with an established measure of knowledge of the nature of science. By limiting the study to grade 10, specific areas of content addressed at this grade level could be targeted and developmental differences among students could be controlled. However, the careful sampling and data collection plan was coupled with inadequate analysis, so the meaningfulness of the findings was somewhat limited.

Table 2. Studies Examining the Relationship of Teachers' Science Content Knowledge and Student Learning

			Content			Type(s) of Knowledge			Measures of Teacher Content Knowledge		
Name of Study	Number of Teachers	Grade Level	Life Science	Physical Science	Various Sciences	Disciplinary Content Knowledge	Ways of Knowing	Pedagogical Content Knowledge	Assessments	Interviews	Observations
Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. (Dogan & Abd-El-Khalick, 2008)	378	10			•		•		•		
The relationship between teacher content and pedagogical content knowledge and student content knowledge of heat energy and temperature. (Magnusson et al., 1992)	6	8		•		•		•		•	
Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. (Lederman, 1999)	5	9–12	•				•		•	•	•

Bibliography for
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