Summary of Research on Experiences Intended to Deepen Teachers' Science Content Knowledge

Studies of two types of experiences were included in the review of research related to deepening teachers' science content knowledge. First, 24 studies investigated the effects of teachers' experience in professional development programs that had deepening teachers' science content knowledge as a goal. Second, two studies examined teaching practice as a context for teachers to deepen their science content knowledge.

If you are interested in how these studies were identified and reviewed, a summary of the methodology can be found at
http://www.mspkmd.net/index.php?page=24_4a-3d2

Effects of Programs Aimed at Deepening Teachers' Science Content Knowledge
Studies of the effects of 24 different interventions designed to deepen teachers' science content knowledge were reviewed. Information about the research studies is displayed in Table 1. Information about the interventions examined in the studies is shown in Table 2.

In all but one[1] of the 24 studies of interventions intended to deepen teachers' content knowledge, participating teachers' science content knowledge increased. At a minimum, these results provide existence proofs that experiences aimed at deepening teachers' science content knowledge can achieve that goal. It is important, however, to bear in mind that studies with positive effects are probably more likely to be submitted, and accepted, for publication than those with no effects.

The diversity of the programs investigated across these 24 studies suggests that there is a variety of effective ways of structuring and delivering experiences to deepen teachers' science content knowledge. About half of the studies included a summer workshop,[2] of which a handful included follow-up sessions during the year.[3] There were also a few studies that looked at the effects of a semester-long course.[4] About half of the studies stated that the teachers were learning through hands-on/laboratory work,[5] and a few programs had teachers work on research projects[6] sometimes with scientists.

[1] Chun & Oliver, 2000.

[2] Basista & Mathews, 2002; Chun & Oliver, 2000; Clermont, Krajcik, & Borko, 1993; Freeman, Pounders, & Teddlie, 1994; Greenwood & Scribner-MacLean, 1997; Irving, Dickson, & Keyser, 1999; Jones, 1997; Lord & Peard, 1995; Odom, 2001; Puttick & Rosebery, 1998; Radford, 1998; Shymansky et al., 1993.

[3] Jarvis & Pell, 2004; Jarvis, Pell, & McKeon, 2003; Jones, 1997; Radford, 1998.

[4] Jones, Rua, & Carter, 1998; Robardey, Allard, & Brown, 1994; Tuan & Chin, 1999.

[5] Alonzo, 2002; Clermont et al., 1993; Freeman et al., 1994; Greenwood & Scribner-MacLean, 1997; Irving et al., 1999; Jarvis & Pell, 2004; Jarvis et al., 2003; Jones, 1997; Jones et al., 1998; Pardhan & Wheeler, 2000; Radford, 1998; Robardey et al., 1994; Summers & Kruger, 1994; Summers, Kruger, Mant, & Childs, 1998; Wang, 2001.

[6] Lord & Peard, 1995; Odom, 2001; Puttick & Rosebery, 1998; Radford, 1998.

The programs also differed in the grade range of participating teachers and the science content that was addressed. Positive effects were found for experiences with teachers from elementary, middle, and high school grades variously targeting earth, life, and physical science. On the whole, more empirical evidence exists regarding interventions for elementary grades teachers than for middle or high school teachers. Over half of the studies focused on elementary grades teachers,[7] and interestingly, almost all of these focused on physical science.[8] There is no clear explanation for the overrepresentation of these studies, but the emphasis is consistent with teachers' own reports of their content backgrounds; i.e., elementary teachers are much more likely to report weak content knowledge in physical science than in either life or earth science.[9]

In about half of the studies,[10] interventions were described in detail, which is helpful for understanding teachers' experiences and interpreting the link between the intervention and the effects on teachers' science content knowledge. In the rest of the studies,[11] however, the intervention was described only partially, making it more difficult to support these interpretations.

The interventions varied widely in the level of commitment required of participants, from as few as six hours to as many as 160 hours. In a handful of instances, the intervention was not described fully enough to determine the duration.[12] Among those for which duration was described, well over half were a week or longer.[13] Generalizability of findings from these studies must be interpreted cautiously, because the populations that these teachers represent are limited to teachers willing and able to commit to participation in such extensive interventions.

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[7] Alonzo, 2002; Basista & Mathews, 2002; Clermont et al., 1993; Freeman et al., 1994; Greenwood & Scribner-MacLean, 1997; Jarvis & Pell, 2004; Jarvis et al., 2003; Jones, 1997; Jones et al., 1998; Pardhan & Wheeler, 2000; Puttick & Rosebery, 1998; Radford, 1998; Robardey et al., 1994; Schibeci & Hickey, 2000; Shymansky et al., 1993; Storti, 1999; Summers & Kruger, 1994; Summers, Kruger, Mant, & Childs, 1998; Wang, 2001.

[8] Alonzo, 2002; Clermont et al., 1993; Freeman, 1994; Greenwood & Scribner-MacLean, 1997; Jarvis & Pell, 2004; Jarvis, Pell, & McKeon, 2003; Jones, Rua, & Carter, 1998; Pardhan & Wheeler, 2000; Puttick & Rosebery, 1998; Schibeci & Hickey, 2000; Summers & Kruger, 1994; Summers et al., 1998.

[9] Fulp, 2002.

[10] Clermont et al., 1993; Irving et al., 1999; Jones, 1997; Jones et al., 1998; Lord & Peard, 1995; Odom, 2001; Puttick & Rosebery, 1998; Radford, 1998; Schibeci & Hickey, 2000; Shymansky et al., 1993; Summers & Kruger, 1994; Tuan & Chin, 1999; Wang, 2001.

[11] Alonzo, 2002; Basista & Mathews, 2002; Chun & Oliver, 2000; Freeman et al., 1994; Greenwood & Scribner-MacLean, 1997; Jarvis & Pell, 2004; Jarvis et al., 2003; Pardhan & Wheeler, 2000; Robardey et al., 1994; Storti, 1999; Summers et al., 1998; van Driel, Verloop, & de Vos, 1998.

[12] Chun & Oliver, 2000; Pardhan & Wheeler, 2000; van Driel et al., 1998.

[13] Basista & Mathews, 2002; Clermont et al., 1993; Freeman, 1994; Greenwood & Scribner-MacLean, 1997; Irving et al., 1999; Jarvis & Pell, 2004; Jarvis et al., 2003; Jones, 1997; Jones et al., 1998; Lord & Peard, 1995; Odom, 2001; Puttick & Rosebery, 1998; Radford, 1998; Robardey et al., 1994; Shymansky et al., 1993; Tuan & Chin, 1999.

Table 1
Studies of Interventions to Deepen Teachers' Science Content Knowledge: Study Characteristics

Name of Study	Purpose of study		Data types		Knowledge Outcomes			Measures of Teacher Content Knowledge				Measurement description		
	Program evaluation	Providing examples	Quantitative	Qualitative	Disciplinary Content	Ways of Knowing	Pedagogical Content	Assessments	Interviews	Observations	Other approach	Validity	Reliability	Triangulation
Evaluation of a model for supporting the development of elementary school teachers' science content knowledge (Alonzo, 2002)	●		●	●	●			●	●	●				
Integrated science and mathematics professional development programs (Basista & Mathews, 2002)	●		●	●	●		●	●		●				
A quantitative examination of teacher self-efficacy and knowledge of the nature of science (Chun & Oliver, 2000)	●		●			●		●[a]						
The influence of an intensive in-service workshop on pedagogical content knowledge growth among novice chemical demonstrators (Clermont et al., 1993)		●		●			●		●				●	
Evaluation of a summer science institute for elementary teachers (Freeman, 1994)	●		●		●			●						
Examining elementary teachers' explanations of their science content knowledge (Greenwood & Scribner-MacLean, 1997)	●			●	●			●						
Retraining public secondary science teachers by upgrading their content knowledge and pedagogical skills (Irving, Dickson, & Keyser, 1999)		●	●		●			●						
Changes in primary teachers' science knowledge and understanding during a two year in-service programme (Jarvis, Pell, & McKeon, 2003) Primary teachers' changing attitudes and cognition during a two-year science in-Service programme and their effect on pupils(Jarvis & Pell, 2004)	●		●		●			●				●	●	
Organization, implementation, and results of an Eisenhower systemic elementary science reform project (Jones, 1997)	●		●		●			●						

Table 1 Continued
Studies of Interventions to Deepen Teachers' Science Content Knowledge: Study Characteristics

Name of Study	Purpose of study		Data types		Knowledge Outcomes			Measures of Teacher Content Knowledge				Measurement description		
	Program evaluation	Providing examples	Quantitative	Qualitative	Disciplinary Content	Ways of Knowing	Pedagogical Content	Assessments	Interviews	Observations	Other approach	Validity	Reliability	Triangulation
Science teachers' conceptual growth within Vygotsky's zone of proximal development (Jones, Rua, & Carter, 1998)	●		●	●	●			●						
Scientist-teacher summer workshops can enhance constructivist views about science and science instruction (Lord & Peard, 1995)	●		●			●		●						
Inquiry-based field studies involving teacher-scientist collaboration (Odom, 2001)	●		●		●			●					●	
Taking "STOCK" of pedagogical content knowledge in science education (Pardhan & Wheeler, 2000)		●	●		●			●						
Teacher professional development as situated sense-making: A case study in science education (Puttick & Rosebery, 1998)		●		●	●			●	●	●				
Transferring theory into practice: A model for professional development for science education reform (Radford, 1998)	●		●		●	●		●					●	
An assessment of the effectiveness of Full Option Science System training for third- through sixth-grade teachers (Robardey & Others, 1994)	●		●		●			●						
Is it natural or processed? Elementary school teachers and conceptions about materials (Schibeci & Hickey, 2000)		●		●	●			●				●	●	
A study of changes in middle school teachers' understanding of selected ideas in science as a function of an in-service program focusing on student perceptions (Shymansky et al., 1993)	●		●		●			●				●	●	
Short-term teacher workshops: Examining the assumption of teacher-to-student transfer (Storti, 1999)		●	●		●			●				●	●	

Table 1 Continued
Studies of Interventions to Deepen Teachers' Science Content Knowledge: Study Characteristics

Name of Study	Purpose of study		Data types		Knowledge Outcomes			Measures of Teacher Content Knowledge				Measurement description		
	Program evaluation	Providing examples	Quantitative	Qualitative	Disciplinary Content	Ways of Knowing	Pedagogical Content	Assessments	Interviews	Observations	Other approach	Validity	Reliability	Triangulation
A longitudinal study of a constructivist approach to improving primary school teachers' subject matter knowledge in science (Summers & Kruger, 1994)	●		●		●			●	●					
Developing primary teachers' understanding of energy efficiency (Summers, Kruger, Mant, & Childs, 1998)		●		●	●			●	●					
What can inservice Taiwanese science teachers learn and teach about the nature of science? (Tuan & Chin, 1999)	●		●			●		●[a]					●	
Developing science teachers' pedagogical content knowledge (van Driel, Verloop, & de Vos, 1998)		●		●			●			●	●	●		
Improving elementary teachers' understanding of the nature of science and instructional practice (Wang, 2001)	●			●		●		●				●		

[a] Indicates use of an existing measure that was not developed specifically for the purpose of this study.

Table 2
Studies of Interventions to Deepen Teachers' Science Content Knowledge: Intervention Characteristics

Name of Study	Grade Level	Intervention[a]					Science Content			
		Full description	Teacher involvement voluntary	STEM faculty involved	Researcher(s) designed	Researcher(s) delivered	Earth sciences	Life sciences	Physical sciences	Various sciences
Evaluation of a model for supporting the development of elementary school teachers' science content knowledge (Alonzo, 2002)	3	N	Y	?	N	N			●	
Integrated science and mathematics professional development programs (Basista & Mathews, 2002)	4–10	N	?	Y	Y	Y				●
A quantitative examination of teacher self-efficacy and knowledge of the nature of science (Chun & Oliver, 2000)	6–8	N	?	?	N	N				●
The influence of an intensive in-service workshop on pedagogical content knowledge growth among novice chemical demonstrators (Clermont et al., 1993)	4–12	Y	Y	N	Y	?			●	
Evaluation of a summer science institute for elementary teachers (Freeman, 1994)	K-5	N	?	?	N	N			●	
Examining elementary teachers' explanations of their science content knowledge (Greenwood & Scribner-MacLean, 1997)	K-5	N	Y	N	Y	Y			●	
Retraining public secondary science teachers by upgrading their content knowledge and pedagogical skills (Irving, Dickson, & Keyser, 1999)	6–12	Y	Y	Y	N	N		●		
Changes in primary teachers' science knowledge and understanding during a two year in-service programme (Jarvis, Pell, & McKeon, 2003) Primary teachers' changing attitudes and cognition during a two-year science in-Service programme and their effect on pupils(Jarvis & Pell, 2004)	K-5	N	?	?	Y	?			●	
Organization, implementation, and results of an Eisenhower systemic elementary science reform project (Jones, 1997)	K-5	Y	Y	?	?	N				●
Science teachers' conceptual growth within Vygotsky's zone of proximal development (Jones, Rua, & Carter, 1998)	K–8	Y	Y	N	Y	N			●	
Scientist-teacher summer workshops can enhance constructivist views about science and science instruction (Lord & Peard, 1995)	9–12	Y	Y	Y	?	N				●
Inquiry-based field studies involving teacher-scientist collaboration (Odom, 2001)	6–12	Y	Y	Y	N	N		●		
Taking "STOCK" of pedagogical content knowledge in science education (Pardhan & Wheeler, 2000)	K-5	N	?	?	?	N			●	
Teacher professional development as situated sense-making: A case study in science education (Puttick & Rosebery, 1998)	K-5	Y	Y	?	Y	Y			●	
Transferring theory into practice: A model for professional development for science education reform (Radford, 1998)	4–10	Y	Y	Y	Y	Y		●		
An assessment of the effectiveness of Full Option Science System training for third- through sixth-grade teachers (Robardey & Others, 1994)	3–6	N	Y	?	Y	?				●

Table 2 Continued
Studies of Interventions to Deepen Teachers' Science Content Knowledge: Intervention Characteristics

Name of Study	Grade Level	Intervention[a]					Science Content			
		Full description	Teacher involvement voluntary	STEM faculty involved	Researcher(s) designed	Researcher(s) delivered	Earth sciences	Life sciences	Physical sciences	Various sciences
Is it natural or processed? Elementary school teachers and conceptions about materials (Schibeci & Hickey, 2000)	K-5	Y	?	?	Y	N			●	
A study of changes in middle school teachers' understanding of selected ideas in science as a function of an in-service program focusing on student perceptions (Shymansky et al., 1993)	4–9	Y	Y	?	Y	N				●
Short-term teacher workshops: Examining the assumption of teacher-to-student transfer (Storti, 1999)	3–9	N	Y	?	N	N	●			
A longitudinal study of a constructivist approach to improving primary school teachers' subject matter knowledge in science (Summers & Kruger, 1994)	K-5	Y	Y	?	Y	?			●	
Developing primary teachers' understanding of energy efficiency (Summers, Kruger, Mant, & Childs, 1998)	K-5	N	Y	?	Y	Y			●	
What can inservice Taiwanese science teachers learn and teach about the nature of science? (Tuan & Chin, 1999)	?	Y	Y	?	N	Y				●
Developing science teachers' pedagogical content knowledge (van Driel, Verloop, & de Vos, 1998)	9-12	N	Y	N	Y	Y			●	
Improving elementary teachers' understanding of the nature of science and instructional practice (Wang, 2001)	K-5	Y	Y	?	Y	?				●

[a] Y = Yes, N = No, ? = Not clear from document

One study measured outcomes in both disciplinary content knowledge and pedagogical content knowledge.[14] Another targeted knowledge of ways of knowing in science in addition to disciplinary content knowledge.[15] Otherwise, though, studies restricted their focus to knowledge in only one of these domains, either disciplinary content,[16] ways of knowing[17] or pedagogical

[14] Basista & Mathews, 2002.

[15] Radford, 1998.

[16] Alonzo, 2002; Freeman, 1994; Greenwood & Scribner-MacLean, 1997; Irving et al., 1999; Jarvis & Pell, 2004; Jarvis et al., 2003; Jones, 1997; Jones et al., 1998; Odom, 2001; Pardhan & Wheeler, 2000; Puttick & Rosebery, 1998; Robardey et al., 1994; Schibeci & Hickey, 2000; Shymansky et al., 1993; Storti, 1999; Summers & Kruger, 1994; Summers et al., 1998; Wang, 2001.

[17] Chun & Oliver, 2000; Lord & Peard, 1995; Tuan & Chin, 1999; Wang, 2001.

content.[18] Across the studies the level of disciplinary content knowledge that was addressed in the interventions varied. For the most part, teachers engaged with the content they teach their students, at the level they are expected to teach it. In a few studies, by contrast, the disciplinary content was clearly more advanced, either beyond what teachers typically teach or in substantially greater depth.[19]

It is important to recognize that particular features of the interventions, although described in detail in some cases and logically tied to the reported impacts on teachers' science content knowledge, were not investigated in any of the studies through either systematic or naturalistic variation. Findings in these studies can be understood to result only from teachers' experience of the programs as a whole. Effects on teachers' knowledge of disciplinary content, ways of knowing, or pedagogical content also cannot be disentangled. Effects of specific experiences on different facets of teachers' content knowledge were not systematically examined in any of these studies.

Since different measures were used across the studies, it is not possible to identify whether features of one program may be more or less effective for a particular purpose than features of another program. Claims that some features are important for deepening teachers' science content knowledge are suggested to some extent by their presence in the multiple programs studied. The importance of these features in deepening particular facets of teachers' content knowledge was also supported on logical or theoretical grounds in some studies. However, the contributions of particular features to effects on different facets of teachers' content knowledge cannot be strongly concluded from the empirical evidence in these studies.

Another important consideration for interpreting the results of several of the studies was involvement of researchers in the interventions, either as developers,[20] deliverers,[21] or both.[22] When researchers develop and deliver interventions, it is more likely that they are delivered as intended. However, these researchers, whether developers or deliverers, have a vested interest in study outcomes, potentially introducing biases toward evidence of intended outcomes. Also, implementation of the programs may have included aspects that remained implicit and would therefore not appear in researchers' descriptions, making replication of the interventions very difficult.

Although all of these studies used either a pre-post design to measure changes in teachers' content knowledge or traced changes in teachers' content knowledge over time, none of the

[18] Clermont et al., 1993; van Driel et al., 1998.

[19] Alonzo, 2002; Basista & Mathews, 2002; Freeman et al., 1994; Puttick & Rosebery, 1998; Radford, 1998; Summers & Kruger, 1994; Summers et al., 1998.

[20] Clermont et al., 1993; Jones et al., 1998; Robardey et al., 1994; Schibeci & Hickey, 2000; Shymansky et al., 1993; Summers & Kruger, 1994; Wang, 2001.

[21] Tuan & Chin, 1999.

[22] Basista & Mathews, 2002; Greenwood & Scribner-MacLean, 1997; Puttick & Rosebery, 1998; Radford, 1998; Summers et al., 1998; van Driel et al., 1998.

studies used comparison groups of teachers who did not participate in the professional development programs. Given the experience levels of many of the participating teachers, the extent of professional development provided, and the nature of the measured changes, it is certainly reasonable to argue that the changes resulted from the interventions, but without comparisons to other teachers these claims are not solidly grounded in empirical evidence. For example, it is possible that the teachers might perform better on a measure of content knowledge on a post-test simply because they had completed it previously, in one case[23] taking the same test at the beginning and end of the same workshop day. The use of multiple measures addresses this concern to some extent, as in the Alonzo (2002) and Summers and Kruger (1994) studies, which used both written instruments and interviews with teachers.

The Evidentiary Base for Claims about Teaching Practice as a Context for Deepening Teachers' Science Content Knowledge

Also included were two studies that investigated whether teachers can deepen their science content knowledge as a result of their teaching practice itself. One was a case study of a new teacher,[24] while the other followed four new teachers through their first year on the job.[25] Both studies showed some positive results on deepening teachers' pedagogical content knowledge, with the latter also reporting positive effects on deepening the teachers' disciplinary content knowledge. Table 3 provides information about the research studies, and Table 4 displays information about the interventions examined in these studies.

[23] Storti, 1999.

[24] Tuan, 1997.

[25] Gee & Gabel, 1996.

Table 3

Studies of Deepening Teachers' Science Content Knowledge Through Their Instructional Practice: Study Characteristics

Name of Study	Purpose of study		Data types		Knowledge Outcomes			Measures of Teacher Content Knowledge				Measurement description		
	Program evaluation	Providing examples	Quantitative	Qualitative	Disciplinary Content	Ways of Knowing	Pedagogical Content	Assessments	Interviews	Observations	Other approach	Validity	Reliability	Triangulation
The first year of teaching: Science in the elementary school (Gee & Gabel, 1996)		•		•	•		•	•						
Development of a grade eight Taiwanese physical science teacher's pedagogical content knowledge development (Tuan, 1997)		•		•	•		•		•	•	•	•		

Table 4
Studies of Deepening Teachers' Science Content Knowledge Through Their Instructional Practice:
Intervention Characteristics

Name of Study	Grade Level	Intervention[a]				Science Content			
		Full description	Teacher involvement voluntary	STEM faculty involved	Researcher(s) involved	Earth sciences	Life sciences	Physical sciences	Various sciences
The first year of teaching: Science in the elementary school (Gee & Gabel, 1996)	K-5	Y	N	?	N				●
Development of a grade eight Taiwanese physical science teacher's pedagogical content knowledge development (Tuan, 1997)	8	Y	Y	N	N			●	

[a] Y = Yes, N = No, ? = Not clear from document

Bibliography for Summary of Research on Experiences Intended to Deepen Teachers' Science Content Knowledge

If you are interested in how these studies were identified and reviewed, a summary of the methodology can be found at
http://www.mspkmd.net/index.php?page=24_4a-3d2

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Gee, C. J. & Gabel, D. L. (1996). *The first year of teaching: Science in the elementary school*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, 69th, St. Louis, MO.

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Puttick, G. M. & Rosebery, A. S. (1998). Teacher professional development as situated sense-making: A case study in science education. *Science Education, 82*(6), 649-677.

Radford, D. L. (1998). Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science Teaching, 35*(10), 73-88.

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