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PERSPECTIVES ON LEARNING, LEARNING TO TEACH AND TEACHING ELEMENTARY SCIENCE

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ABSTRACT

The framework that characterizes this work is that of elementary teachers' learning and development. Specifically, the ways in which prospective and beginning teachers' develop pedagogical content knowledge for teaching science in light of current recommendations for reform emphasizing teaching and learning science as inquiry are explored.

Within this theme, the focus is on three core areas: a) the use of technology tools (i.e., web-based portfolios) in support of learning to teach science at the elementary level; b) beginning teachers' specialized knowledge for giving priority to evidence in science teaching; and c) the applications of perspectives associated with elementary teachers' learning to teach science in Cyprus, where I was born and raised.

The first manuscript describes a study aimed at exploring the influence of web-based portfolios and a specific task in support of learning to teach science within the context of a Professional Development School program. The task required prospective teachers to articulate their personal philosophies about teaching and learning science in the form of claims, evidence and justifications in a web-based forum. The findings of this qualitative case study revealed the participants' developing understandings about learning and teaching science, which included emphasizing a student-centered approach, connecting physical engagement of children with conceptual aspects of learning, becoming attentive to what teachers can do to support children's learning, and focusing on teaching science as inquiry. The way the task was organized and the fact that the web-based forum provided the ability to keep multiple versions of their philosophies gave

prospective teachers the advantage of examining how their philosophies were changing over time, which supported a continuous engagement in metacognition, self-reflection and self-evaluation.

The purpose of the study reported in the second manuscript was to examine the nature of a first-year elementary teacher's specialized knowledge and practices for giving priority to evidence in science teaching. The findings of this study indicated that Jean not only articulated, but also enacted, a student-centered approach to teaching science, which emphasized giving priority to evidence in the construction of scientific explanations. It also became evident through data analysis that Jean's practices were for the most part consistent with her knowledge and beliefs. This contradicts the findings of previous studies that indicate a mismatch between beginning teachers' knowledge and practices. Furthermore, the findings of this study illustrated that critical experiences during teacher preparation and specific university coursework acted as sources through which this aspect of pedagogical content knowledge was generated.

The third manuscript proposes new directions for teaching science in elementary schools in Cyprus and makes recommendations to improve the current teacher preparation program in light of the need for a reform. This manuscript is built upon contemporary perspectives of learning and cognition, and is informed by current trends in science education in the United States and United Kingdom. Issues of teaching and learning science as inquiry, engaging in scientific argumentation, and the use of software scaffolds in support of learning and learning to teach science are discussed with special attention to the unique educational setting of Cyprus.

TABLE OF CONTENTS

LIST OF FIGURES

Figures **Page**

LIST OF TABLES

List of tables **Page**

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I dedicate this work to my mom, Kika, and to my advisor and friend, Carla. My mom has been the ideal and ever patient non-specialist mentor and her belief in this work and perceptive understanding of what I was trying to achieve have been immensely helpful throughout.

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CHAPTER 1

LEARNING TO TEACH SCIENCE: AN INTRODUCTION

In this multiple manuscript dissertation I address issues associated with elementary teachers' science learning and development. Specifically, this dissertation is concerned with how prospective and beginning teachers develop their pedagogical content knowledge (PCK) for science teaching in light of contemporary reform efforts in science education that emphasize learning science as inquiry. Within this theme, the three manuscripts deal with the following issues: a) supporting prospective elementary teachers in learning to teach science through the use of web-based portfolios; b) investigating the nature and sources of a first year elementary teacher's specialized practices, knowledge and beliefs for giving priority to evidence in science teaching; and c) applying perspectives associated with my research and teaching in the United States to the educational system in Cyprus, particularly the preparation of elementary teachers in the area of science education.

The theoretical framework for this work is based upon the current vision of reform in science education and is informed by contemporary perspectives in cognitive psychology, in particular, situated cognition. These perspectives have been applied to teacher learning with emphasis on Shulman's work with the development of teacher knowledge, specifically Pedagogical Content Knowledge (PCK). Technology integration for the purpose of supporting science learning and learning to teach science also is a central theme that is evident across the manuscripts.

Perspectives on Learning and Learning to Teach

Recent trends in learning theory portray new perspectives on how people learn and particularly how students learn and how teachers can support their learning. Recently, cognitive learning theory has taken the place of the behavioristic conceptions of learning and development. These changes refer to what people should learn and what their roles are in the process of learning. Brown (1994) explained that “learners came to be viewed as active constructors, rather than passive recipients of knowledge…learners were imbued with powers of introspections, one verboten” (p. 6). These new views about learning as an active process have inevitably influenced ways of thinking about teaching and learning as well. Borko and Putnam (1996) emphasized three shared cognitive themes on learning and thinking that could be applied to studies of learning to teach: a) the central role of knowledge in thinking, acting, and learning, b) learning as an active, constructive process, and c) knowledge and learning as situated in contexts and cultures. These three themes are discussed and applied in the area of teacher development accross the three manuscripts.

The role of knowledge in thinking, acting and learning

From studies of expert performance and problem solving in various domains outside of education, psychologists have learned that knowledge plays a central role in expert performance (Glaser, 1984 as cited in Borko & Putnam, 1996). Thus, it is important to explore the nature and the role of teachers' knowledge and beliefs in their learning to teach.

Particularly, in education, Shulman (1986) distinguished among three categories of knowledge: a) subject matter content knowledge, b) pedagogical content knowledge (PCK), and c) curricular knowledge. As he described, subject matter content knowledge refers to the knowledge of facts and concepts for a specific discipline. PCK refers to subject matter knowledge for teaching, which relates to "the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Curricular knowledge refers to the knowledge of particular subjects, topics, programs and materials used in teaching.

Pedagogical content knowledge has been of particular interest among researchers and educators over the past few years (Gess-Newsome, 1999; Shulman, 1986; Zembal, Starr & Krajcik, 1999). According to Shulman (1986), PCK refers to ways of representing subject matter knowledge and understandings of learning difficulties.

Moreover, PCK includes teachers' beliefs about teaching and learning. Many researchers have argued that by the time prospective teachers get to college they hold well-established beliefs and practices related to being a teacher (Pajares, 1992). Not surprisingly, these views of teaching and learning have been shown to influence classroom teaching practice (Pajares, 1992). Schubert (1992) argued that teacher educators need to respect the integrity and the sophistication of teachers' personal theorizing as a valuable and necessary form of research and teacher education. Therefore, targeting teachers' personal theorizing is essential to supporting their learning to teach. Examining teachers' PCK is the emphasis of the second manuscript, a study aimed at characterizing a first-year teacher's specialized practices, knowledge and beliefs for giving priority to evidence in science teaching.

Research findings suggest that beginning teachers' knowledge and beliefs are influenced by the types of experiences that they have during their preparation to teach (e.g., Bryan & Abell, 1999; Lortie, 1975; Pajares, 1992). A study by Bryan and Abell (1999) illuminated the significant role of field experiences in shaping prospective teachers' professional knowledge - understandings and beliefs about science teaching and learning. The issue of the role of field experience, and particularly the potential of the Professional Development School (PDS) to integrate university coursework and field experience, is discussed in the third manuscript and focuses on the context of science education in Cyprus. PDS has be also been the context of the study related to the use of web-based portfolios in support of learning to teach science at the elementary school.

Another important finding of Bryan and Abell's (1999) study has to do with the role of reflection in the development of professional knowledge. As the researchers pointed out, accompanying experiences with reflection supports prospective teachers in becoming more cognizant about their beliefs (Bryan & Abell, 1999). Making explicit these beliefs provides a reference point for analyzing practices The ability to engage in reflective practices has been widely addressed in the literature as one of the most important activities associated with learning (e.g., Clift, Houston, & Pugach, 1990; Dewey, 1933; Schon, 1983). Supporting prospective teachers' reflection on their learning to teach science is a central feature of the study related to the use of web-based portfolios in teacher education. In particular, the way the task was organized (i.e., develop three versions of a personal philosophy of teaching and learning science) and the fact that the web-based format provided prospective teachers with the possibility of keeping multiple versions of their philosophies, giving them the advantage to view how their philosophies were changing over time and supporting continuous engagement in metacognition, self-reflection and self-evaluation.

Learning as an active, constructive process

Current perspectives of learning and instruction are focused on learning environments that are designed to encourage students to integrate information instead of merely being provided with it by the teacher (Linn, 1996). According to this view, meaningful learning occurs when learners actively construct their own learning outcomes (Bruner, 1961; Mayer, 1992; Wittrock, 1990). However, the ways in which learners interpret new learning experiences and construct learning outcomes depend on their existing ideas, priorities and perspectives (Driver, 1997). The role of existing knowledge in learning has been stressed through conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982). The application of conceptual change theory is discussed in the manuscript related to science education in Cyprus, which makes recommendations for the reconstruction of teacher preparation.

Also, conceptual change pedagogy grounded in constructivist learning theory was used to frame the study related to the first year elementary teacher's specialized knowledge and beliefs for giving priority to evidence in science teaching. According to Stofflett (1994), in a constructivist teacher education program, learning experiences should be included that allow prospective teachers, who were taught science in didactic ways, to reconstruct their knowledge of science content and existing notions of pedagogy. This framework guided the PCK study, which aimed to investigate possible sources of PCK and identify experiences that were critical in the development of the participant's specialized knowledge and practices for giving priority to evidence in science teaching.

Situated learning

According to Greeno (1996), a theory of cognitive situations is emerging that takes the distributed nature of cognition as a starting point and implies that thinking is situated in a particular context of intentions, social partners and tools. According to this situative/pragmatist-sociohistoric view, knowledge is distributed among people and their environments, including the objects, artifacts, tools, books, and the communities of which they are a part (pp. 16-17).

According to Brown, Collins and Duguid (1989), "All knowledge is like language…its constituent parts index the world and so are inextricably a product of the activity and situations in which they are produced" (p. 33). From the perspective of situated cognition, according to Duit and Treagust (1998), learning means the change from one sociocultural context to another or changes from the practice of one culture to another. This view about how knowledge is situated within specific contexts implies the social and cultural nature of learning, which has significant implications for research on learning science (Roth, 1995). These implications are discussed in the manuscript related to science education in Cyprus. Perspectives from situated cognition are also applied in the second manuscript, which examines the influence that specific university coursework and an innovative teacher preparation program had on the participant's development of a specific aspect of PCK.

Cognitive views on learning also have influenced the instructional design and the development of new technologies. Collins (1991) discussed how networked technologies make the invisible visible and tacit knowledge explicit. Specifically, he stated that the benefits of technology include making visible the parts of a process that are not normally seen. By revealing these processes in detail, learners will have the chance to figure out how processes unfold. In the case of teacher education, by making their thinking visible, prospective teachers engage in reflective and metacognitive activities about their own learning, but also they get a better understanding about their peers' thinking about teaching. Such a technology and the ways in which a specific task supported prospective teachers in articulating and making their views of science teaching and learning explicit is discussed in the first manuscript, which explores the use of web-based portfolios within the context of an innovative elementary science methods course.

Overview of Manuscripts

In closing, this work is built upon a situated cognition learning theory and is informed by conceptual change pedagogy and reveals important information on elementary teachers' science learning and development. In particular, this work illuminates types of experiences that are critical in supporting the development of prospective and first-year teachers' understandings of science and science teaching.

Data gathered from the studies reported in this dissertation have allowed me to gain understanding of the ways in which technology tools can be used to support teacher learning of science. In particular, the findings of the first study illustrated that web-based portfolios appeared to be a powerful tool for supporting the participants' learning. Engaging prospective teachers in thoughtful reflection through web-based portfolio development appeared to have had an impact on their conceptions of teaching and learning science. In this study, web-based portfolios served as a vehicle for these prospective teachers to reconsider and reevaluate their views of teaching and learning science in light of new learning experiences.

In addition to providing an insight into prospective teachers' personal pedagogical theories, the web-based portfolio task revealed the significance of the Professional Development School context and its impact on participants' learning. As the findings of this study suggest, prospective teachers benefited from the close integration of their university coursework and their field experiences. This assertion is based on the fact that the participants incorporated in evidence from both the model lessons they experienced in their science methods course and from their observations in the field. At the same time, the participants were reflecting on their teaching through their experiences in the science methods course and observations in the field.

The role of the context also was illuminated through the findings from the PCK study, which suggested that the school context and the teacher preparation program influence teachers in forming innovative views of teaching and learning science. The participant's case illustrated how her innovative preparation program supported her learning to teach science in ways that were consistent with reform efforts in science education. According to the participant, two elements of her preparation program were critical to her learning to teach and her induction as a first-year teacher: a) opportunities to work closely with experienced mentor teachers and b) the opportunity to concurrently develop and apply in practice a personal philosophy of science teaching and learning. Her case implies that situating learning to teach experiences in meaningful contexts is important for successful induction. Hence, further research needs to be done in the area of exploring ways for situating prospective teachers' experiences in meaningful ways.

Furthermore, data collected through the PCK study provided insight into a specific aspect of PCK for science teaching – giving priority to evidence – and how that is translated into classroom practice. This study also sheds light on the possible sources from which this type of PCK was generated. Specifically, this study illustrates that specific experiences during teacher preparation were critical in the development of this aspect of the participant's PCK. What we can learn from the case of Jean is that supporting the development of specific aspects of PCK is a difficult and complex task, which requires the combination and interaction of a variety of experiences. Data analysis illustrated that the participant's specialized knowledge for giving priority to evidence in science teaching was enhanced through specific courses, assignments and activities during her preparation. In fact, it became evident through this study that learning experiences in Jean's university coursework, along with the teacher preparation program, promoted her conceptual change as they provided her with opportunities to reflect on and reconstruct her understandings of teaching and learning science. These findings have implications for the design of teacher preparation programs that aim to support teachers in examining and reconstructing their existing knowledge and beliefs in light of contemporary ideas about teaching and learning science, particularly for giving priority to evidence in science teaching.

Giving priority to evidence in the construction of explanations is a central component of scientific argumentation, which is advocated by a number of researchers (e.g., Driver, Newton & Osborne, 2000; Duschl & Osborne, 2002; Kuhn, 1993; Zembal-Saul et al, 2002) as a way of supporting science learning and gaining an understanding of the nature of science. As Duschl and Osborne (2002) argue, “The conditions for supporting argumentation are dependent on the use of evidence in the process of building and evaluating explanations” (p. 44). The adoption of revolutionary ideas about argumentation, scientific inquiry and software scaffolds, rooted in the United States and United Kingdom and the ways those could find their application in the unique setting of a small island has framed the third manuscript, which deals with science education in Cyprus. More specifically, this paper suggests a shift of the emphasis for the Cypriot elementary science curriculum away from discovery learning and toward inquiry that would support children in construing knowledge about science through participation in the social and physical environment of the classroom (Keys & Bryan, 2001) and engagement in argumentation. The use of technology tools and particularly software scaffolds in support of such learning also is recommended. Evidence reported in a number of studies is used to support the argument that software scaffolds have the potential to engage learners in inquiry-based investigations (Edelson, 2001) and support engaging in critical reflection and the development of evidence-based explanations (Land & Zembal-Saul, 2001).

This paper has implications connected to efforts that attempt to apply theoretical recommendations for reform in practice in the unique educational settings of Cyprus without neglecting the traditional, societal, and cultural beliefs that hold the community together. As Gray (1999) notes, “It is important for science educators to recognize that traditional beliefs provide some *glue* that holds the community together, enabling individuals to operate in, and make sense of their world” (p. 263).

In an attempt to respond to the calls for reform in science education in Cyprus, a systematic and critical examination of the research associated with current trends in science teaching and learning is needed, as well as research associated with curricular implementation in developing countries with special attention to implementing changes that are contextually relevant to the Cypriot societal needs and with respect to the country’s history, values, and traditions.

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CHAPTER 2

EXPLORING THE INFLUENCE OF WEB-BASED PORTFOLIO DEVELOPMENT ON LEARNING TO TEACH ELEMENTARY SCIENCE

Abstract

This qualitative case study examined web-based portfolio development in the service of supporting reflective thinking and learning within the innovative context of Professional Development Schools. Specifically, this study investigated the nature of the evidence-based philosophies developed by prospective teachers as central part of the web-based portfolio task and the ways in which the technology contributed to the portfolio task. The findings of this study illuminated the participants' understandings about learning and teaching science emphasizing a student-centered approach, connecting physical engagement of children with conceptual aspects of learning, becoming attentive to what teachers can do to support children's learning and focusing on teaching science as inquiry. The way the task was organized and the fact that the web-based format provided the possibility to keep multiple versions of their philosophies gave prospective teachers the advantage to view how their philosophies were changing over time, which supported a continuous engagement in metacognition, self-reflection and self-evaluation. Built on these findings we suggest that future research be directed in the area of teachers'

knowledge and beliefs about science teaching and learning and the kinds of experiences that influence their development. The ways in which technology tools can contribute to supporting prospective teachers in developing personal theories consistent with current recommendations of reform focusing on supporting learning through inquiry should also be explored.

Introduction

In recent years, the notion of a 'portfolio' has become easily recognizable as a part of the everyday language. Olson (1991) reported that a portfolio was originally defined as a portable case for carrying loose papers or prints – *port* meaning to carry and *folio* pertaining to pages or sheets of paper. Today *folio* refers to a large collection of materials, such as documents, pictures, papers, work samples, audio or videotapes.

Portfolios have been used in teacher education in different formats, in a variety of ways and for different purposes. The diversity of the functions and uses of portfolios have consequently produced multiple definitions depending on the purpose that the portfolio serves. Initially portfolios were associated with a scrapbook that included artifacts that had been saved and which could eventually be shown to a prospective employer (Aschermann, 1999). Portfolios also were described as a purposeful, integrated collection of work (Paulson, Paulson, & Meyer, 1991), and as an extended resume (Wolf, 1994). Dana and Tippins (1998) referred specifically to the science portfolio as "a researched presentation of the accomplishments of a teacher of science documented with teacher and student work and substantiated by reflecting writing" (p. 723).

Portfolios can be used to demonstrate effort, progress, and achievement (Barrett, 1998) and to illustrate good teaching (Aschermann, 1999). According to Wolf (1991) portfolios can give teachers a purpose and framework for preserving and sharing their work and stimulate them to reflect on their own work and on the act of teaching. Other purposes of portfolio development involve the enhancement and development of teaching skills (Collins, 1990), the encouragement of reflection upon one's teaching (Richert, 1990), and professional growth through collegiality (Shulman, 1988). As Lyons (1998a) suggested, “the portfolio may be considered from three perspectives: as a credential, as a set of assumptions about teaching and learning, and as making possible a powerful, personal reflective learning experience” (p. 4).

This study focused on the development of web-based portfolios in science teacher education. Two issues are important in this study: the emphasis on supporting prospective elementary teachers’ reflection and the construction of their knowledge of learning and teaching science. The literature review that follows illustrates the different approaches to portfolio development in teacher preparation programs.

Literature Review

Several studies have been conducted to investigate the use of portfolios in teacher education programs. For example, in their study, Dana and Tippins (1998) proposed a model of portfolios for science teaching as a form of self-reflection and evidence of the prospective teachers’ thoughts and understandings of what it means to teach science to children. For their study, prospective teachers were asked to identify a problematic aspect of science-specific pedagogy, and then collect and select evidence demonstrating what they knew and were able to do about it. In addition, prospective teachers had to organize the evidence for presentation in the teaching portfolio and to engage in conversations with their peers about their thinking, growth and development. The science teaching portfolios were required to have an opening statement expressing the portfolios purpose, a variety of evidence with tags or captions; and a reflective synthesizing statement (Dana

& Tippins, 1998). The findings of this study supported the argument that science teaching portfolios support reflective self-inquiry about science pedagogy. More specifically, as the findings of this study revealed, participants engaged in reflective activities while developing their opening statements. In addition, most of them used lesson plans and student work as evidence while a few of them produced artifacts especially for their portfolios (e.g., bibliography, HyperCard stack, videoclips and pictures). In their synthesizing statements, many of the participants reported that in the beginning it was difficult to develop their own questions or how to go about learning about their questions, but they were comfortable in doing so at the end. As the researchers concluded:

> Engaging prospective teachers in the preparation of portfolios as a form of self-reflective inquiry in collaboration with peers, university instructors, and classroom teachers fits well with the goal of making explicit the knowledge, skills and dispositions that teachers of science have about teaching, learning and content. (p. 730)

Despite their potential to facilitate thoughtful reflection, traditional paper-based portfolios often fail to capture the dynamic and complex process of teaching and learning (Aschermann, 1999). Depending on the ways in which they are used, traditional paper-based portfolios may be nothing more than a container of papers. Paper-based portfolio development enhances the danger of paying too much attention to the final product rather than the process. Other drawbacks of the traditional paper portfolios have to do with the substantial photocopying costs (Dollase, 1996) and storage problems (Aschermann, 1999). A solution to these problems appears to be in the use of hypermedia technology. Jonassen, Myers and McKillop (1996) define hypermedia as a way of representing and organizing information using electronically connected networks of nodes, which are the basic units of storage in hypermedia. One hypermedia tool is the electronic portfolio, which has recently gained popularity among teacher educators.

A growing number of studies are reporting the uses of electronic portfolios, also known as e-portfolios, in teacher education (e.g., Aschermann, 1999; Barrett, 1998; Glasson & McKenzie, 1999; McKinney, 1998). For example, Glasson and McKenzie (1999) examined the development of multi-media portfolios for enhancing learning and assessment in a science methods class. Their study focused on the portfolio development of a group of four prospective teachers who planned three days of investigative science activities with middle school students. According to the researchers, the activities engaged students in collecting and identifying macro-invertebrates to assess stream quality. Follow up activities involved the students working in groups to negotiate pertinent aspects of development along the stream, such as where to locate homes and industry (Glasson & McKenzie, 1999). The prospective teachers collected information and documented in portfolios their own and their students' learning using a multimedia-authoring tool. They also included in their portfolios videotaped interactions with students, scanned samples of student work, digitized photographs, curriculum plans, and written assessments of their learning. Two prospective teachers participated in videotaped interviews where they discussed their perceptions of the process of developing a portfolio. Both of them mentioned that the portfolio was useful for understanding and assessing the progress of the children while serving as an assessment tool for themselves to be used by their teachers. As Glasson and McKenzie (1999) concluded, "Through this process of designing their own portfolio, the ability of these prospective teachers to assess their own learning and students' learning was greatly enhanced" (p. 342).

A type of hypermedia portfolios is the web-based portfolio. When e-portfolios are specifically created for and placed on the web, they are referred to as web-based portfolios (Watkins, 1996). The Web, as both a technology and an interface, enables prospective teachers to have ultimate control in assembling and re-organizing, as well as integrating narrative captions among the evidence to emphasize the interrelated nature of learning (Watkins, 1996). Similar to other forms of hypermedia, web-based portfolios have the potential to support reflection and revaluation because they provide a means of storing multiple iterations over time and a mechanism for ease of editing and revisions. Substantial revisions involve reflection on course content encompassing processes like reordering and reevaluating, resulting in new insights (Yates, Newsome & Creighton, 1999).

The literature suggests that the web-based format has additional benefits to offer beyond those of other types of e-portfolios. In specific, the web-based format provides instant access to a variety of audiences. As Pierson and Kumari (2000) illustrated, the Web environment permits prospective teachers the flexibility to maintain their portfolios in a Web-space that can be remotely accessed from anywhere at any time, by the prospective teacher, faculty, peers, and potential employers. Research in the area of web-based portfolio development is limited. However, the few findings that exist are consistent and suggest that web-based portfolio development is a constructivist process that facilitates meaningful reflection (e.g., Avraamidou, 2001; Milman, 1999; Morris & Buckland, 2000; Watkins, 1996; Zembal-Saul, 2001).

A study by Milman (1999), for example, suggested that engaging prospective teachers in web-based portfolio development results in engaging them in reflective activities while connecting course work and field experience. In this study, Milman (1999) documented the use of the World Wide Web to create electronic teaching portfolios in a pilot prospective teacher education course as a tool for reflection. The objectives of the course were for prospective teachers to create electronic teaching portfolios, to reflect upon their coursework and teaching experiences, and to become more proficient with the technology. Interviews with the participants, analysis of their journals, and observations in their classes revealed that the process was constructivist, demanding and multifaceted. The prospective teachers reported that the process of creating electronic teaching portfolios was very positive, resulting in reflection about themselves as teachers. Through the process of analytic induction of the participants' journals, interviews and observations, the following assertion was made, "Creating electronic teaching portfolios is a constructivist process that promotes an examination of prospective teachers' beliefs, philosophies, objectives, and purposes for teaching" (Milman, 1999, p. 3).

According to Pearson (1989), the challenge in teacher education is to enable prospective teachers to take what they have learned about teaching and to use it on their own in the teaching situations in which they find themselves . In an attempt to meet this challenge, and considering the fact that the two innovations, portfolios development and hypermedia authoring combined in support of learning are largely unexplored, this study aimed to investigate the use of web-based portfolios in a reform oriented elementary science methods course as a vehicle for supporting reflection and learning to teach.

Purpose and Research Questions

Given the need to incorporate opportunities for critical reflection into teacher preparation and the potential of hypermedia authoring to support this level of reflection, this study examined web-based portfolio development in the service of supporting reflective thinking and learning within the context of a reform-oriented science methods course. In this course, portfolios were used to assist prospective teachers in developing meaningful understandings about learning to teach science. Using the web-based format to develop portfolios was intended to provide prospective teachers with opportunities to connect their personal theories of teaching and learning with their field experiences. In addition, the web-based format facilitated the development of dynamic and complex interconnections among claims made by prospective teachers and multimedia evidence used to support those claims.

The web-based portfolios included two main components: a) a collection of evidence that consisted of course assignments; and b) a personal, evidence-based philosophy about science teaching and learning. The purpose of the web-based philosophies was to: a) support the development of personal theories about teaching and learning science explicitly and publicly; b) promote reflection on personal theories in light of new experiences and learning; and c) facilitate the development of connections among theory and practice.

At a general level this research aimed to answer the question: What is the nature of prospective elementary teachers' science teaching philosophies for supporting children's science learning and how do they change over time. Specifically, the questions that guided this research were:

- What is the nature of prospective elementary teachers' philosophies about science teaching and learning?
    - What kinds of claims do prospective elementary teachers pose?
    - What is the nature and sources of evidence prospective elementary teachers use to support their claims?
    - In what ways do prospective elementary teachers justify their evidence in light of the claims used to support?
- In what ways does the web-based portfolio task support thoughtful reflection associated with learning to teach science?
- In what ways does the technology contribute to the portfolio task?

Methods

Design

This study utilizes a qualitative case study design to examine the development of prospective elementary teachers' understandings of teaching science as supported by and illustrated through the development of web-based portfolios, within the context of a reform-oriented elementary science methods course. Specifically, this study manifests the characteristics of a multi-participant case study (Merriam, 1998). For the purpose of this study, two individuals were investigated within the larger case of prospective elementary teachers' understandings of teaching science with the support of web-based portfolios. These two individuals were chosen because it was believed by the authors that their representativeness would lead to main assertions about prospective teachers' understandings of teaching science. Both of the participants were traditional prospective elementary teachers (i.e., 22 years old, females with no science-specific background). In order to maintain the confidentiality of the participants, the pseudonyms Sarah and Jane were used in all aspects of this study.

Context

As described by the instructor of the course (Zembal-Saul, 2001) the participants in this study were members of a cohort of prospective elementary teachers engaged in a year-long internship program. The internship took place during the final year of a four-year teacher education program. The prospective teachers spent the entire year in one of four professional development schools (PDSs) that were part of a local school-university partnership (Zembal-Saul, 2001). Mentor teachers in these schools were actively engaged in their own professional development (e.g., taking coursework, engaging in classroom-based research, participating in methods course planning). The web-based portfolio project was completed as part of the elementary science methods course. The course was co-designed by the university-based methods instructor and a team of five mentor teachers, a PDS principal, and a curriculum support teacher. The web-based task was structured as an evidence-based argument about teaching and learning science that was developed over time. Prospective teachers generated a series of assertions or claims, supported those claims with multiple pieces of evidence/artifacts (e.g., course projects, classroom observations), and justified evidence in light of the claims they made. Over the course of the semester, claims were added, modified, or rejected on the basis of new evidence (Zembal-Saul, 2001).

Specifically, in the first version of their science teaching philosophies, prospective teachers were required to include at least three claims and use at least one piece of evidence to support each claim. In addition, all evidence needed to be justified. That is, an explanation should have been included of why the specific piece of evidence supported the corresponding claim. The prospective teachers were asked to develop a second version of their philosophy halfway through the semester, and a third version at the end of the semester. In the second version of their philosophies, prospective teachers had to include at least four claims about how children learn science and what teachers can do to support children's science learning. Same as the first version of the science teaching philosophy, all evidence should have been justified. In the third version of their philosophies, each new claim needed to be supported by at least two pieces of evidence. Each existing or modified claim should have been supported by at least three pieces of evidence. Again, all pieces of evidence had to be justified in light of the claims they were used to support. An example of the main page of the web-based portfolio is presented in Figure 1.

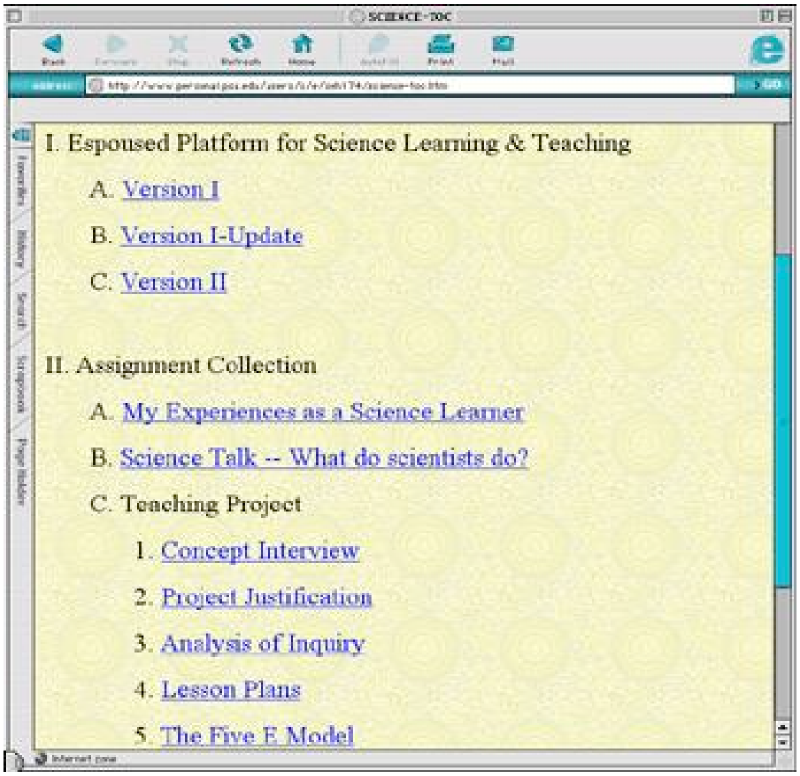

Figure 1. Sample of the main page of a web-based portfolio.

Data Sources

Multiple sources of data were used in this study. The main source of data were the web-based portfolios that the participants developed during the Fall 2000 semester. More specifically, three versions of the web-based science teaching philosophies that each of the participants developed as part of their web-based portfolios were examined. Another source of data were the reflection statements developed by each of the participants. In their reflection statements, participants were asked to discuss what changes were made in the different versions of their philosophies and explain why. Specifically, participants were asked to reflect on how they saw their science teaching philosophies changing over time and to comment on the revisions they were making in each iteration.

Data analysis

Three analytic techniques were used to analyze the web-based portfolios: pattern-matching, explanation-building, and time-series analysis (Yin, 1984). Pattern matching refers to the patterns identified, through multiple readings of the web-based portfolios, in relation to the nature of claims developed, evidence used to support claims and justifications. The purpose of the explanation-building was to analyze the data by building an explanation about each case (Yin, 1984), referring to why the science teaching philosophies developed the way they did in the different versions. The time-series analysis refers to the analysis of changes over time and identification of trends in developing a web-based science teaching philosophy throughout the semester. Identification of trends refers to the changes noticed in the science teaching philosophies, moving from the first version to the second and from the second version to the third.

Furthermore, a content analysis of the participants' reflective statements was done in order to illuminate their understandings of how their views of teaching and learning were changing over time. In order to investigate how technology contributed to the task, the way participants made use of the multimedia possibilities of the web-based format and the way they used hyperlinking were investigated. Specifically, the kinds of artifacts the participants used as evidence in the three versions of their philosophies and how they chose to link further information and artifacts within the text were examined. After the within-participant analysis was done, a cross-participant analysis followed in order to identify similarities and differences across the two participants.

Findings and Interpretations

Data from the three versions of the participants' science teaching philosophies and from their two reflection papers were analyzed in order to explore the nature of their philosophies, the ways that the web-based portfolio task supported thoughtful reflection and the ways technology contributed to this task. The findings are described based on the assertions that were made around three core areas: a) The nature of the prospective elementary teachers' claims, evidence and justifications; b) Prospective elementary teachers' understandings about teaching and learning science; and c) The role of the task and the affordances of technology.

Nature of participants' claims, evidence and justification

The claims that Sarah and Jane developed throughout the three versions of their philosophies are presented in Table 1. and Table 2. Overall, the claims that both of the participants developed, transformed from being generic in initial versions of their philosophies to being precise and science specific in the final versions. A discussion about the nature of the evidence and justifications the participants developed, and how they transformed from the first to the later versions of their philosophies follows.

Making connections between university coursework and field experiences

As it became evident through the participants' web-based philosophies, the greatest influence on their learning were the model lessons they experienced in the science methods course. Specifically, the most commonly used source of evidence were the model lessons of the elementary science methods course. In addition, moving from the first to the third versions of their philosophies, participants incorporated more evidence drawn out of their teaching experiences while they continued using evidence drawn from their science methods experiences. Table 3 illustrates how Sarah and Jane used evidence to support their claims in the three versions of their philosophies:

Versions	Claims
V1	Children learn science by asking questions. Children learn science by relating it to the world outside through hands-on activities. Children learn science by being challenged to reflect deeply on science observations.
V2	Children learn science by asking questions. Children learn science by experiencing it through hands-on and minds-on activities. Children learn science by being able to reflect deeply on science observations. Teachers support science learning best when they ask questions to probe students' thinking as opposed to asking questions to elicit a certain answer.
V3	Same as Version 2.

Table 1. Jane's claims across the three versions of her philosophy

Versions	Claims
V1	Children learn science through hands-on activities. Children learn science through inquiry-based investigations. Children learn science through activities that engage and challenge all learners. Teachers can support children's learning by modeling joy in science. Teachers can support children's learning by creating a safe and collaborative learning environment.
V2	Children learn science through hands-on and minds-on activities. Children learn science through inquiry-based investigations. Children learn through talking about science. Teachers can support children's learning by mediating their science experiences.
V3	Children learn science through hands-on and minds-on activities. Children learn science through inquiry-based investigations. Children learn best through talking about science. Children learn science through collaboration. Teachers can support children's learning by mediating their science experiences.

Table 2. Sarah's claims across the three versions of her philosophy

Participant	Methods Course			Readings			Teaching Experience		
``	V1	V2	V3	V1	V2	V3	V1	V2	V3
Sarah	2	3	3	0	2	2	0	1	6
Jane	3	5	5	0	1	2	0	1	5

Table 3. Sources of evidence across the three versions of the participants' philosophies

In general, the participants relied heavily on their experiences as learners in the methods course throughout the different versions of their philosophies. As shown in Table 1, both

Sarah and Jane used several pieces of evidence that reflected central concepts from the model lessons they experienced in their science methods course to support their claims.

Furthermore, both Sarah and Jane included an increasing number of examples of their teaching experiences over time. Specifically, as soon as they began teaching, they incorporated these experiences as evidence. As presented in Table 3, in the second version of her philosophy, Sarah used one piece of evidence capturing her teaching experiences. In the final version of her philosophy she used six of them. A similar trend was identified in relation to how Jane made use of evidence drawn out of her teaching experiences. In the second version of her philosophy, Jane used one piece of evidence and in the final version she used five pieces of evidence drawn out of her personal teaching experiences. Additionally, Sarah used many pieces of evidence that captured her observations of her mentor and other teachers teaching. Specifically, in the final version of her philosophy, Sarah referred to six pieces of evidence from her observations in the field.

The fact that both of the participants integrated evidence drawn out from both their experiences from the science methods course and the field, suggests that they were making connections between university coursework and field experiences. The impact of the mentor teachers' teaching activities on the participants' personal philosophies became apparent through the evidence that Sarah used in her philosophy that was drawn out of observations of her mentor and other mentor teachers' practices. This finding is significant because research suggests that prospective teachers often lack powerful models in school contexts that reflect what they are learning in their coursework. For a variety of reasons, including strong socialization pressures, prospective teachers often conform with school context and culture (Darling-Hammond, 1994). This suggests the need for a better cooperation between school and university and particularly the pairing with mentor teachers. Mentoring is crucial to the prospective teachers' development as professionals and it greatly affects their enculturation into the teaching profession (Putnam & Borko, 2000).

Transformation from being descriptive to being explanatory

A trend that emerged through the participants' justification statements is that they shifted from being descriptive and brief to being explanatory, reflective and elaborative. However, some differences in the way Sarah and Jane developed their justification statements throughout the three versions of their philosophies were observed.

Specifically, in the first version of her philosophy, Sarah did not really justify the ways in which different pieces of evidence supported her claims, but instead she just further described the specific pieces of evidence used to support the claims. For example, in order to justify *Air Activities* for the claim stating that children learn science through hands-on and minds-on activities, she described the model lesson:

> This is an example of a hands-on/minds-on activity. Before experimenting, the class generated a list of things we knew about air. (The "K" or "Know" portion of the modified KLEW chart.) While performing various experiments, we were required to make predictions and conclusions based on what we observed. When the class reconvened for a science talk, class members shared things they learned about air ("L") and their evidence ("E") to support their claims. This led the class to generate new wonderings ("W") in light of what we learned. (Sarah, v. 1, justification of evidence for claim #1)

In contrast, in her final version, Sarah developed extensive and explanatory justification statements for the evidence used to support specific claims. The justification statement below refers to the use of journals as a way for teachers to mediate children's science experiences:

> In both my own fourth grade classroom and Y's second grade classroom, children record their thoughts, predictions, observations, and conclusions in science journals. In providing children the opportunity to use science journals, teachers are providing their students the opportunity to reflect on their own actions and thoughts. In recording predictions, for example, students are creating a record to which they can refer later. Students can then compare their thoughts before and after a science activity, thus reflecting on and learning from their own action. Promoting student reflection is another quality of the teacher's role as mediator. (Sarah, v. 3, justification of evidence for claim #5)

In this justification statement, Sarah explained how students engaged in reflection when they developed science journals. She connected the evidence with the claim by stating that engaging students in reflection is one aspect of the teacher's role as mediator.

Jane made strong connections between the evidence and the claims through her justifications in the first version of her philosophy, but her statements were more reflective than evaluative in their nature. In particular, she commented on how each piece of evidence contributed to her own learning but she did not explain how the specific evidence supported the associated claim. The example that follows is the justification statement that Jane developed about *Oobleck* in support of the claim stating that children learn science by being challenged to reflect deeply on science observations:

> We not only observed and considered possible explanations for the *Oobleck*'s behavior, but we also tried to find evidence for these explanations. Because we were able to think beyond the observable and reflect on the whys and hows, I was able to learn about much more than the properties of liquids and solids; I learned about science as a process. (Jane, v.1, justification of evidence for claim #3)

Like Sarah, Jane developed more explanatory justification statements in the third version of her philosophy. In order to justify a piece of evidence from the book *Talking Their Way Into Science* (Gallas, 1995) used to support her claim that teachers learn science by asking questions, Jane stated:

> This piece of evidence supports my claim because this reading includes examples and substantiation of why using open-ended questions is important for a child's scientific development. The section discusses how much more thinking and synthesizing occurs when open-ended questions are used instead of closed-ended. The following is an example from the book. If someone asks, "Who made the first clock?" the conversation is over when this inventor's name is found. Not only this, but the bulk of the conversation would involve students trying to recall possible names, not deep analytical thinking. Think instead about students discussing possible reasons for why a clock works. The scientific ideas generated would increase ten fold. By asking students a question that is not expected to elicit a correct answer, students are able to think, analyze any data they have, and make a prediction without fear that they will be wrong. Through examples such as these and testimony from researchers in the field, the Gallas reading attests to the many benefits of asking open-ended questions for science learning. (Jane, v. 3, justification of evidence for claim #1)

In this justification statement, Jane described how the author of the book discusses the value of asking open-ended questions in supporting children's learning.

The fact that both of the participants moved from being descriptive to being more explanatory in their articulation reveals that the development of evidence-based claims proved to be an important element of the task and a good strategy for supporting their ability to distinguish evidence from explanation. Having to craft justification statements, prospective elementary teachers had to explicitly distinguish between the claims they made, the evidence they used to support their claims and the explanation used to back up their evidence. The above finding is important since several lines of research (e.g., Kuhn, 1991) have found that people have difficulties in making distinctions between the respective roles of explanation and evidence in an argument. Explanations and evidence are essential to our understanding and evaluation of claims (Brem & Rips, 2000).

In addition, the development of justification statements appeared to be a powerful technique for engaging prospective teachers in meaningful reflection since they required explicit and justified connections between the claims and evidence used to support them. According to Nettles and Petrick (1995), writing a rationale allows prospective teachers to reflect on their work, both in deciding for which outcome the artifact provides evidence and in realizing their proficiency in that particular teaching strategy or skill.

Engaging in reflective and metacognitive activities

In addition, prospective teachers engaged in metacognitive activities while developing their reflection statements where they had to discuss about the changes they had made in each newer version of their philosophies. Jane commented on how her teaching experience with *Shadow Lessons* helped her develop a better understanding of teaching science as inquiry. Specifically, she stated in her reflection statement:

> Three pieces of evidence are my shadow lessons as a whole and one of the pieces of evidence is the free exploration station…teaching and preparing the shadow lessons really opened my eyes to the possibilities of inquiry in science. It was this reason that I used my shadow lessons as evidence for all fours claims. (Jane, first reflection)

In Sarah's reflection, it becomes evident that she was aware of the way in which her web-based philosophy had been changing. In the reflection statement she crafted at the end of the semester she pointed out how her philosophy had evolved:

> As I was working on version 3, there were several things I noticed about how my philosophy is taking shape. First of all, the majority of my claims

> (four out of five) deal with how children learn science, and only one deals with what teachers can do to support children's science learning. I think that this reflects a very general principle of my philosophy of education - that the focus should be on children and not on the teacher...I believe that a strong focus on children and how children learn naturally leads to child-centered practices. (Sarah, second reflection)

The development of a reflection statement on how their personal science teaching philosophies were taking shape required prospective teachers to think about their knowledge, understandings, ideas and beliefs about learning and teaching. This is important because research suggests that it is very difficult to move prospective teachers beyond focusing on surface level ideas to engaging in more substantive reflective practices, such as analyzing and evaluating their planning and teaching (Borko, Livingston, McCaleb & Mauro, 1988). Dollase (1996) agreed, pointing out that prospective teachers have difficulty reflecting on their experiences, understanding teaching goals, and developing an adequate rationale for their lessons.

Participants' understandings about teaching science

Becoming sensitive to children's thinking. The first trend that was apparent through the different versions of the participants' web-based philosophies was that they became more sensitive to children's thinking and learning and emphasized a student-centered approach. Sarah argued about the importance of Science Talk in one of her justification statements:

> …it gives the teacher a window of insight into the children's thinking. It allows teachers to listen to their students, find out about their preconceived notions, their thought process, and their understandings of previous concepts. (Sarah, v. 2, justification of evidence for claim # 3)

Similarly, Jane described how students learn through reflecting on observations:

> While students didn't always answer that question to me, their minds were definitely reflecting, as was shown by their actions. For example, one student was observing how the shadow size of scissors changes when the scissors are moved towards and away from the light source. She was merely moving the scissors back and forth, making up sounds as she went along. I then asked her why she thought this was happening. She stopped for a minute, shrugged her shoulders and said, "I don't know." At this point she wasn't reflecting very much. As she continued the exploration I pushed more questions and then asked how we could find the answer to these questions. After a number of questions and ponderings, the student formed a hypothesis. (Jane, v. 3, justification of evidence for claim #3)

Sarah commented on the importance of the Science Talk in gaining an insight into the children's thinking which reveals her sensitivity to their knowledge and thinking. Jane explained the importance of reflecting on observations in support of children's learning with the use of an example from her own teaching experience. Through Jane's statement it is shown that she was considering how to support the specific student's reflection. Both of the participants seemed to be sensitive to their students' thinking about science. This finding is significant because it stands in contrast to the literature that suggests that prospective teachers view themselves as the transmitters of knowledge to the children (e.g., Aguirre & Haggerty, 1995; Aguirre, Haggerty & Linder, 1990; Cohen, as cited in Prawat, 1992).

Connecting physical engagement of children with conceptual aspects of learning. Another trend that was noticed was that in the later versions of their philosophies, the participants of this study began to recognize a connection between physical engagement in activities and more conceptual aspects of learning. They explicitly stated that it is not enough to engage children in hands-on activities in order to support their learning. Sarah stated that:

> Hands-on/minds-on activities go a step beyond traditional hands-on activities, asking children to think about and explain science concepts…the activity moves beyond the realm of hands-on and requires students to apply their minds to the activity. (Sarah, v. 3, justification of evidence for claim #1)

In a similar way, Jane explained:

> Students need to experience science concepts by using their senses to see first hand how science works. However, just the experiences aren't enough. Students also need to be able to think about the hows and whys of the science. (Jane, v.3, claim #2)

The nature of the claims that the participants developed in the initial versions of their philosophies supports the findings of previous studies reporting that beginning teachers tend to emphasize the physical engagement of children in activities (e.g., Gustafson and Rowell, 1995). Both participants claimed that children learn science through hands-on activities. An example is Jane’s justification statement for an evidence related to a stream study which was used to support the claim that children learn science by relating it to the world outside through hands-on activities.

> Before the stream study I knew little about how one finds water quality of a stream and even less about macro invertebrates. Discussing this type of topic in a classroom, or reading about it in a text book would most likely be very hard to grasp. Because I was able to actually walk in the stream and catch the macro invertebrates and look up what each organism was, I felt I gained a much better understanding of the topics than I would have if my information would have come only from a book. I actually saw the bugs and went through the process of a stream study and because of this I will remember the experience for quite some time. (Jane, v. 1, justification of evidence for claim #2)

According to Prawat (1992), the emphasis on the physical engagement is firmed with a set of beliefs about teaching and learning, termed ‘naïve constructivism’. As Prawat (1992) stated, beginning teachers have the notion that student interest and involvement (i.e., in ‘hands-on activities’) constitutes both a necessary and sufficient condition for worthwhile learning. However, as it becomes apparent through the participants' statements, they were aware that in order to make the physical engagement of children in activities meaningful and beneficial, they had to engage them in thinking about them as well.

Focusing on teaching science as inquiry

A pattern that was observed throughout the participants' web-based portfolios, and particularly within their justification statements, was that they became more focused on the essential features of inquiry (National Research Council, 1996, 2000). When Jane justified a methods course investigation in which she and her peers participated as science learners, in support of her claim stating that children learn science by asking questions, she emphasized the fact that they were given some information and they had to figure out how to use it in order to provide explanations for the dinosaurs:

> The questions asked during this activity helped my peers and I take learning into our own hands and search for answers to our own questions. During the dinosaur unit activity our group was given information and was then challenged to figure out what this information meant. If we were merely spoon fed the information through the letters from the paleontologists it would be passive learning. But because we had to ask questions about the information we received, we probed our own understanding and then searched for more. Questions such as, "I wonder how big the dinosaur is?" caused us to postulate ways we could figure such a thing out. If the questions would have been asked for us it would have been us finding the "right" answer that the teacher wanted to know. But because we asked it, we searched for many different possible explanations: "We could look at his foot size, or we could measure his stride and then find out how big his legs are." (Jane, v. 2, justification of evidence for claim #1)

Similarly, in her justification of evidence from a lesson she had designed and taught about bird beak adaptations, Sarah emphasized teaching science as inquiry:

> The bird beak adaptation activity invites children to get physically involved with the science concept. They become birds, have beaks, and must experiment to find out which food they can acquire most easily with their beak. However, the simulation does not end there. The students must collect and organize data on their trials, and think about how to analyze that data. The students must form hypotheses to explain the data they have gathered, and support these explanations with evidence. (Sarah, v. 2, justification of evidence for claim #1)

The emphasis on teaching science as inquiry was evident in both of the participants' justification statements that stressed question-driven investigations, the use of observational data, making connections between evidence and explanations and communicating these explanations to others. According to the National Science Education Standards, in inquiry, the focus is on children cooperatively investigating and developing an understanding of their world, and at the same time, learning about science and inquiry – procedures, scientific habits of mind, and significant knowledge of science content (National Research Council, 1996, p. 133).

The fact that the two participants emphasized teaching science through inquiry is important because it reveals that their views were becoming more consisted with contemporary reform efforts in science education. Specifically, the participants explicitly discussed how teaching science through inquiry enhances students' learning. This is significant because these prospective teachers had no science-specific background and their elementary education orientation, which requires them to teach a variety of subjects, does not leave room for specialization.

Becoming attentive to what teachers can do to support children's learning

Another trend that emerged through analysis of the web-based portfolios is that the participants became more attentive to what teachers can do to support children's science learning. Sarah pointed out that teachers support children's learning when they mediate their experiences. In particular, she articulated the following in relation to a science corner she started in her classroom, which she used as evidence to support her claim:

> A few weeks ago, I started a science corner in my classroom. Because of it
>
> I have learned a lot about the teacher's role in helping students learn science. I have learned that one of my roles as mediator of my students' science experiences is to provide them with informal science experiences related to their interests and to our current unit of study. For example, when I set up a "crystal cave" at our science corner the week we took a field trip to Penn's Cave, I gave them the opportunity to observe what was happening, predict what will happen, and witness change over time. As mediator, it is my responsibility to keep the science corner updated and in tune with my students' interests. (Sarah, v. 3, justification of evidence for claim #5)

Jane claimed that teachers support children's science learning best when they ask questions to probe their thinking as opposed to asking questions to elicit a certain answer. In specific, this is how she justified her Science Talk evidence for this claim:

> This piece of evidence supports my claim because it shows how much information can be gained when a student is pushed further through teacher questioning that isn't aimed at a single correct answer. When I asked questions during the science lessons I didn't want to elicit a certain answer; I honestly wanted to know what students were thinking. So when I asked questions like, "what do you think is going on here, or why do you think this is happening," I wasn't expecting a single correct answer. While I can't deny that I did have the correct answer in my mind, I didn't expect this answer, or necessarily want this answer to come out of the mouths of my students. What I wanted was a description of what the kids thought was happening so that I could have a window into the thinking of the

> children. This glimpse into students' thinking helped me to plan activities to foster the further development of students' understanding of shadows. (Jane, v. 2, justification of evidence for claim #4)

Through Sarah’s and Jane’s justifications it is apparent that they were both considering how to make science content meaningful to their students. This attitude contradicts the literature related to teachers’ beliefs that suggests that they tend to view content and students in static, noninteractive terms (Prawat, 1992).

The role of the task and the affordances of technology

Keeping multiple versions of the philosophies and viewing changes over time

Web-based portfolios provided the vehicle through which prospective teachers explored their understandings of learning to teach, through the development of different versions of their philosophies. The web-based format supported the engagement of prospective teachers in reflecting on and reevaluating their ideas about teaching and learning science since it allowed them to keep multiple versions of their philosophies.

> The way the task was organized and the fact that the web-based format provided the possibility to keep multiple versions of their philosophies gave prospective teachers the advantage to review prior versions of their philosophies, build on their initial ideas, revise their views about teaching and learning science and easily reorganize their philosophies. Prospective teachers were able to view how their philosophies were changing over time, which supported a continuous engagement in metacognition, self-evaluation and self-reflection.

Taking advantage of the hypermedia component

The hypermedia possibilities of the web-based portfolio allowed prospective elementary teachers to make nonlinear, dynamic representations of their science teaching philosophies. Through the hyperlinking process, prospective teachers made connections between their coursework and field experiences and between their claims, evidence and justification statements, which resulted in an interconnected presentation of their learning experiences. Additionally, with the use of hyperlinking prospective teachers were able to reorganize their philosophies by redefining links. Specifically, this became apparent through Jane's web-based philosophy. Jane used the same piece of evidence in order to support multiple claims in different versions of her philosophy. She created a link that would take the reader to the specific evidence for each claim, then she changed her justification statements in each version of her philosophy to reflect the claim-evidence relationship.

The hypermedia component fosters connections between coursework, concepts, and applications because it allows the individual to designate links between ideas and themes (Morris & Buckland, 2000). Through the construction of their hypermedia science teaching philosophies, prospective elementary teachers took a more active approach to learning.

Making thinking visible.

Another aspect of the web-based format is its public nature since it makes the portfolio available to a variety of audiences. The web-based portfolio has the potential of being viewed by a greater number of people. Thus, greater effort and pride is taken to create a public document (Aschermann, 1999). Moreover, the public nature of the web-based portfolios makes it easier for prospective teachers to give and receive feedback from peers or professors. They are easier to share, making it possible for prospective teachers to see a variety of exemplars, view other perspectives of teaching and learning and challenge their own practices and beliefs (Morris & Buckland, 2000).

In this study, web-based portfolios provided a place where prospective teachers articulated their science teaching philosophies and presented them in a hypermedia format. In particular, web-based portfolios made participants' thinking visible and documented their growth. As Loughran and Corrigan (1995) noted, "A major focus of the process of developing a portfolio and the product is to help prospective teachers begin to articulate their understanding of what they think it means to be a teacher" (p. 17). An emerging characteristic of a teacher as a professional is this ability to articulate, evaluate, engage in, and respond to criticism about teaching, their own practice and student learning (Lyons, 1998b). As Shulman (1998) stated, portfolios institutionalize norms of collaboration, reflection and discussion. Perhaps the most striking consequence of a portfolio process for new teacher professionalism is the creation of new norms for teachers: that is, making public discussion and debate about what constitutes good teaching (Lyons, 1998a).

Conclusions and Implications

The general conclusion to be drawn from this study is that web-based portfolios seemed to be a powerful tool for supporting the participants' learning. Engaging them in thoughtful reflection through web-based portfolio development within an innovative context, appeared to have had an impact on their conceptions about teaching and learning science. In particular, a shift in the participants' understandings about learning and teaching became apparent through the web-based portfolio analysis.

In contrast, many studies have concluded that it is very difficult to influence prospective teachers' prior ideas about learning and teaching (Aguirre & Haggerty, 1995; Calderhead, 1989; Gustafson & Rowell, 1995; Hollingsworth, 1989). Calderhead (1989) questioned whether teacher education courses really do encourage prospective teachers to reflect and supported his inquiry with the observation that prospective teachers' prior ideas are "highly influential in shaping what prospective teachers extract from their preservice training, how they think about teaching, and the kind of teacher they become within the classroom" (p. 47).

The findings of this study are congruent with the literature that suggests that portfolio development may support reflection. The justification statements appeared to be a powerful technique for engaging these prospective teachers in meaningful reflection since they required explicit and justified connections between the claims and evidence used to support them. According to Nettles and Petrick (1995), writing a rationale allows prospective teachers to reflect on their work, both in deciding for which outcome the artifact provides evidence and in realizing their proficiency in that particular teaching strategy or skill. Similarly, Schon (1983) states:

> Practicum experiences must engage teachers in tasks where they can explore their own learning, reflect on their processes in inquiry, examine their own shifting understandings – and compare their actual learning experiences with the formal theories of learning built into standard pedagogies. Later, they might shift their attention to the classrooms in which they interact with children. Here, they would be attentive to the ways in which children's learning is like or unlike the kinds of learning they have detected in themselves. (p. 323)

Particularly, in this study, web-based portfolios served as a vehicle for these prospective teachers to reconsider and reevaluate their views of teaching and learning science in light of new learning experiences.

The development of the web-based portfolios was a constructivist process that required prospective elementary teachers to reflect on and critically examine their own beliefs and ideas about teaching and learning. The process was constructivist in the sense that prospective elementary teachers were engaged and had to make decisions regarding the organization and content of their portfolios. As Perkins (1986) illustrates, central to the vision of constructivism is the notion of organism as active – engaging, grappling, and seeking to make sense of things.

Moreover, prospective teachers engaged in metacognitive activities while developing their philosophies. The development of a personal science teaching philosophy required them to think about their knowledge, understandings, ideas and beliefs about learning and teaching science. According to Hoban (1997), prospective teachers should be encouraged to be metacognitive and become more aware of how they learn in teacher education courses with the intention of informing their decision-making as they construct their personal pedagogies.

In addition to providing an insight into prospective teachers' personal pedagogical theories, the web-based portfolios revealed the significance of the Professional Development School context and its impact on participants' learning. In this study, the professional development schools were part of an ongoing local school-university partnership. The mentor teachers in the schools where the participants were placed were actively engaged in their own professional development (e.g., taking coursework, engaging in classroom-based research, participating in methods course planning). As it became evident through the participants' science teaching philosophies, they benefited from this symbiotic relationship between their university coursework and their field experiences. According to Zembal-Saul (2001), professional development schools have the potential to foster contexts in which school-wide and classroom-based environments offer prospective teachers multiple opportunities to examine and reevaluate their personal theories of teaching and learning.

In this study, web-based portfolios served as a bridge between the university coursework and field experiences. It provided the vehicle for prospective elementary teachers to make connections between what they were learning in their science methods course and what they were applying in their practices. As one of the trends of this study suggests, the participants were making connections between university coursework and field experiences. Connecting coursework with field experiences implies transferring and applying knowledge that prospective teachers gained within one context to a different one. Research suggests that such a learning experience is supported within the context of the PDS, which enhances prospective and beginning teachers' learning by creating settings in which novices enter professional practice by working with expert practitioners (Darling-Hammond, 1994).

Concluding, our findings strongly suggest that prospective elementary teachers' learning could be enhanced through the web-based portfolio development, which engages them in reflective and metacognitive activities about their views of science teaching and learning. The findings of this study suggest the need to rethink ways in which teacher education programs engage prospective teachers in meaningful reflection and metacognition about their understandings of science teaching and learning. We recommend that future attention be directed in the area of web-based portfolios, and specifically through the development of personal philosophies, as a vehicle for supporting such level of reflection and metacognition. This is based on the potential of web-based portfolios to engage prospective teachers in thoughtful reflection, which influences their ideas about learning and teaching.

Furthermore, in our study, specific elements of the context (i.e., the coherence between university coursework and classroom practices) appeared to be critical in supporting prospective elementary teachers' learning and deserve further attention. Future research on the effects of the context within which prospective elementary teachers develop their theories about science teaching and learning and how technology can enhance the chances of articulation and successful integration of these theories and personal teaching practices is recommended.

Moreover, examining the types of experiences that seem to be critical on the prospective teachers' development of personal philosophies is valuable and essential form of research as we aim to support them embracing the current reforms in science education focusing on supporting learning through inquiry. Built on these implications we suggest that future research should be directed in the area of teachers' knowledge and beliefs about science teaching and learning and the kinds of experiences that influence their development in order to inform teacher educators about the design of effective teacher preparation programs. The ways in which technology tools can contribute to supporting prospective teachers in developing personal theories consistent with current recommendations of reform focusing on supporting learning through inquiry should also be explored.

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CHAPTER 3

A FIRST-YEAR ELEMENTARY TEACHER'S SPECIALIZED KNOWLEDGE AND PRACTICES FOR GIVING PRIORITY TO EVIDENCE IN SCIENCE TEACHING

Abstract

The purpose of this study was to examine the nature of a first-year elementary teacher's specialized knowledge and practices for giving priority to evidence in science teaching. This study is informed by current trends in science education calling for supporting learning science through inquiry and is based on the literature of pedagogical content knowledge.

The practices and beliefs of Jean were examined in depth to provide insights into specialized knowledge and practices for giving priority to evidence in science teaching and particularly for the development of scientific explanations. Multiple sources of data were used in order to capture Jean's knowledge and practices for giving priority to evidence in science teaching. Data included three audio taped interviews, six video taped classroom observations, lesson plans, and samples of students' work. The approach to analysis involved categorical aggregation and a search of correspondence and patterns. Data were analyzed by means of open coding strategies consistent with constant comparative analysis. Codes were developed and refined using the research questions as a guide. The qualitative software NVIVO was used to do the analysis.

Unlike previous studies' findings that show that beginning teachers usually espouse and enact a teacher-centered teaching style, the findings of this study indicate that Jean not only articulated, but also enacted, a student-centered approach to teaching science, which emphasized giving priority to evidence in the construction of scientific explanations. Specifically, as the findings of this study reveal, Jean gave priority to evidence in her teaching practices by constantly engaging students in collecting evidence through observations and tests, recording and representing evidence, and using that evidence to construct explanations. This also reveals that Jean's practices were for the most part consistent with her knowledge and beliefs, which contradicts previous studies' findings which indicate a mismatch between beginning teachers' knowledge and practices. Furthermore, the findings of this study illustrate that critical experiences during preparation to teach and specific university coursework acted as sources through which this aspect of PCK was generated.

This study underscores the need for more longitudinal research to explore the development of specific aspects of PCK and identifies critical experiences that support its development. Implications of this study are associated with issues of supporting teachers' conceptual change through specific university coursework and situating learning to teach experiences in classroom contexts.

Introduction

Recent science education trends have called for substantial reforms in learning environments, focusing on supporting learning through inquiry (AAAS, 1993; NRC, 1996). Scientific inquiry refers to the ways in which scientists study the natural world and propose explanations based on evidence. In the context of school science, it refers to the activities of students in which they develop knowledge and understanding of scientific ideas and how scientists study the natural world (NRC, 1996, p. 23). Learning science as inquiry emphasizes the active engagement of learners as constructors of knowledge:

> When children or scientists inquire into the natural world they pose questions, they plan investigations and collect relevant data, they organize and analyze collected data, think critically and logically about relationships between evidence and explanations; use observational evidence and current scientific knowledge to construct and evaluate alternative explanations and communicate investigations and explanations to others. (NRC, 1996, p. 122)

However, these new trends in science teaching and learning require new roles from teachers who were taught science in traditional ways. As Putnam and Borko (1997) note, "For teachers to move successfully toward these new visions of classrooms will require in many cases major changes in their knowledge, beliefs and practice" (p. 1224). Pajares (1992) states that teachers' knowledge and beliefs of teaching and learning have been shown to influence classroom teaching practices. Similarly, Putnam and Borko (1997) note, "Teachers, like students, interpret experiences through the filters of their existing knowledge and beliefs. A teacher's knowledge and beliefs – about learning, teaching, and subject matter – thus are critically important determinants of how that teacher teaches" (p. 1228).

Current recommendations for reform proposed by the National Science Education Standards call for a shift in emphasis from science as exploration and experiment to science as argument and explanation (NRC, 1996, p. 113). Hence, teachers' knowledge and beliefs for teaching science based on these recommendations become of great interest. Teaching science as argument and explanation, however, requires a focus on how evidence is used in science for the construction of explanations, and "the criteria used in science to evaluate the selection of evidence and the construction of explanations" (Duschl & Osborne, 2002, p. 40). Therefore, targeting teachers' specialized knowledge, beliefs and practices for giving priority to evidence in science teaching is a valuable and essential form of research aimed at supporting teachers in embracing the recommended changes associated with teaching science as inquiry.

Teachers' knowledge and beliefs have been described within the concept of pedagogical content knowledge (PCK). Shulman (1986) first described this construct as "the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Giving priority to evidence in science teaching is used in this study as a specific aspect of PCK for science teaching and is drawn upon Grossman's (1990) model of teacher knowledge in which PCK is central. Specialized practices, knowledge and beliefs for giving priority to evidence in science teaching relates to two central components of PCK: a) knowledge and beliefs about the purposes for teaching a subject at different grade levels; and b) knowledge of instructional strategies and representations for teaching particular topics.

Pedagogical Content Knowledge

Pedagogical content knowledge has been of particular interest among researchers and educators over the past few years (Gess-Newsome, 1999; Shulman, 1986; Zembal, Starr & Krajcik, 1999). Shulman (1986) first introduced pedagogical content knowledge (PCK) as a specific category of teacher knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter for teaching" (p. 9). Shulman (1987) defined PCK:

> It represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction. (p. 8)

The key elements in Shulman's conception of PCK are knowledge of representations of subject matter and understanding of specific learning difficulties and student conceptions. Grossman (1990) states that the concept of pedagogical content knowledge "is inherent in Dewey's admonition that teachers must learn to psychologize their subject matter for teaching, to rethink disciplinary topics and concepts to make them more accessible to others" (p. 8). This knowledge guides the teachers' actions in practice; it encompasses teachers' knowledge and beliefs about pedagogy, students, subject matter, and the curriculum (Grossman, 1990). A recent large scale study done by Weiss, Pasley, Sean Smith, Banilower and Heck (2003), investigated the factors that influenced science and mathematics teachers' selections of instructional strategies in K-12. In most cases, as the results of this study revealed, teachers' decisions appeared to be primarily influenced by their beliefs about instruction and how students learn best. Hence, understanding teachers' knowledge and beliefs about teaching and learning is important as these views influence their classroom practices.

Many studies have explored teachers' PCK during the past few years (e.g., Cochran, DeRuiter and King, 1993; Loughran, Milroy, Berry, Gunstone & Mulhall, 2001; van Driel, Verloop & de Vos, 1998; Zembal-Saul, Krajcik & Blumenfeld, 2002). According to Cochran, DeRuiter and King (1993), recent research shows that inexperienced teachers have incomplete and superficial levels of PCK. In particular, studies indicate that novice teachers have major concerns about PCK and struggle to transform and represent the concepts and ideas to make sense to the students they are teaching (Feiman-Nemser & Parker, 1990; Wilson, Shulman & Richert, 1987). However, a different picture emerges when dealing with experienced teachers.

As Brickhouse (1990) reported, experienced teachers seem to have developed a conceptual framework in which knowledge and beliefs about subject matter, students, science, teaching and learning are interrelated in a coherent manner, and their teaching practices are consistent with this framework. Moreover, studies on teacher expertise show that experts recall more meaningful events that occur in complex, dynamic classrooms than inexperienced teachers (Carter, Cushing, Sabers, Stein & Berliner, 1988). A study done by Schempp, Tan, Manross, & Fincher (1988) to investigate the knowledge differences between competent and novice teachers, suggested that novices, because of their lack of experience and limited knowledge bases, differ in their interpretive abilities of classroom events and their planning skills. Specifically, the novice teachers in this study reported using few assessment procedures in contrast to competent teachers who continually assessed and monitored all classroom related activities.

Another set of studies have investigated the first year of teaching and illustrated that it is often particularly difficult (Marso & Pigge, 1987) and that teachers' classroom practices differ from their beliefs (Simmons, Emory, Carter, Coker, Finnegan, Crockett,

Richardson, Yager, Craven, Tillotson, Brunkhorst, Twiest, Hossain, Gallager, Duggan-Haas, Parker, Cajas, Alshannag, McGlamery, Krockover, Adams, Spector, La Porta, James, Rearden, & Labuda, 1999). For example, a study by Simmons et al., (1999) illuminated that the performance of first year teachers did not always reflect their knowledge and beliefs about their understanding of content and process and their actions in the classroom. Specifically, the findings of this study revealed that first-year teachers espoused a student-centered approach in their teaching but demonstrated teacher-centered actions in their classrooms.

Of interest is another related research area exploring the sources of teachers' pedagogical content knowledge. According to Shulman (1987) it is important to know, "What are the sources of teacher knowledge" and "What does a teacher know and when did he or she come to know it?" Research findings illustrate that the types of experiences that teachers have during their preparation programs and specific university coursework influence the development of their pedagogical content knowledge (e.g., Friedrichsen, 2002, Grossman, 1990). In specific, Grossman (1990) identified the following sources of PCK development: a) observation of classes as a student and as a student teacher; b) disciplinary education; c) specific courses during teacher education; and d) classroom teaching experience.

Pedagogical Content Knowledge for Science Teaching

Magnusson, Krajcik and Borko (1999) described pedagogical content knowledge as consisting of five components. The first refers to orientations toward science teaching, which represents a general way of viewing science teaching. The next relates to knowledge and beliefs about science curriculum, which refers to the goals and objectives and specific curricular programs and materials. Knowledge and beliefs about students' understanding of specific science topics is the third component and includes knowledge about students' difficulties with specific science concepts. The fourth component consists of knowledge and beliefs about assessment in science, and the last refers to knowledge of instructional strategies for teaching science. This knowledge includes both subject-specific strategies and topic-specific strategies (p. 110).

Even though the understanding of the construct of PCK is, as illustrated through the literature, of great value in teaching, it has not received much attention in the field of science education (Magnuson, Krajcik & Borko, 1999). The reasons why limited research has been done on PCK are associated with the fact that the construct represents an integrated knowledge system (Magnusson, Krajcik & Borko, 1999). It is broad and complex which makes it hard to draw clear distinctions among its categories and hence assess it. In an attempt to uncover science teachers' pedagogical content knowledge with the use of interviews and insights into their teaching procedures, Loughran, Milroy, Berry, Gunstone and Mulhall (2001) reported that, "PCK was more identifiable, not as an individual item, but as a mixture of items that were not necessarily fixed but varied with the context of the teaching and learning situation" (p. 202). Other researchers also have reported similar difficulties associated with examining PCK (Baxter & Lederman, 1999; Gess-Newsome, 1999; Magnusson, Krajcik & Borko, 1999).

Nevertheless, research done on teachers' knowledge, beliefs and practices has illuminated dichotomies between novices and experts knowledge and practices, contradictions between the emphasis that generalists and specialists place on subject-matter (Magnusson, Krajcik & Borko, 1999), and a mismatch between teacher knowledge, beliefs, and practices (Simmons et al., 1999).

A mismatch between knowledge and practices was revealed through a study of a second-year middle school science teacher's beliefs and practices done by Brickhouse and Bodner (1992). Specifically, their study analyzed this teacher's beliefs about effective science teaching and compared them with his practices. Through interviews and classroom observations, the researchers found that this teacher's lessons often took a different path than he intended. The authors noted about this contradiction between his beliefs and his actions: "His actions, which indicate a belief that his role as the teacher is to transmit knowledge to his students in a way they can make sense of it, contradict his beliefs about formal schooling, in which he expresses a high regard for informal educational experiences" (p. 477). Similarly, when summarizing the results of research on science teachers' practical knowledge, van Driel, Beijaard and Verloop (1998), concluded that in contrast with experienced teachers, beginning teachers seem to experience conflicts between their personal beliefs about science and science teaching and their own actual classroom practice on the other hand.

Other studies related to inexperienced teachers' knowledge and practices, however, have produced more encouraging results. For example, a study by Zembal-Saul, Krajcik and Blumenfeld (2002), which examined prospective elementary teachers' content representations, a subset of PCK for science teaching, illustrated how two prospective elementary teachers "maintained a solid subject-matter emphasis when planning content representations and included multiple representations of key concepts that were accurate with respect to science content" (p. 459). This finding stands in contrast with literature stating that novice teachers indicate a surprisingly low level of content-specific pedagogical understandings (Wilson, Shulman, & Richert, 1987).

Moreover, reported investigations into teachers' practices revealed that novice teachers face institutional constraints and deal with socialization and management issues that prevent them from focusing on supporting students' learning (Brickhouse & Bodner, 1992; Fuller & Brown, 1975). This appeared to be the problem with a prospective elementary teacher that participated in Zembal-Saul, Krajcik and Blumenfeld's (2002) study, who shifted from a subject matter emphasis to "survival mode" when she started her student teaching. As the authors described, the participant was "sidetracked and overwhelmed by intense teaching responsibilities and her approach became of one progressing from lesson to lesson while imitating her cooperating teacher and crafting instruction around fun but superficial activities" (p. 460). The findings of this study are, however, encouraging in the sense that they illustrate that it is possible to support prospective elementary teachers who are generalists and typically address issues that are important to learning regardless of subject matter (Magnusson, Krajcik & Borko, 1999), in developing an emphasis on subject matter.

Purpose, Research Questions and Contribution of the Study

Given the problems encountered when attempting to study the intertwined elements of PCK, this study focuses on a specific aspect of PCK for science teaching: specialized knowledge for giving priority to evidence. Due to the fact that most studies on teacher knowledge focus on secondary and middle school teachers, this study will contribute to PCK research by examining a specific aspect of an elementary school teacher's PCK. Considering research findings that report a mismatch between teachers' knowledge and practices, this study aims to examine both the knowledge and practices of a teacher and look for consistencies and inconsistencies between them. Dichotomies revealed between novices and experienced teachers' PCK (Magnusson, Krajcik & Borko, 1999) justifies the importance of studying a first-year teacher's PCK and the possible sources from which it was generated.

Specifically, the purpose of this study is to gain an in-depth understanding about a first-year elementary teacher's specialized practices, knowledge and beliefs for giving priority to evidence in science teaching and identify possible sources from which this specialized knowledge was generated. Specifically, the research questions that guide this study are:

- What is the nature of a first-year elementary teacher's specialized knowledge and practices for giving priority to evidence in science teaching?
- In what ways are a first-year teacher's practices influenced by her knowledge and beliefs for giving priority to evidence in science teaching?
- What are the possible sources of a first-year teacher's specialized knowledge and beliefs for giving priority to evidence in science teaching?

This study is important due to its contribution to the research area dealing with the ways in which first-year elementary teachers transform their specialized knowledge and beliefs for giving priority to evidence in science to make it comprehensible to their students. In particular, this study is significant because it provides empirical evidence about a specific aspect of the construct of PCK, and suggests a research method for studying its intertwined elements. Also, classroom teachers would benefit from understanding a specific aspect of PCK because it could be used as input in preparation programs and in-service workshops.

Moreover, not only this study is intended to reveal inconsistencies, if any, between the participant's knowledge, beliefs, and practices, but also it illuminates the support she received from the school context as she attempted to apply her knowledge and beliefs in practice. By gaining an insight into the sources of the participant's knowledge and beliefs, teacher preparation programs could identify the kinds of experiences that are critical for the development of this specific aspect of PCK and situate learning experiences for teachers in meaningful contexts (Magnusson, Krajcik & Borko, 1999; Putnam & Borko, 2000).

Limitations of this study are connected to issues of generalization due to the single case study approach to methodology. Donmoyer (1990) argued about the notion that single case studies are not worthwhile because their results cannot statistically be generalized to a larger population. As he explained, since many studies in education deal with individuals instead of groups, a new understanding of the word "generalizability" is needed for questions concerned with meaning, perspective and the situated complexities of contextualized studies. Although the results of this study cannot be extended beyond the case of Jean, they do reveal the nature of a specific aspect of PCK and the possible sources from which it was generated. Hence, this study can be used to conceptualize this specialized knowledge and define what it means to give priority to evidence in science teaching, which could be used to inform larger scale studies.

Other limitations of the study are connected to my biases as a researcher. In particular, one of my biases was that I taught both *ENT315: Teaching with Insects* and *SCIED458: Teaching Science at the Elementary School*. Hence, my beliefs about the purposes and the impact that I would like these courses to have on prospective teachers' learning, might have influenced the way in which I interpreted the participant's words particularly about the ways in which specific experiences through these courses acted as sources of her PCK.

Methods

Theoretical Framework

This study is concerned with conceptual change pedagogy and is grounded in constructivist learning theory. A conceptual change approach in science education holds that learners must become dissatisfied with their existing conceptions and find new concepts intelligible, plausible, and fruitful, before conceptual change will occur (Posner, Strike, Hewson, & Gertzog, 1982; Stofflett, 1994). According to Stofflett (1994), in a constructivist teacher education program, learning experiences should be included that allow prospective teachers, who were taught science in didactic ways, to reconstruct their knowledge of science content and existing notions of pedagogy. Investigating these kinds of learning experiences and how they could promote first-year elementary teachers' conceptual change is one of the goals of this study.

This study also is informed by perspectives from cognitive psychology and particularly situated cognition. Situated learning theory has its roots in Vygotsky's work on social learning and argues that learning is a function of the activity, context and culture in which it occurs (Lave & Wenger, 1991). Situated learning theory is applied to teacher education and proposes that prospective teachers' learning is situated in both the university and the school context (Putnam & Borko, 2000). This theory is used to explain the ways in which the contexts of teacher preparation and the first-year of teaching could influence teacher learning, development. More specifically, situated learning theory is used in this study as a framework for identifying the ways in which learning to teach. As Putnam and Borko (2000) state, "Important tasks facing teacher education include identifying key characteristics of field-based experiences that can foster new ways of teaching, and determining whether and how these experiences can be created within existing school cultures" (p. 10).

Drawing on conceptual change pedagogy and situated cognition perspective, this study aims to investigate the kinds of learning experiences and the ways in which those supported a first-year elementary teacher in reconstructing and applying in practice her knowledge and beliefs for giving priority to evidence in science teaching.

Research Design

The purpose of this study fits under the umbrella of qualitative case study research, which is "an intensive, holistic description and analysis of a single instance, phenomenon, or social unit" (Merriam, 1998, p. 21). As Grossman (1990) described, the case study approach to research on teacher knowledge "represents an attempt to gather in-depth data on the content, character and organization of an individual's knowledge for the purposes of contributing to a broader conceptualization of teacher knowledge and its use in teaching" (p. 150).

This study has the characteristics of a single case study (Merriam, 1998). That is, it is an exploration of a case through detailed, in-depth data collection involving multiple sources of information rich in context (Creswell, 1998). According to Yin (1994), single cases are used to confirm or challenge a theory, or to represent a unique case. In this holistic study, the purpose was to represent a unique case, which would help us understand the nature and sources of a specific aspect of PCK. Specifically, this study is an intrinsic case study as defined by Stake (2000), which refers to a case being undertaken "not because it represents others cases or because it illustrates a particular trait or problem but because in all its particularity and ordinariness, the case itself is of interest" (p. 437).

The exploratory nature of the research questions of this study required the use of a single case study approach that would allow for deep analysis and understanding of an individual, for whom facts would be gathered from various sources and conclusions would be drawn on those facts. In-depth exploration of only one individual allows us to described specifically and in detail the unique practices and knowledge that she demonstrated and also provides insight into her prior learning experiences that may have served as sources of this type of PCK.

Hence, the purpose of this single qualitative case study was not to formulate generalizations about first-year teachers' practices, knowledge and beliefs for giving priority to evidence. Rather, the purpose of this study was to illuminate the characteristics of the particular case, which could enhance our learning about what to look for when studying this specific aspect of PCK. As cited in Eisner (1998), "According to Lee Shulman, if we learn something about a case that we did not know at the outset of the study, not only have we achieved consciousness of feature, but also we learn to look for that quality or feature in other places" (p. 207).

The decision of following a single case study approach was inspired by the results provided by a large scale study of K-12 Mathematics and Science Education in the United States illustrating that, "fewer than 1 in 5 mathematics and science lessons are strong in intellectual rigor; include teacher questioning that is likely to enhance student conceptual understanding; and provide sense-making appropriate for the needs of the students and the purposes of the lesson" (p. 103). The findings of this study raise questions related to the reasons why only so few lessons are exemplary, which suggests an in depth exploration of the nature of exemplary teachers' practices and the factors that influence their development is warranted.

Professional Development School Context

A fifth grade classroom of a public elementary school in a small, rural town near a large university defined the context of this study. The class consisted of twenty-one students of the same social and ethnic backgrounds (i.e., middle class Caucasians) with a variety of abilities and skills. This school was part of the Elementary Professional Development School (PDS) Program – a collaboration between a large northeastern university and the local school district (see http://www.ed.psu.edu/pds).

The partnership offers undergraduate elementary education majors an opportunity to pursue an intensive field-based alternative for completion of their teacher preparation program. The work in a Professional Development School is designed to immerse the prospective teacher into the school's culture, develop deeper understanding of student learning, and create a wider experience base from which the prospective teacher can draw when they enter the profession.

During this year long, highly-mentored internship prospective teachers learn to teach through teaming with a mentor teacher and a university-based teacher educator. Through the internship, prospective teachers are provided with opportunities to teach alongside a mentor and inquire into their work with children in a public school classroom. Mentor teachers in these schools are actively engaged in their own professional development (e.g., taking coursework, engaging in classroom-based research, participating in methods course planning).

Selection of participant

A first-year elementary teacher was purposefully selected to participate in this study for a number of reasons. Jean, a pseudonym, was selected because she was considered to be an information rich case. In specific, she was forthcoming in interviews about her knowledge and beliefs about science teaching and learning and her learning experiences, which would allow the collection of a rich set of data. According to Merriam (1998), purposeful sampling "is based on the assumption that the investigator wants to discover, understand and gain an insight and therefore must select a sample from which the most can be learned" (p. 61). In particular, Jean was typical of first-year elementary teachers in terms of age, gender and years in college – she was a 22 year-old Caucasian female who finished her undergraduate studies in four years.

However, she was atypical in terms of her preparation to teach and her university coursework. Specifically, Jean went through a year-long, highly-mentored internship (PDS), and she was then employed by the same school district. She was placed in a second grade classroom during her internship, and she was teaching in a fifth grade classroom when this study took place. Another reason for selecting the specific participant had to do with the fact that she took three science courses in college that were designed specifically for prospective elementary teachers, which would provide an understanding of the ways in which, if any, these courses acted as sources of pedagogical content knowledge. Moreover, Jean performed well academically in the elementary science methods course; therefore, it was believed that she would be more likely to attempt teaching science in ways consistent with how she learned to teach, focusing on scientific inquiry. In fact, this was the main reason Jean was selected instead of examining a random elementary teacher.

Other reasons for choosing the specific individual had to do with the fact that she consented to participate, and she was employed at a school located close to the researcher's university.

Data Sources

Magnuson, Krajcik and Borko (1999) suggest the use of multiple data sources when trying to examine teachers' pedagogical content knowledge as a way to capture the "complexity of changes in teachers' knowledge, beliefs, and practices across components of pedagogical content knowledge" (p. 127). Therefore, multiple sources of data were used in this study in order to develop rich descriptions about the nature and sources of Jean's specialized knowledge and practices for giving priority to evidence in science teaching. Two primary sources of data were used in this study: a) six videotaped classroom observations (40-60 minutes each); and b) three semi-structured interviews (60 minutes each). Secondary sources of data included the teacher's lesson plans, assessments tasks, such as homework, and student-generated artifacts. Table 1 illustrates the connections between these sources of data and the research question:

Research Foci	Data Sources	Example outcomes
Specialized practices for giving priority to evidence in science teaching	Primary: six classroom observations Secondary: planning and reflection interviews, lesson plans, students' products	Providing students with opportunities to collect, record and represent evidence; Providing students with opportunities to use evidence to construct explanations; Providing students with opportunities to talk and write in terms of evidence and explanations through classroom activities and assignments
Specialized knowledge and beliefs for giving priority to evidence in science teaching	Initial, planning and reflection interview	Understandings about the nature of scientific knowledge; Understandings of the role of evidence in the construction of explanation; Views of teaching and learning science in terms of evidence and explanations
Possible sources of specialized knowledge and beliefs for giving priority to evidence	Initial interview	K-12 science learning experiences; Influential teachers; Specific university coursework; Teacher preparation program

Table 1: Parallels in research questions and data sources

The first phase of data collection involved an initial interview with Jean in order to get an understanding of her knowledge and beliefs about teaching and learning science. Another purpose of conducting the initial interview was to identify the ways in which K-12 and college experiences acted as sources of Jean's specialized knowledge and beliefs for giving priority to evidence in science teaching. The questions that guided this interview are presented in Appendix A. This phase of data collection also involved an interview through which information was obtained on how Jean planned to teach a science unit in order to examine the reasons behind her pedagogical decisions. The guiding questions of this interview are presented in Appendix B.

The second phase of data collection involved videotaping six classroom observations, each about 40-60 minutes long, of randomly selected lessons from the science unit. These lessons included critical incidents that represented the kinds of teaching activities that gave priority to evidence in science teaching.

The third phase of data collection involved an interview at the end of the unit where Jean was asked to respond to questions (Appendix C) that would engage her in reflecting on her teaching practices and provide evidence of student learning.

During the interview phase of data collection, data taken from each teaching observation was compared, and Jean was asked how her teaching methods did or did not support her goals and purposes for teaching science.

Data Analysis

Analysis involved categorical aggregation and a search for correspondence and patterns based on the nature of the research questions (Stake, 1995). Data were analyzed by means of open coding strategies consistent with constant comparative analysis based on Glaser and Strauss's (1967) rule for the constant comparative method, which states that, "while coding an incident for a category, compare it with the previous incidents in the same and different groups coded in the same category" (p. 106).

Audiotaped interviews and videotaped classroom observations were first transcribed, and teaching episodes related to the research questions were identified. Multiple readings through the transcribed interviews and classroom observations followed. Summaries were generated for sections with descriptive codes based on a sentence/paragraph analysis approach (Strauss & Corbin, 1998). Axial codes were then developed and refined using the research questions as a guide. Data were analyzed using the qualitative software NVIVO. Drawn upon the axial coding, broad categories were retrieved from the subconstructs of the study and they were then split into subcategories, spliced and linked together for the case (Coffey & Atkinson, 1996). The codes and the categories regarding each of the three research questions are presented in Appendix D.

Findings and Discussion

This section is an attempt to characterize Jean's specialized practices, knowledge and beliefs for giving priority to evidence. This is done through a description of her teaching practices with special attention to the ones related to opportunities that she provided for students to collect, record, represent and use evidence to construct explanations. Jean's interviews provide the means to describe her knowledge and beliefs about teaching and learning science, specifically the ones related to giving priority to evidence in science teaching.

First, however, information about Jean's experiences as a learner of science throughout her education is provided and the context of the science unit that she taught is described. Information provided about her prior learning experiences through K-12, university coursework and her internship sheds light on certain experiences that acted as sources of her PCK for science teaching and specifically for giving priority to evidence.

Jean's background as a science learner and unit context

Jean's background as a science learner

Jean described herself as an enthusiastic science learner in elementary school and identified her third grade teacher as her favorite one because she was very passionate about science and had pets in the room. Jean stated that she had interest in science and thought science was "cool" because of this teacher who was one of her role models. Jean explained how she lost interest in science in middle school and referred to contextual factors mostly related to gender dynamics:

> …you remember little things in middle school with lab tables and it's automatically the guys get the stuff and the girls write down the answers. You know, and just those dynamics that happen based on gender when you are so young in middle school and actually just watching these kids and their experiences, I am so nervous for them that this going to happen. (First interview, 11/5/02)

The issue of gender dynamics came up again when Jean talked about a negatively influential teacher she had in sixth grade, which she attributed to the different kind of relationship that this teacher had with the girls and the boys. Jean made explicit that this impacted her confidence as a science learner.

> I do not know what he did but just my competence just was, and that's what I had him for, science and math, and I think it was just that his relationship with the girls it was so different than his relationship with the boys...I remember one day it was something really inappropriate kind of thing, not that he was trying to make me feel immature but kind of making me feel that I was there to flirt. (First interview, 11/5/02)

Jean gained confidence as a learner of science after she went to college, and she came across strong female science models, and took specific university coursework. She described a science course that she took that was specially designed for prospective elementary teachers and explained how she enjoyed it. The course, *ENGR497F: Fundamentals in Science Education, Technology and Engineering*, when Jean described this class, she commented again on the gender dynamics.

> I took this engineering class and I loved it, I mean, seriously, the others had to be like: "Stop raising your hand" because I basically answered all the questions. It was me talking to the teachers and everyone else staring waiting for me to shut up. It was so interesting because we were doing the lego bridges and that stuff and it was fascinating to me to think about it that way. I think also because it was all women in the class, I think, or if were any men in the room they obviously did not make much impression to me but the dynamic was so different...I loved that class. (First interview, 11/5/02)

Jean described how quickly she gained confidence in herself as a successful science learner because of this course.

> In a matter of two months or so I went from wanting to take three easy science courses and putting it all behind me to concentrating in science. I mean, it w as so fast, and all it took was: I can think like this, this isn't hard, you know it was just one experience where I did not feel like it was beyond me and then I was hooked again. And I think that was so, I mean, I do not think I was necessarily enthusiastic about teaching in general until I had that experience and I do not know what kind of a teacher I would be if I hadn't because the passion for learning that centers my philosophy now, I do not think I felt that way until I kind of rediscovered that. I think I did have barriers you know and I think I was going into teaching because I love kids and I knew it was a great thing to do but my excitement about learning did not come about until I realized that I could learn anything I'd want to. (First interview, 11/05/02)

Jean also commented on how excited she was about her year-long, highly mentored internship in the Elementary Professional Development School (PDS) Program.

> You told me about PDS and from then on I was just: "Oh PDS", I was so excited about that, and so I had that and concentrating in science at the back on my mind was kind the driving force to the rest of it and I only took one normal college science class, you know normal science class that was not connected to the college of education and that was, it was so important that I cannot even remember. (First interview, 11/05/02)

In response to a question related to experiences that shaped her philosophy of science teaching, Jean stated how important it was that during her preparation she was able to apply her philosophy to practice.

> I think one really good thing about my teacher education is that I had chances to apply things with kids all along so it was not like other programs that all of the sudden you are with kids and you are thinking: "Oh…" all that philosophy stuff is not true I think so my philosophies are a lot realistic I think instead of if I had just studied the philosophy and then did the teaching. (First interview, 11/05/02)

Jean shared that her science methods course, which was part of her internship program, helped her better understand an inquiry approach and specifically the role of evidence in the construction of scientific knowledge.

> I would not say it's unique to science but I think science helped me better understand the inquiry approach and how I wanted that fit it in my philosophy and I think the inquiry is part of what I said already about…question things and going out to find more about them and hypothesizing and developing tests and I think, I found that I use it everywhere now, but going out and finding things, don't just tell me things but tell why you support it. I actually just had a big discussion with my kids, it was something that, just the fact that you know you make the best claim you can of what you know but you will never know everything. (First interview, 11/05/02)

A science specific university course, *SCIED410: Using Technology to Enhance Science Learning,* influenced her thinking of science in terms of claims and evidence. In the context of this course, prospective teachers participated in THREE extended data-rich, technology-enhanced, science investigation that emphasized giving priority to evidence and the construction of evidence-based arguments (Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002).

> It was so fascinating to me. It was some article about the creationism debate and I just remember thinking that because I mean personally my religious beliefs were so different but then it really bothered me that it was

> a debate and I remember going home and saying it does not even make sense cause they are not even talking about the same thing. I was saying they are talking about the claim and they are trying to teach and you cannot even compare them and it's just does not make sense to teach about it. And I just remember I was really able to argue it because I had such a census you know, that this was a claim that was to back up with evidence so it did not offend me at all cause I understood that when you are teaching science you are not teaching facts you are teaching that you know, this a way that somebody organizes information and turn it into an argument about the way they see the world. (First interview, 11/05/02)

Jean applied these understandings of science and the construction of science knowledge claims as she designed and implemented a science unit on geological processes.

Unit context

Jean was planning a unit on geological processes, the second science unit of the school year, when this study took place. Prior to the beginning of each science unit, all teachers in a building get together for a unit planning meeting in which they review major concepts and activities associated with the unit, discuss possible extensions, prepare appropriate assessments, etc. Jean participated in this meeting for the geological processes unit, as well as planned with her mentor.

In addition to the activities from the unit, Jean also used her ideas and modified several lessons based on her views of teaching and learning science and her students' characteristics. When asked to state the extent to which she would make changes in the unit, Jean noted that she would make a few changes now, but probably more in the future, as she gained more experience. However, she stated that she would use more small group activities instead of whole class demonstrations, and she also would emphasize the use of claims and evidence in science. A change that she incorporated about assessing her students' understandings was the development of a geology book by each student. Specifically, the students were asked to develop pages for their books for each of the lessons where they had to explain what they learned using evidence gathered from the classroom activities. Jean described the three cores of the unit:

> It starts out with what's underneath the ground you walk on, what is it inside the earth, and then we go into the theory of continental drift and we are going to do the tectonic plates and how the earth is moving. Then we are going to do volcano activity and then earthquakes and volcanoes and we do the ring of fire. (Planning interview, 12/9/02)

Describing the goals of the unit, Jean stated that teaching this unit was a unique way to get into the nature of science because it illustrated that scientific theories do change. Talking more about the goals of the unit, Jean mentioned:

> In terms of the content, what I am really hoping that they will understand is, I do not know, I think a lot of this is pretty complicated really and I think what I am going for is more like the idea that the earth is a dynamic thing because I think they think of it as a stable thing. And I think the hardest thing to get across, the most global thing is the idea that the earth is changing and I really hope that they will get that through one of all these, I think that's the most important idea. (Planning interview, 12/9/02)

Jean described lessons of the unit that would involve the students in different experiments and demonstrations to explore geological processes such as earthquakes, volcanic activity, plate tectonics, etc. Six of these lessons were observed, videotaped and analyzed for the purposes of this study: Mystery Boxes, two lessons on Oobleck, Convection Currents, Layers of the Earth, and Volcanoes. Table 2 summarizes students' roles and ways of participating in these lessons.

Lesson & Date observed	Students' role
Mystery Boxes 11/11/02	Made observations, designed, carried out tests, recorded evidence and constructed evidence-based explanations
Oobleck (a) 1/13/03	Made observations and designed tests
Oobleck (b) 1/14/03	Carried out tests, recorded evidence and constructed evidence-based explanations
Layers of the earth 2/19/03	Carried out an experiment designed for them by the teacher and recorded evidence
Convection Currents 2/21/03	Observed a demonstration done by the teacher, recorded evidence and constructed evidence-based explanations
Earthquakes and Vocanoes 2/21/03	Designed an experiment that was later done by the teacher, recorded evidence and constructed evidence-based explanations

Table 2. Summary of lessons

Specialized practices for giving priority to evidence

This section deals with Jean's specialized practices for giving priority to evidence in science teaching and is drawn upon analysis of the videotaped classroom observations. Jean's practices refer to her actions in the classroom and specifically the kinds of teaching methods and strategies she used, demonstrations and hands-on activities, the nature of assignments, and interactions that occurred during the science lessons observed. When presenting these findings, emphasis is placed on the specific practices that Jean demonstrated related to giving priority to evidence in the construction of explanations. Evidence in science refers to the data that emerge from observations of phenomena and different types of investigations and it provides the basis for explanations about how the natural world works. Regarding school science, students can obtain evidence to develop explanations about scientific phenomena through observations and measurements or from the teacher and other instructional materials (NRC, 2000).

Jean's practices for giving priority to evidence in science teaching are described within three main themes: providing students with opportunities to collect evidence; providing students with opportunities to record and represent evidence; and providing students with opportunities to construct evidence-based explanations.

Providing students with opportunities to collect evidence

It became apparent through analysis of the videotaped lessons that Jean provided her students with multiple opportunities to collect evidence through observations and direct experimentation. Specifically, during the lessons, *Convection Currents, Earthquakes* and *Volcanoes* (see Table 5) the students collected evidence through observing demonstrations that Jean performed in front of the classroom. These three lessons were all part of the unit, and Jean implemented them in the way they were designed. In two other lessons, Jean had students design and conduct their own experiments. One of those lessons, *Mystery Boxes*, she experienced as a learner in her elementary science methods course, and she taught it in a very similar way. The other lesson, *Oobleck*, was part of the unit, but she used a modified version of it. This lesson was also experienced through the science methods course.

During *Mystery Boxes* and *Oobleck* lessons, the students had opportunities to engage in inquiry-based investigations and collect evidence to answer scientific questions posed to them at the beginning of each lesson. During the first lesson, *Mystery Boxes*, the students were provided with small sealed boxes and were asked to figure out what was inside without opening them. The students were asked to work in small groups to collect evidence through observations. The students first used their senses to make different observations, that they shared during a whole class discussion. After the students were done recording and sharing their observations with the class, Jean asked them to develop some tests that they could do in order to gather more information about the content of their boxes. Some tests that the students developed included, but were not limited to, shaking the box to see if anything was bouncing, smelling the box and recording different types of smells, shaking it and recording what kinds of sounds it produced, touching the box and recording what type of material it was made of, measuring the box and recording its exact size, etc. The students were then asked to share the evidence they collected through their observations and tests:

J: Who can tell me what evidence they gathered through doing that?

S1: It smells like cinnamon

J: Smells like cinnamon. Any other interesting smells

S2: It smells like candy

J: Smells like candy a little bit

S3: It smells like basketball

J: Basketball, okay, S4?

S4: It smells like cinnamon.

J: Okay, other observations. S5?

S5: It made noise

J: What kind of noise

S6: Like…<makes the noise>

J: Any other observations that were interesting during this time? S7?

S7: They were like a cardboard

S8: They smelled like sugar candy

S9: It has to be something small.

J: It has to be something small. How do you know?

S10: Because the box is small

S11: I think it's money, because when you shake it, it sounds like two pieces of money banging up against each other, and when you throw it up on the air it sounds like money and when it comes down you kind of see how much it weighs, and it weighs around money.

(*Mystery Boxes*, 11/11/02)

Similarly, when investigating the properties of *Oobleck*, the students were asked to collect evidence based on observations and tests in order to answer the question of whether *Oobleck*, a substance made of water, cornstarch and food coloring, was a liquid or a solid. *Oobleck* is a colloid and can exhibit properties of both solids and liquids, depending on various conditions. It's an avenue to teach about properties of matter and also model the process of scientific inquiry.

First, the students spent five minutes recording their predictions and made some casual observations without touching *Oobleck,* and then Jean asked them to do some formal observations through tests that would help them figure out whether *Oobleck* was a solid or a liquid. The students brainstormed their ideas about some possible tests first and they then worked in their groups to carry out those tests. Some of those tests included: smelling it, touching it, hitting it with a hammer and observing changes in its shape, shaking the bowl that was in and observe changes in its shape. The lesson continued the next day when students carried out their tests. As these two lessons reveal, Jean was able to create an open-inquiry learning environment as she had the students design investigations and collect evidence to answer scientific questions that she posed to them.

In two other lessons (i.e., *Convection Currents* and *Volcanoes and Earthquakes*) that were part of the unit curriculum, Jean again provided students with opportunities to collect evidence, however, the lessons were different in nature. In contrast with the *Mystery Boxes* and *Oobleck*, these lessons were more teacher-centered in the sense that the students did not engage in any investigations; instead they were asked to observe Jean doing demonstrations in front of the classroom. The *Convection Currents* aimed to illustrate the relationship between temperature and density. Through an experiment, Jean illustrated how adding head energy to water causes molecules to spread out and become less dense. The higher energy, less dense layer of water molecules rise through the cooler water to the surface and dissipate its heat. It becomes cooler, hence denser, and then sinks to start the process over. Specifically, Jean had the students observe what happened when she poured some food coloring into the bowl of water, draw their observations and share them with the rest of the class.

> J: Okay, what did it look like when you came up? Where was most of the food coloring when the water was cold, when there was not any heat?
>
> S1: Down
>
> J: Most of it stayed where I poured it, right in the center. What did you notice about the water?
>
> S2: It was like some of the other stuff, there was some blue around it, some traces
>
> J: A little bit yeah, there were blue traces around it, yeah. What else did you notice just about the water, not the food coloring
>
> S3: The water was really still.

J: The water was pretty still yeah

S4: When you dropped the food coloring in it looked like waves

J: Neat! Good observation.

J: So, what do you think about what that cold temperature does? That was cold. Was there any movement there?

S: No movement.

(*Convection Currents*, 2/21/02)

After the students shared their observations about the water (i.e., whether it moved or it stayed still) and about where the food coloring was positioned in the water, Jean lit a candle to heat the water and the students again took turns observing the Convection Currents. Jean followed similar procedures during the lesson about volcanoes where students again had to collect evidence through their observations of her doing an experiment, which modeled why eruptions of volcanoes occur.

Providing opportunities to record and represent evidence

Jean consistently provided her students with opportunities to record and represent the evidence they gathered in all lessons either through observations or tests. For example, during the *Mystery Boxes* lesson, the students were asked to take notes recording the evidence that they gathered through their observations and tests. In the lesson with *Oobleck*, Jean provided the students with a data observation sheet to complete with the evidence they gathered. This sheet was divided into four columns: test, observations, liquid and solid. The students had to record the tests they did, what observations they made, and report whether *Oobleck* acted as a solid or a liquid under those conditions.

During the *Convection Currents* lesson the students were asked to draw diagrams that summarized their observations about how convention currents worked after they made and shared their observations with peers. Similarly, in the lesson *Layers of the Earth,* the students had to draw diagrams that represented their observations about the different layers of earth after experimenting with a model of earth.

When teaching about volcanoes, Jean had the students go outside the classroom and observe a demonstration of an experiment with two bottles of water at different temperatures that modeled how volcanoes erupt. During the demonstration the students were asked to observe and then share their observations with the rest of the class.

Providing opportunities to construct evidence-based explanations

Through Jean's practices, it became apparent that she provided her students with opportunities to construct evidence-based explanations through a variety of assignments: whole class discussions, writing in the form of claims and evidence, completion of worksheets and responding to specific questions. During the Mystery Boxes lesson, the students constructed and shared orally their explanations in class about the content of their boxes based on both observations they made using their senses.

J: Read us your claim.

S1: It could be a card because it's the right shape

J: Makes sense. It could be a card because it has the right shape. Anybody else have a claim?

S2: It could be some sort of food, strawberry food because it has a strawberry smell

J: Very observative. Maybe.

S3: I think it is a cinnamon stick because it has the shape and it also smells like cinnamon and a cinnamon stick could fit in the box

J: Maybe. These are excellent! I like how you're telling me why using your evidence. That's good. It's not enough to just say I think it could be a cinnamon stick but you need to tell me why it could be a cinnamon stick.

(*Mystery Boxes*, 11/11/02)

In the lesson *Convection Currents*, Jean asked the students to develop written explanations about how convection currents work using the evidence they collected throughout their observations of the demonstrations that she did. The students had to develop their explanations in 2-3 paragraphs. Jean followed similar procedures during the lesson, *Layers of the Earth,* where students had to develop written explanations about the different layers of the earth based on the evidence they collected through experimenting with a model of the earth.

In other lessons Jean asked the students to construct evidence-based explanations at home. For example, during *Oobleck* investigations, Jean asked her students to use the evidence that they had collected through their observations and tests and develop a claim about whether *Oobleck* was a solid or a liquid using their evidence.

J: Eventually, tonight, you will be making a claim with your evidence. So, you're going to take the information you've gathered and answer the question: is this substance a liquid or a solid and you're going to use your evidence that you gathered to figure it out.

J: Your homework tonight, is to take a piece of notebook home and write a paragraph that answers this question (writes on the board and reads it at the same time): is this substance a liquid or a solid and how do you know. When I ask how do you know, what are you going to mention? When explaining how do you know.

S1: Because of the test

> J: What about the test that you're going to mention?
>
> <Some students say at the same time: Evidence>
>
> J: You're going to talk about your evidence. So, I think this substance is a liquid because when I did this it did that and just tell me what happened. Describe what you saw, okay?
>
> (*Oobleck*, 1/14/02)

In a lesson, *Continental Drift Theory*, the students were asked to respond to the following questions as homework:

> Who came up with this theory?
>
> What is the theory?
>
> What evidence supports the theory?
>
> Why did some people doubt the theory?
>
> (*Continental Drift Theory*, assessment)

Through this assignment, the students were asked to use evidence to support the theory of continental drift. An example of a student's work follows:

> The theory is that once the continents were all joined together many millions of years ago. Some evidence is that there were the same fossils of sheep-sized animals that could not swim or fly were found in South America and Africa. Another piece of evidence is that there were signs of glaciers in Africa. Some more evidence is that there were tropical plants in England, the same type of rock in different places, and because the rivers were flowing in odd ways (*Continental Drift Theory*, student work)

Jean was able to engage her students in giving priority to evidence in the construction of explanations through a variety of tasks and assignments. It is important to notice how she was able to provide her students with opportunities to construct explanations with the use of evidence in all the lessons described here, no matter how different those were in their design and implementation. As noted earlier, in two of the lessons (i.e., *Mystery Boxes* and *Oobleck*) that Jean experienced as a learner in her science methods course during her internship, the students engaged in inquiry-based investigations to collect evidence and construct explanations. The rest of the lessons (i.e., *Convection Currents*, *Layers of the Earth*, *Earthquakes and Volcanoes*) were part of the unit, and during those lessons, the students collected evidence through observations of demonstrations.

Specialized Knowledge and Beliefs

This section describes Jean's specialized knowledge and beliefs for giving priority to evidence as they became evident from data collected through the interviews. Moreover, this section is concerned with the extent to which these knowledge and beliefs are consistent with Jean's practices. The approach to describing Jean's knowledge and beliefs involves close attention to the ways in which she viewed science and science teaching. Emphasis is placed on language related to the nature of scientific knowledge and the role of claims and evidence in the construction of explanations. In particular, three overarching themes emerged through analysis of the data: a) study of science and the nature of scientific knowledge; b) the role of evidence in the construction of scientific explanations; and c) writing in terms of claims and evidence. These themes are presented next with examples from the interview discourse.

Study of science and the nature of scientific knowledge

Discussing the reasons for teaching science at the elementary school, Jean referred to science as a way of knowing and she emphasized the importance of providing young learners with strong female role models. She stated,

> If I can be a strong role model of a young and capable woman who enjoys science then that will send a more powerful message than any content I can teach. And it's the fact that I say it's important and I act like it's important and I think this is the point I want to get across than anything else. (First interview, 5/11/02)

Jean explained how she could be a strong role model for her students as a young female who enjoys science and how this is important to teaching science at the elementary school. Jean's attitude about women in science was not explicitly discussed in any classroom discourse; however, it was indirectly reflected through her enthusiasm about science subject matter and science teaching.

Talking about the role of evidence in science, Jean portrayed science as being uncertain, dynamic and subject to change.

> I think in science, particularly, because science is so uncertain and so dynamic that you need to be able to support what you think happened or what you think, you know something in, with your solid evidence, because my understanding of the nature of science is what is out there right now as an accepted explanation of things is what nobody else has proven wrong and so I think that itself, these kids see the immediate need that you need to be able to explain this or the next person coming along can prove you wrong and there goes your theory. And they really, they want to be that next person coming along which is a really good way I think to motivate them, well you know you need evidence to prove to other persons (Reflection interview, 3/6/02)

The above statement reveals Jean's basic understandings that science is tentative and subject to change depending on the evidence used to support explanations or theories.

However, it appears that Jean believesonly one explanation or theory is accepted at a time.

Nevertheless, classroom observations revealed that Jean's understandings of science and the scientific knowledge were not translated into her classroom practices. In fact, Jean missed a prime opportunity when teaching the lesson *Mystery Boxes* to explicitly discuss with her students issues related with the nature of scientific knowledge. Specifically, this lesson could have provided an avenue to illustrate that scientific knowledge is tentative and subjective. When students shared their individual explanations about the content of the boxes, Jean could have related their experiences to the study of science in that there are not clear 'right' answers and agreed upon conclusions. Also, this lesson could have been used to model the work of scientists who do not always develop the same explanations as they interpret data based on their backgrounds, beliefs, and interests.

The role of evidence in the construction of scientific explanations

Jean articulated what it means to know something in science and stated that there are no right or wrong answers, but rather are well-supported arguments and unsupported arguments.

> But I just think you can't say that you know something in science unless you can support it with evidence because that's what knowing something in science is. You know, there's nobody that can tell you whether you're wrong or right you just have to have that proof to back up what you're saying (Reflection interview, 3/6/02)

As evident through Jean's words, central in the construction of scientific knowledge is the use of evidence in the development of arguments and scientific theories.

Jean talked more about the use of evidence when she explained how through her elementary science methods course she developed an understanding about scientific inquiry.

> I think science helped me better understand the inquiry approach and how I wanted that fit it in my philosophy and I think the inquiry is part of what I said already…about question things and going out to find more about them and hypothesizing and developing tests and I think, I found that I use it everywhere now, but going out and finding things, don't just tell me things but tell why you support it. I actually just had a big discussion with my kids, it was something that, just the fact that you know you make the best claim you can of what you know but you will never know everything. (First interview, 11/5/02)

Something of this proportion was evident in Jean's practices during the lessons *Mystery Boxes* and *Oobleck*. During these two lessons, students engaged with scientific questions, developed hypotheses and then developed different tests to collect data. In both of these lessons, Jean asked her students to develop claims and use evidence collected through observations and tests to support their claims.

Writing in science in terms of claims and evidence

Jean emphasized the importance of writing in science primarily because it is a different style of writing that emphasizes the use of claims and evidence.

> I like the idea of the geology book. I think it's good for them to having to write about what they learn in science… because I think it's important to express what they know and I think it's a different kind of writing than writing something for language arts you do not always have to back yourself up in language and arts you can just say whatever because you think it was but in this I am really trying to have them make a claim and then support it so I just want them to express orally or on paper or whatever what they know with that kind of format. (Planning interview, 12/9/02)

Through these words, Jean illustrated the value of writing in science not only as a way of expressing what the students know, but also as a way to support learning how to write in terms of claims and evidence. Observations revealed that Jean's knowledge and beliefs found their way into her practices as she provided her students with multiple opportunities to talk and write using the structure of evidence-based explanations.

Discussion

This section provides a discussion of the findings of the study and connects to literature findings related to giving priority to evidence in science teaching. Jean's specialized practices, knowledge and beliefs for giving priority to evidence are discussed first and then an attempt to identify possible sources of this specialized knowledge is presented. Other issues that are discussed in this section deal with Jean's attitude toward science and science teaching, the context of her first-year of teaching and her understandings of science and scientific knowledge and how those were not translated into her practices.

Specialized practices, knowledge and beliefs for giving priority to evidence

Overall, Jean's practices, knowledge and beliefs appeared to be in line with contemporary views of science teaching and learning emphasizing teaching science as inquiry (NRC, 1996) in which the role of evidence is central. The fact that Jean demonstrated these practices and understandings of scientific inquiry is important in light of current recommendations for reform focusing on teaching science as inquiry (NRC, 1996). Because Jean stressed the role of evidence in the construction of explanations is also important as Duschl and Osborne (2002) exp lain that emphasis should be placed on “how evidence is used in science for the construction of explanations, and what are the criteria used in science to evaluate the selection of evidence and the construction of explanations” (p. 40). The fact that Jean provided her students with opportunities to engage in using evidence to construct explanations is significant for two reasons. First, Jean, a first-year elementary teacher, made alterations to the district curriculum through modifications and the development of a supplemental lesson. Second, she was able to design and implement contemporary, student-centered lessons as she engaged her students in constructing evidence-based explanations, which is central to scientific inquiry. This contradicts literature describing that first-year teachers follow closely the curriculum and they struggle with implementing student-centered inquiry activities (Loughran, 1994).

Jean’s approaches to collecting and recording data were fairly consistent with other elementary classrooms, as reported in the literature, teachers often have their students engage in hands-on activities (Gustafson & Rowell, 1995). What makes Jean’s case unique, however, is her ability to have her students take the next step of interpreting the collected data, making meaning out of them, and using them to construct explanations. Jean’s practices were unique because they went beyond simply engaging students in activities and physical interaction with materials. Instead, Jean was able to create appropriate tasks to engage her students in the more conceptual tasks of explaining the data collected through observations and different types of investigations. By engaging her students in the construction of explanations, not only did Jean support their science learning, but she also met epistemological objectives. This is important because as Duschl and Osborne (2002) state, “Teaching science as an enquiry into enquiry must address epistemic goals that focus on *how we know* what we know, and *why we believe* the beliefs of science to be superior or more fruitful than competing viewpoints” (p. 43).

It is also important to notice how Jean did not only ask her students to talk about their explanations using the evidence they collected through the classroom activities, but at the end of each lesson she also asked them to write about their explanations in the form of claims and evidence. This illustrates Jean’s view, which became explicit during the reflection interview, that learning to talk science supports science learning in terms of claims and evidence, which relates to Lemke’s (1990) argument that, “Scientific reasoning is learnt by talking to other members of the community; we practice it by talking to others, and we use it in talking to them, in talking to ourselves, and in writing and other forms of more complex activity” (p. 122).

Osborne (2002) argues about the importance of providing students with opportunities to use and explore the language of scientific reasoning. Students need to “read science, to discuss the meaning of its texts, to argue how ideas are supported by evidence and to write and communicate in the language of science” (p. 204). Another aspect of the value of writing in science is the one that models scientists’ discourse and communication of ideas. Central to the discourse of scientists is the development of scientific claims and theories, which are challenged and progressed through dispute, conflict and paradigm change in the public domain (Driver, Newton & Osborne, 2000). Therefore, when students are provided with opportunities to construct arguments, gather evidence to support them and communicate them to their peers they are experiencing the process and culture of science in similar ways as scientists do.

Sources of specialized knowledge and beliefs for giving priority to evidence

The mismatch between knowledge and practices related to the study of science and scientific knowledge could be connected with the conditions needed for conceptual change to occur (i.e., dissatisfaction, intelligibility, plausibility and fruitfulness). Specifically, it is clear that particular aspects of science and scientific knowledge were intelligible to Jean. An intelligible concept is understood and internally represented by a learner (Strike & Posner, 1985). This can be traced back to her prior science learning experiences and particularly to two science courses she took (i.e., *SCIED410: Using Technology to Enhance Science Learning* and *Teaching with Insects*) that addressed issues of the study of science and scientific knowledge. However, evidence gathered through observations suggests that these concepts were not fruitful for her. For a concept to be fruitful, the learner must be "aware of, generate or understand novel practical applications or experiments which the new conception suggests" (Strike & Posner, 1985, p. 221). The question then becomes of one of how to facilitate elementary teachers' conceptual change of their conceptions of science and scientific knowledge. Also a critical question is: what is appropriate for elementary teachers to know about science and scientific knowledge and how to facilitate their learning throughout their preparation? Other issues related to supporting elementary teachers develop adequate understandings of science are connected to the context (i.e., science content courses or elementary science methods course or both) in which these could take shape and what approach (i.e., implicit or explicit) could be undertaken to support the development of their understandings.

Specific university coursework, which emphasized the use of evidence in the construction of scientific claims, appeared to have influenced Jean's specialized knowledge and beliefs about the use of evidence in science teaching and learning significantly. Moreover, the elementary science methods course influenced Jean's philosophy about teaching and learning science, which focused on scientific inquiry. This is congruent with the findings of a study done by Adams and Krockover (1997), with four beginning science teachers. The results of this study illustrated that specific aspects of the science education program were translated into practice and that it provided a framework from which the beginning teachers constructed their ideas of the science classroom.

This finding is significant as it illustrates that critical experiences during preparation are influential in the development of specific aspects of PCK and could promote teachers' conceptual change. Data gathered through interviews, provide evidence on how Jean's views of science were reconstructed through specific university coursework that provided her with new ways of viewing teaching and learning science. Specifically the course, *ENGR497: Fundamentals of Science, Technology and Engineering Design* engaged prospective elementary teachers in meaningful learning experiences with selected engineering principles and physical science concepts. In this course, prospective teachers engaged in active inquiry that promoted their learning and also offered insights into effective ways to introduce children to active learning in the applied physical sciences (http://www.ed.psu.edu/ci/research/engr_scied_proj.asp). Furthermore, the course, *SCIED410: Using technology to Enhance Science Learning*, through which prospective teachers engaged in inquiry-based investigations and emphasized giving priority to evidence in the construction of evidence-based claims, appeared to have influenced Jean's thinking of science in terms of claims and evidence.

Moreover, the elementary science methods course supported Jean in developing contemporary views about science and science teaching. According to Zembal-Saul (2001), the elementary science methods course was designed around several central areas of emphasis. First, prospective teachers were actively engaged in learning science throughout the course. A conceptual change orientation (Strike & Posner, 1992) drove instruction and concepts were selected based on the National Science Education Standards (NRC, 1996) K-4/6-8 content. One of the main purposes of the course was to provide prospective teachers with opportunities to experience, as learners, a more conceptual approach to science teaching and learning – one that is consistent with contemporary reform efforts in science education.

Specific university coursework and the elementary science methods course appeared to have supported Jean in reconstructing her existing notions of science and pedagogy by engaging her in meaningful experiences designed to facilitate the development of the conceptual change conditions (i.e., intelligibility, plausibility, dissatisfaction and fruitfulness). As Stofflett (1994) described, changing teachers' pedagogical knowledge occurs through reconstruction and "if teachers are to change their views of science teaching, they must undergo a process of conceptual change themselves" (p. 788).

Attitude toward science and science teaching

It is critical to address Jean's attitude toward science and particularly her perception of how important it is to be a strong female science role model for her students, as young learners of science. Jean's views become of even greater importance if we pay attention to her science learning experiences throughout her education. As revealed through data gathered from the first interview, Jean was an enthusiastic learner of science in elementary school. However, this enthusiasm lasted only through the years of elementary school. Going to middle school, Jean reported that she lost interest in doing science because of issues related with gender dynamics. This is in line with literature suggesting that by middle school, girls' attitudes toward science tend to decline (Sullins, Hernandez, Fuller, & Tashiro, 1995). Specifically, during the first interview Jean stated that she had no interest in science in the middle school because "the guys get the stuff and the girls write down the answers". This also is consistent with research findings reporting that male students have more opportunities to conduct experiments, carry out demonstrations, and manipulate equipment (Jones & Wheatley, 1990).

Of interest are the negative experiences Jean had with her science teacher in middle school, a male, who appeared to have developed different interpersonal relationships with the boys and the girls. Jean perceived that her teacher had different expectations from boys and girls, and his comments and actions toward her made her feel that she "could not do science". This was discouraging for Jean, a young female learner, who very soon lost confidence as a successful learner of science and she went to the university disliking science and with no desire to teach it. This is consistent with reseach findings suggesting that prospective elementary teachers hold negative attitudes that appear to have arisen from their past experiences in science, particularly at secondary school (Abell & Smith, 1994; Palmer, 2001) and lack confidence in their ability to teach science (Westerback, 1982).

It was not until Jean went to the university and came across strong female role models in science and took a course specifically designed for prospective elementary teachers (i.e., *ENGR 497: Fundamentals of Science, Technology and Engineering Design*) that she gained confidence in herself as a successful learner of science. Gaining confidence as a learner of science resulted in her becoming interested in science and science teaching. This is significant considering that, “one of the main aims of the preservice preparation of elementary teachers should be to cultivate a more positive self-efficacy by developing their confidence to teach science effectively” (Palmer, 2001, p. 123).

Given the negative science experiences Jean had in middle school and how influential the female teachers she came across in the university were, it is not surprising that she wanted to be a strong female science role model for her students. As she stated in the orientation interview, she did not want her students to have similar negative and discouraging experiences with learning science, particularly feelings of ‘not being able to understand science’ throughout their schooling.

First-year of teaching

Jean’s case is not consistent with literature suggesting that novice teachers have to survive the reality shock as they adjust to the complexities of day-to-day teaching, and deal with the complementary roles of learning to teach on the job and teaching effectively (Fuller & Brown, 1975; Veenman, 1984). The findings of this study suggest that Jean had a successful induction in the school culture and was able to concentrate on developing appropriate teaching methods, assignments and tasks to support student learning. These findings are consistent with Zembal-Saul, Krajcik and Blumenfeld’s (2002) study, that illustrated the contribution of the school context to supporting first-year teachers in applying their frameworks for teaching and learning science that they developed during their student teaching.

According to Appleton and Kindt (2002), beginning teachers’ growth is influenced by not only their personal experiences and views of themselves as teachers but also by the school policy and ethos, curriculum and collegial support. Kagan (1992) described three common contextual factors that appear to be determinants of growth and success: “the teaching assignment (the nature of the content and pupils to be taught); colleagues (their willingness to provide support and assistance); and parental relationships” (p. 153).

As it became apparent through Jean’s words, the school context provided her with the support she needed to have a smooth transition from the internship to the first year of teaching and apply her personal knowledge and beliefs of teaching and learning science to practice. She explicitly stated that she loved the school, she enjoyed collaborative relationships with other teachers, and she had a principal who was "supportive and open to new ideas."

As described in the methods section, this study took place within the PDS school context, a partnership between a university and the local school districts. Jean was one of the interns in this program and she was then employed by the same school district. Through this partnership she taught in an elementary school throughout her senior year of college. The fact that the school context was supportive in helping Jean make a successful induction has implications about the PDS context, which provided unique opportunities to integrate university coursework and field experiences and situate prospective teachers' experiences in the context of school. Putnam and Borko (1997) pointed out that recent scholarship about teacher learning suggests that teacher education must be situated in classroom practice. This view is drawn upon the perspective of situated cognition, which states that people's learning is determined by the context within which it occurs (Collins and Brown, 1989; Putnam & Borko, 1997). As Putnam and Borko (1997) described, teachers develop knowledge, which is developed in context, stored together with characteristic features of the classrooms and activities within which it is developed, and accessed for use in similar situations (p. 1256).

Knowledge VS practices related to the study of science

Although it was not the focus of this study, some aspects of Jean's knowledge and beliefs regarding issues of the nature of science were revealed in the interviews. As one might expect, these understandings were somewhat naïve and did not translate into her classroom practices. This is consistent with research findings reporting that teachers' conceptions of the nature of science do not necessarily translate into classroom practice (Brickhouse, 1990; Lederman, 1992, 1998). According to Schwartz and Lederman (2002), research reports suggested that the translation of one's views into practice is influenced by a variety of factors: contextual, personal and factors related to teachers' NOS content knowledge and subject-specific pedagogical knowledge. Evidence gathered through interviews and classroom observations, suggested that Jean did not face any contextual constraints in attempting to apply her knowledge and beliefs in practice. Instead, her case raises questions connected with whether she had the pedagogical knowledge for applying her understandings in practice. As Schwartz and Lederman (2002) noted, in order to be able to teach NOS, "a teacher must have not only a firm understanding of NOS but also knowledge of effective pedagogical practices relative to NOS and then intentions and abilities to merge these two elements in the classroom" (207). This has implications for teacher education programs as it suggests the need to provide prospective teachers with experiences that would not only contribute to the development of an understanding of science and scientific knowledge but also the development of pedagogical knowledge that would allow them to apply those understandings in their classroom practices.

Conclusions and Implications

The twofold purpose of this study was to characterize a first-year elementary teacher's specialized practices, knowledge and beliefs for giving priority to evidence in science teaching and also gain an understanding of the possible sources of development of this specialized knowledge. Data gathered through classroom observations and interviews help describe this specific aspect of PCK.

In particular, the case of Jean illuminates the nature of the knowledge and beliefs for giving priority to evidence in science teaching and shows how it is translated into everyday classroom practices. Jean's practices, knowledge, and beliefs demonstrate a view of teaching and learning science that moves beyond empirical enquiry and focuses on more conceptual and epistemological aspects learning. This was evident in data collected through observations and interviews supporting the notion that Jean intentionally provided her students with opportunities to collect and use data to construct and interpret meaning.

The findings of this study revealed a coherence between Jean's knowledge, beliefs and practices for giving priority to evidence in science teaching, which contradicts previous studies findings reporting a gap between beginning teachers' personal theories of teaching and learning and their actual teaching practices (Simmons et al., 1999, Kagan, 1992). Specifically, with the exception of knowledge about science and scientific knowledge, Jean's knowledge and beliefs for giving priority to evidence in science teaching were translated in her classroom practices. Hence, more research needs to be done to explore ways and approaches to support teachers not only develop a firm understanding of the NOS, but also develop specific pedagogical knowledge that enables them apply their understandings in their practices.

Moreover, gaining an understanding of Jean's specialized knowledge and beliefs for giving priority to evidence is a valuable source for preservice and inservice education aiming in supporting teachers' development of this specific aspect of PCK. This study sheds light on the possible sources from which this type of PCK was generated. Specifically, this study illustrates that specific experiences during teacher preparation were critical in the development of this aspect of Jean's PCK. What we can learn from the case of Jean is that supporting the development of specific aspects of PCK is a difficult and complex task, which requires the combination and interaction of a variety of experiences. Data analysis illustrated that Jean's specialized knowledge for giving priority to evidence in science teaching was enhanced through specific courses, assignments and activities during her preparation. In fact, it became evident through this study that learning experiences in her university coursework along with the teacher preparation program promoted Jean's conceptual change as they provided her with opportunities to reflect on and reconstruct her understandings of teaching and learning science. These findings have implications for the design of teacher preparation programs that aim to support teachers in examining and reconstructing their existing knowledge and beliefs in light of contemporary ideas about teaching and learning science.

In light of the vision of reform in science education focusing on learning science as argument and explanation (NRC, 1996), there is a need to incorporate specially designed learning activities in both preservice and inservice education that support teachers in experiencing science as argument and explanation themselves and enhance their specialized knowledge for giving priority to evidence in the construction of scientific explanations. Built on the implications related to teacher preparation and the kinds of experiences that are critical in supporting the development of specific aspects of PCK, further research must be done to obtain a better understanding of these kinds of experiences and how they influence the development of PCK. In order to do so, a case study research approach is recommended in light of the research results reported by Weiss, Pasley, Sean Smith, Banilower and Heck (2003). This report indicated that 59 percent of mathematics/science lessons in the US are judged to be low in quality, 27 percent medium in quality, and only 15 percent high in quality. Hence, it is important to better understand the nature of the exemplary teachers' practices and the reasons why those came to be. Researchers, teacher educators, and policy makers could benefit by gaining a deeper understanding of the cases of exemplary teachers. These cases could provide important information on how to support other teachers in implementing appropriate lesson plans and following similar approaches and strategies in their practices.

Jean's case illustrates how her innovative preparation program supported her learning to teach science in contemporary ways. According to Jean, two elements of her preparation program were supportive of both her learning to teach and her induction as a first year teacher: a) she had the opportunity to work closely with experienced mentor teachers; and b) she had the opportunity to concurrently develop and apply in practice a personal philosophy of science teaching and learning. Even though the purpose of the study was not to evaluate the program, specific elements of it (i.e., the coherence between university coursework and classroom practices) appeared to be critical in supporting Jean in applying her views of science teaching and learning in practice and deserve further attention. The case of Jean implies that situating learning to teach experiences in meaningful contexts is important in supporting successful induction. Further research is hence needed in the area of exploring ways for situating prospective teachers' experiences in meaningful contexts. Situating prospective teachers' experiences in this way could provide the means to empower them to develop substantive knowledge, frameworks, and teaching repertoires to meet current recommendations of reform (Putnam & Borko, 2000).

In closing, this type of study adds to the value of the concept of PCK within the domain of research on science teaching (van Driel, Verloop, & de Vos, 1998) by illustrating how to study and what to look for when studying this specific aspect of PCK. At the same time, this study underscores the need for further research in the area of teachers' PCK for giving priority to evidence in science teaching. More longitudinal studies are needed to explore the development of this specific aspect of PCK in order to identify factors that influence its nature and development over time.

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Appendix A

First semi-structured interview protocol

- What are your experiences with learning science both in and outside of school?
- Did you enjoy learning science? Why?
- Describe the most positive experiences that you had with learning science. What makes them the post positive ones?
- Who were your favorite science teachers? Why?
- Tell me about your background in science
- What college science courses did you take?
- In what ways did each of these courses influence your ideas about how to teach science?
- How did your teacher preparation program influence the way that you teach?
- How would you describe your personal philosophy of teaching and learning science?
- What do you think are the reasons for studying science at the elementary school?
- What are the goals for your students for learning science?
- How would you describe your school setting and the student population?
- Do you feel there are constraints that prevent you from teaching the way you would like to? What are these barriers?

Appendix B

Second semi-structured interview protocol

- Why it is important to teach this unit?
- What goals do you have for your students in this unit?
- What difficulties are you expecting connected with teaching this science concept?
- What do you expect your students to know about this unit?
- What misconceptions do your expect your students to have?
- How will you introduce this unit?
- How will you teach this concept? (teaching procedures) Why?
- How will you assess your students' understandings?

Appendix C

Third semi-structured interview protocol

- Did you think the unit was successful? Why?
- What were the strengths of the unit?
- What would you change about it if you had to teach it again?
- Did you think the students met your objectives?
- What do you think that they got out of the unit?
- Can you think of other ways/alternative pedagogical approaches to teach the unit?

Appendix D

Codes summary

Open Coding for specialized practices for giving priority to evidence in science teaching	Asking students to make predictions Directing students to look for data Prompting students to design tests to collect data Engaging students in observations of demonstrations Engaging students in observing patterns in data Engaging students in collecting data Providing examples of observations Providing examples of tests Providing examples of explanations Prompting students to interpret data Checking for students' understandings of the meaning of evidence Prompting students to make diagrams with the use of their data Prompting students to share observations Prompting students to share interpretations of Support students' critical thinking Construction of evidence-based claims as a way of constructing scientific knowledge Scientific knowledge changes throughout the years Writing in the form of claims and evidence as a way of learning science Writing in the form of claims and evidence as a way to communicate explanations		
Major categories: specific practices related to the use of evidence the construction of explanations	Collect evidence	Record and represent evidence	Construct evidence-based explanations
Subcategories: ways in which opportunities to collect, record and represent evidence and construct explanations were provided	Observations Designing tests Carrying out tests	Completion of observation sheets Developing diagrams Developing written reports	Class discussions Writing in class Homework assignments

Open Coding for knowledge and beliefs for teaching and learning science	Teaching is personally fulfilling Teaching as a way to learn about her self Teaching as way to learn about the world along with the students Science as a different way of explaining the world Teaching science as a way to provide young learners with female science role models Making learning science an enjoyable experience Supporting children in gaining confidence as learners of science Providing students with a different way of viewing science Teaching science as inquiry Teaching science with the use of demonstrations and experiments Student-centered approaches in science teaching Physical engagement of students in activities alone is not enough to support learning Engage students in thinking about what they are doing Passion for learning as a central element of her philosophy Life-long learning as a central element of her philosophy Ownership for learning as an important element of her philosophy Engage students in activities that are meaningful to them Understanding students' needs Understanding students' background knowledge Understanding students' individual differences Support students' critical thinking Construction of evidence-based claims as a way of constructing scientific knowledge Well-supported claims by strong empirical evidence Scientific knowledge changes throughout the years Writing in the form of claims and evidence as a way of learning science Writing in the form of claims and evidence as a way to communicate explanations		
Major categories: specific knowledge related to the use of evidence the construction of explanations	Nature of scientific knowledge	The role of evidence in science	Talking and writing in terms of claims and evidence
Subcategories: ways in which the participant addressed major components of each category	Scientific knowledge is tentative and subjective Only one explanation is accepted at a given time Scientific knowledge consists of evidence-based claims	Evidence has an essential role in science Evidence is used to support scientific explanations Evidence is central in scientific inquiry	Express what students know orally and in writing Format of claims and evidence as a way of learning science Uniqueness of the discipline

CHAPTER 4

VISIONS OF REFORM IN SCIENCE EDUCATION IN CYPRUS

Abstract

The objectives of the elementary science curriculum in Cyprus, as described by the Ministry of Education, demonstrate the emphasis of the curriculum on the concept of discovery learning and the development of the skills connected to the use the scientific method to acquire information. However, these objectives also reveal the absence of consideration of current perspectives on learning and cognition. Therefore, this chapter aims to propose new directions for teaching science at the elementary school in Cyprus and makes recommendations to improve the current teacher preparation program in light of the need for a reform. This chapter is built upon major perspectives on learning and cognition and is informed by current trends in science education in the US and UK.

Introduction

This chapter seeks to provide an overview of the current elementary science curriculum in Cyprus and make recommendations for future directions in science education. Specifically, the first section of this chapter provides a brief overview of the educational system in Cyprus and describes the goals and objectives of the elementary science curriculum. The second section of this chapter consists of a critique emphasizing the traditional nature of the objectives of the curriculum and the ways in which science is taught. Following this critique, visions of reform in science education are discussed. The theoretical framework of these visions of reform is drawn upon contemporary perspectives from cognitive psychology, in particular, situated cognition. The proposed reforms are focused around three core areas: context-specific knowledge, the role of argumentation in science and the use of technology in science teaching and learning. The recommendations for reform are also informed by my research and teaching experiences in the US. It is important to note that this chapter deals with Greek Cypriot education only because of the current political situation in Cyprus. As Persianis (2000) points out, "the complete physical separation between the Greek and Turkish communities of the island since 1974 leaves no possibility for any cooperation, communication or academic influence among higher education institutions of the two communities" (p. 36).

This chapter is intended to reach curriculum developers, elementary teachers and elementary teacher educators.

Geographical and Political Setting

Cyprus is a small island of 3,572 square miles and is strategically situated in the far eastern end of the Mediterranean at the crossroads of Europe, Africa, and Asia with a population of 759,000 (Press & Information Office, 2000). Cyprus is currently divided into two parts, the north part with a population being predominantly Turkish and of about 125,000 and the south part with the remaining population being predominantly Greek and following the Christian Orthodox religion. As Constantinou (1999) describes, the island "is divided into two parts by a *green line* that runs roughly east-west and is policed by a UN force. There is essentially no movement across this line except for mutually pre-approved visits that are rare and always negotiated through the UN" (p. 23).

The national problem of Cyprus and its development during various periods of its history affected the educational policy, priorities, goals and objectives of education. Kliebard (1990) notices that "the curriculum is a manifest expression of the cultural values just as laws are manifest expressions of what a society deems to be right or wrong behavior" (p. 157). As described by the Ministry of Education and Culture, one of the top priorities of Cyprus education is to retain the national identity and keep alive the memory of the occupied areas in Cyprus. Koutselini-Ioannidou (1997) discusses how the political context in Cyprus has influenced the development of the secondary curriculum: "Curriculum choices were to a considerable extent determined by the political situation in Cyprus which contributed to the almost autonomous functioning of the national culture" (p. 395). A review of the educational system, priorities, aims and objectives of Cyprus education is presented next.

Cyprus Educational System

Cyprus follows a centralized educational administration system. The highest authority for educational policy making is the Council of Ministers and the Ministry of Education and Culture is responsible for Cyprus education. Specifically, the Ministry of Education and Culture is responsible for the administration of education, the enforcement of education laws and, in co-operation with the Office of the Attorney General, the preparation of education bills (International Institute for Educational Planning, 1997). Education is compulsory up to the age of 15. Elementary and secondary education is free. Cyprus has one university and 34 colleges and institutions of further education (Press & Information Office, 2000). The University of Cyprus, established in 1992, is a public corporate body governed by the University Senate, which is responsible for academic affairs, and the University Council, which is responsible for the management, control, and administrative and financial affairs.

The general principles, aims, and objectives of Cyprus education as described in the Analytic Elementary Curriculum (Ministry of Education and Culture, 1996) are the following:

1. Education must constitute part of the wider socioeconomic, cultural, and traditional characteristics, and values of Cyprus, which should be transformed successfully into educational objectives.
2. Education should have internal and external coherence, an educational planning system and a democratic structure of educational administration.

3. There should always be a strong link and mutual influence between education and life.

As it becomes evident through these general principles, education in Cyprus is strongly linked to societal needs and traditions. The specific objectives related to elementary science proposed by the Analytic Elementary Curriculum are discussed next.

Elementary Science Curriculum

Cyprus has had a national curriculum in science since its independence in 1960 with two reviews having been made since then, the last one completed in 1994. As stated in the Analytic Elementary Education Curriculum (Ministry of Education and Culture, 1996), the general goals of teaching elementary science are the following: (a) The students will develop a research spirit and adopt the scientific approach to solving problems; (b) The students will acquire scientific knowledge in order to understand themselves and the world; and (c) The students will develop attitudes for appreciating the environment and adopt an active role in activities that enhance its maintenance and improvement.

The Cypriot elementary science curriculum developed in 1996 "is based on hierarchical-developmental views of learning and the main underlying philosophical perspective is *guided discovery"* (Zembylas, 2002, p. 505). The concept "discovery learning" traces back to Dewey (1910) who argued that children learn best when discovering for themselves the "verities of life." According to Zembylas (2002), the elementary science curriculum "shows the emphasis on the new philosophy on both the acquisition of scientific facts and principles and the implementation of scientific methods and skills" (p. 505).

The elementary science curriculum consists of 13 main topics, which are structured spirally and are taught over a period of six years. Specifically, the objectives of the elementary science curriculum, as defined by the National Curriculum (Ministry of Education and Culture, 1996) are the following. The students will be able:

- To investigate using all their senses.
- To develop the ability of asking questions and finding feasible answers to them.
- To communicate and register their observations and ideas.
- To work in a team and carry out certain tasks.
- To classify elements and organisms in accordance to their properties, structure, and behavior.
- To formulate predictions.
- To comprehend and carry out experiments.
- To be able to register and categorize their measurements, data, and observations.
- To interpret any given scientific data.
- To formulate hypotheses and revise them in light of new facts.
- To deduce conclusions.
- To identify and supply simple scientific concepts into their everyday life.
- To develop awareness about preserving, protecting, and improving the natural environment.
- To make use of scientific instructions in their investigations.

These objectives demonstrate the emphasis of the curriculum on the concept of discovery learning and the development of the necessary skills to use the scientific method to acquire information. However, these objectives also reveal the absence of consideration of current perspectives on learning and cognition. Constantinou (1999) points out that the educational system in Cyprus is “highly traditional in its objectives and methods and has been demonstrated repeatedly by both international comparative research and more in-depth qualitative local investigations, to promote rote memorization of factual knowledge with the explicit purpose of passing landmark examinations” (p. 25). Similarly, Zembylas (2002) observes that reform efforts in the USA and UK that emphasized constructivism and conceptual change had no impact on the latest reform of the Cypriot curriculum in 1994.

Therefore, the purpose of this chapter is to propose new orientations in teaching science at the elementary school in Cyprus and to make recommendations for new directions in the current teacher preparation program in light of the need for reform and based on major perspectives on learning and cognition, and currents trends in science education in the USA and UK.

Visions of Reform in Science Education

Context-Specific Knowledge

A main aspect of my recommendations draws upon current perspectives of learning and instruction that are focused on learning environments designed to encourage students to integrate information instead of merely being provided with it by the teacher (Linn, Songer, & Eylon, 1996). According to this view, meaningful learning occurs when learners actively construct their own learning outcomes (Bruner, 1961; Mayer, 1992). The learning of individuals, including teachers, is a constructive and iterative process in which the person interprets events on the basis of existing knowledge, beliefs, and dispositions (Borko & Putnam, 1996, p. 674), which also reflects the perspective that learning is situated within specific sociocultural contexts. As Greeno, Collins and Resnick (1996) point out, a theory of situated cognition is emerging that takes the distributed nature of cognition as a starting point and implies that thinking is situated in a particular context of intentions, social partners, and tools (pp. 16-17).

However, the development of a centralized, national curriculum does not take into consideration the view that thinking and learning are situated within specific sociocultural contexts. I grew up in Cyprus and became an elementary school teacher at a rural school of 150 students coming from eight different villages where the majority of the parents were occupied in the areas of farming and agriculture. Consequently, the students at this school had a great interest in farming and agriculture as well, as they were spending most of their time before and after school helping their parents. Reilly (1989) describes life in the small villages of Cyprus: “Life in the villages is difficult and many people are quite poor. Farming is the chief occupation, particularly for the older inhabitants. Roads are narrow and unpaved and the pace of life especially during the summer months is slow” (p. 45).

Yet, the national curriculum does not make any specific reference to these rural and isolated settings but instead proposes the same learning goals for the students as other large schools at urban settings. Inevitably, the learning goals proposed by the curriculum become disconnected from these students’ sociocultural backgrounds, knowledge, interests, and experiences—scientific knowledge then becomes abstracted, disembodied, and decontextualized. However, as the literature suggests, in order for knowledge to be of use for classroom practice it must be context-specific (Lampert, 1984). The importance of developing curriculum situated within specific contexts, taking into consideration both teacher knowledge and teaching style and students’ backgrounds, interests, and characteristics, has been illustrated by a number of researchers (Barnett & Hodson, 2001; Lave & Wenger, 1991; Wells, 1994). Wells (1994) emphasizes how each classroom setting is unique:

> Every class is different from every other.…Individual students each have their own interests, and their strengths and limitations; they also have different contributions to make from their own past experiences, both personal and cultural. Equally, every teacher has a particular style of teaching that is based on personal beliefs, values and past experiences. Together, teacher and students make up a classroom community that is unique, with its own particular potentials and problems. Therefore, teaching can never be a matter of simply ‘implementing’ packages developed by others, for the generalized curricular guidelines and pedagogical procedures that are thought up by distant experts are rarely appropriate, as they stand, to the needs of particular classrooms. (p. 3)

Considering the above, I suggest that curriculum developers in Cyprus take into account what is described by Grossman (1990) as "knowledge of context" and includes the "knowledge of the districts in which teachers work, including the opportunities, expectations and constraints posed by the districts, knowledge of the school setting, including the school culture … knowledge of specific students' backgrounds, families particular strengths, weaknesses and interests" (p. 9). This will provide the base for achieving the goal of supporting meaningful learning and personalized understandings of science for all children.

Learning science as inquiry and through argumentation

Another aspect of my recommendations for new directions in the Cypriot elementary science curriculum is based on recent trends in science education that have called for substantial reforms in learning environments and specifically focusing on supporting learning through inquiry (National Research Council [NRC], 1996, 2000). Inquiry refers to posing questions, making observations, designing investigations, collecting information, analyzing and interpreting data, and explaining and communicating findings (NRC, 1996). Central to learning science as inquiry is the construction and communication of scientific claims and explanations:

> When children or scientists inquire into the natural world they pose questions, they plan investigations and collect relevant data, they organize and analyze collected data, think critically and logically about relationships between evidence and explanations; use observational evidence and current scientific knowledge to construct and evaluate

> alternative explanations and communicate investigations and explanations to others. (NRC, 1996, p. 122)

Practices, such as assessing alternatives, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims are all seen as essential components in constructing scientific arguments (Latour & Woolgar, as cited in Driver, Newton, & Osborne, 2000). Engaging in the construction of scientific arguments as a way of learning science has been emphasized by a number of researchers (e.g., Driver, Newton, & Osborne, 2000; Kuhn, 1993; Linn, 2000; Newton, Driver, & Osborne, 1999). Learning science as argument is important because it supports learners in gaining an understanding of how scientists conduct their work (NRC, 2000) and in developing a rational for their thinking and actions (Geddis, 1991), it illuminates the social and public nature of science (Newton, Driver, & Osborne, 1999) and it also illustrates the idea that science should not be viewed as a static set of facts that represent a spectrum of absolute truths, scientific theories, and laws not being subject to change (Schwab, 1962).

Engaging in the construction of scientific arguments as a way of learning science has been emphasized by a number of researchers (e.g., Driver, Newton, & Osborne, 2000; Kuhn, 1993; Newton, Driver, & Osborne, 1999). As Jimenez-Aleixandre, Rodriguez, and Duschl (2000) point out, "argumentation is particularly relevant in science education since a goal of scientific inquiry is the generation and justification of knowledge claims, beliefs and actions taken to understand nature" (p. 758). Students have to understand the rational basis for their actions, and for this to occur they have to work their own ways through issues "until they arrive at a consistent, acceptable position which can be defended persuasively and which takes other points of view into consideration" (Bourne & Eisenberg, as cited in Geddis, 1991, p. 11).

Moreover, engaging in thinking and learning science in terms of argument supports gaining an understanding of how scientists conduct their work (NRC, 2000). Central to the discourse of scientists is the development of scientific claims and theories, which are challenged and progressed through dispute, conflict, and paradigm change in the public domain (Driver, Newton, & Osborne, 2000). When students are provided with opportunities to construct arguments, gather evidence to support them and communicate them to their peers they are experiencing the process and culture of science the same way as scientists do. Driver, Newton, and Osborne (2000) refer to this process as enculturation into science where students not only hear explanations being given to them by experts but they also practice using the ideas themselves and develop an understanding of scientific practices and ways of thinking as scientists do.

Drawn upon the views on the role of argumentation in science, I suggest a shift of the emphasis of the Cypriot elementary science curriculum away from discovery learning and toward learning science as inquiry that would support Cypriot children in constructing scientific knowledge through engagement in learning science in terms of argument (Driver, Newton, & Osborne, 2000) and participation in the social and physical environment of the classroom (Keys & Bryan, 2001). However, these new trends in teaching and learning science require new roles from the teachers. The question then becomes: Do Cypriot teachers who were not taught science this way have the skills and knowledge needed to teach science as inquiry and engage their students in thinking about and learning science in terms of argument? The next section of the chapter explores the issue of preparing teachers to teach based on current recommendations for reform in science education.

Preparing Teachers to Teach Science

Putnam and Borko (1997) point that, “for teachers to move successfully toward these new visions of classrooms will require in many cases major changes in their knowledge, beliefs and practice” (p. 1224). How can the teacher preparation program of the University of Cyprus support prospective teachers in developing the skills and knowledge needed to teach science according to the current recommendations of reform? Putnam and Borko (1997) state that recent scholarship about teacher learning and teacher education is captured in a number of statements about effective teacher education programs. These statements are:

1. Teachers should be treated as active learners who construct their own understandings,

2. Teachers should be empowered and treated as professionals,

3. Teacher education must be situated in classroom practice, and

4. Teacher educators should treat teachers as they expect teachers to treat students. (p. 1225)

The learning of individuals, including teachers, is a constructive and iterative process in which the person interprets events on the basis of existing knowledge, beliefs, and dispositions (Borko & Putnam, 1996, p. 674). Shuell (1996) describes how learners construct their own knowledge:

The learner does not merely record or remember the material to be learned. Rather, he or she constructs a unique mental representation of the material to be learned and the task to be performed, selects information perceived to be relevant, and interprets that information on the basis of his or her existing knowledge and current needs. (p. 743)

The central role of the learner in the acquisition of knowledge has been emphasized through the conceptual change theory which describes the substantive dimensions of the process by which people's central, organizing concepts change from one set of concepts to another set, incompatible with the first (Posner, Strike, Hewson, & Gertzog, 1982).

According to Posner et al. (1982), four conditions are common to most cases of accommodation: (a) there must be dissatisfaction with existing conceptions; (b) a new conceptions must be intelligible; (c) a new conception must appear initially plausible; and (d) a new concept should suggest the possibility of a fruitful research program (p. 214). As Brown and Palincsar (1989) note "conceptual change is more likely to result when the purpose of procedures is emphasized rather than blind drill and practice, even when that drill and practice is devoted to appropriate procedures" (p. 393). Thus, it is important that teacher educators in Cyprus engage prospective teachers in activities that emphasize procedures and cause them dissatisfaction with their existing conceptions in order to lead to their conceptual change.

Activities that support conceptual change have been associated with the term "reflection." According to Houston and Clift (1990), the implication for reflective practice is that the practitioners stand back from a situation, analyze it, recognize nuances within it, and propose solutions that are then tested. Reflection's important role in learning to teach has been emphasized by a number of scholars through the years (e.g., Clift, Houston, & Pugach, 1990; Dewey, 1933; Schon, 1983). Schon (1983) states:

> Practicum experiences must engage teachers in tasks where they can explore their own learning, reflect on their processes in inquiry, examine their own shifting understandings—and compare their actual learning experiences with the formal theories of learning built into standard pedagogies. (p. 323)

As illustrated above, it is important to draw connections among prospective teachers' experiences in their methods courses and their practical experiences and also to engage them in meaningful reflection on how these experiences influence their thinking. An approach to this challenge is the use of portfolio development. Bird (1990) suggested that portfolios are a logical vehicle for encouraging prospective teachers to observe and reflect upon their teaching because they provide a systematic, continuous way of planning, supporting and monitoring a teacher's professional advance (p. 244). A number of studies suggest that portfolio development may be a useful tool for supporting thoughtful reflection (Avraamidou, 2001; Avraamidou & Zembal-Saul, 2002; Dana & Tippins, 1998; McKinney, 1998; Zembal-Saul, 2001, Wade & Yarbrough, 1996). Through the portfolio development prospective teachers reflect on their experiences, interrogate their practices, understand their effects on students, and shape their practices (Lyons, 1998).

In a study investigating the use of web-based portfolios and particularly the development of personal philosophies of teaching and learning science, Avraamidou and Zembal-Saul (2002) reported an apparent shift in prospective elementary teachers' understandings about science teaching and learning. Specifically, the participants of this study became more sensitive to children's thinking, placed more emphasis on teaching science as inquiry and became attentive to what teachers can do to support children's science learning. The researchers noted that portfolio development enabled prospective teachers to view how their philosophies changed over time, which supported a continuous engagement in metacognition, self-evaluation and self-reflection.

Implications of this study suggested the role of technology and specifically web-based portfolios in enhancing prospective elementary teachers' learning to teach. In specific, as Avraamidou and Zembal-Saul (2002) state, the web-based forum provided the possibility to keep multiple versions of their philosophies which gave prospective teachers the advantage to review prior versions of their philosophies, build on their initial ideas, revise their views about teaching and learning science and easily reorganize their philosophies. Moreover, the hypermedia possibilities of the web-based forum allowed prospective elementary teachers to make nonlinear, dynamic representations of their science teaching philosophies. Through the hyperlinking process, prospective teachers made connections between their coursework and field experiences and between their claims about science teaching and learning, evidence drawn from personal experiences to support their claims and justification statements, which resulted in an interconnected presentation of their learning experiences.

Situating prospective teachers' experiences into the classroom and making strong connections between coursework and field experience is another characteristic of effective teacher preparation programs (Putnam & Borko, 1997). Decisions about what effective teacher preparation programs should include, have been influenced by the theory of situated learning and emphasize supporting prospective teachers in becoming encultured into the teaching community (Putnam and Borko, 2000). However, as research suggests, this may be problematic when the experiences that prospective teachers gain during their preparation do not represent the teaching communities in which they are asked to teach (e.g., Putnam & Borko, 2000). Therefore, it is important that teacher educators engage prospective teachers in practices that bridge the gap between university coursework and field experiences. As Putnam and Borko (2000) state, “Important tasks facing teacher education researchers include identifying key characteristics of field-based experiences that can foster new ways of teaching, and determining whether and how these experiences can be created within existing school cultures” (p. 10).

Field experience is currently a fundamental component of the curriculum of teacher preparation programs (Darling-Hammond & Cobb, 1996). As cited in Maxie (2001), in the 1970s, research on field experience exposed a disconnection between teacher preparation and the practice of teaching. Studies reported negative outcomes of field experience, including changes in student teachers’ attitudes (Mahan & Lacefield, 1978) and the development of bureaucratic orientations after student teaching (Hoy & Rees, 1977). By the end of 1970s, major efforts to restructure field experiences in teacher education had been made. Such efforts, according to Maxie (2001) included the extension of time in the field, the modification of supervision (Griffin, 1983), and the establishment of partnerships and professional development schools, linking university teacher training programs and public schools (McIntyre, Byrd, & Foxx, 1996).

Recently, Professional Development Schools (PDSs) have been recognized for their potential to provide unique opportunities to integrate university coursework and field experiences (Darling-Hammond, 1994; Levine & Trachtman, as cited in Zembal-Saul, 2001), bridging the theory-practice divide. Connecting coursework with field experiences implies transferring and applying knowledge that prospective teachers gained in one context to a different one. According to Pearson (1989), the challenge in teacher education is to enable prospective teachers to take what they have learned about teaching and to use it on their own in the teaching situations in which they find themselves (p. 154). Transferring is affected by the context of original learning; people can learn in one context, yet fail to transfer that knowledge to other contexts (Bjork & Richardson-Klavher, as cited in Bransford, Brown, & Cocking, 2000). Bransford, Brown and Cocking (2000) argue that, “It is important to understand the kinds of learning experiences that lead to transfer, defined as the ability to extend what has been learned in one context to new contexts” (p. 51). Such a learning experience is supported within the context of the PDS, which supports the learning of prospective and beginning teachers by creating settings in which novices enter professional practice by working with expert practitioners (Darling-Hammond, 1994). This way teacher education is situated in classroom practice, which was one of the recommendations of the literature about the nature of effective teacher education programs.

Putnam and Borko’s (1997) last statement about the effectiveness of teacher preparation programs states that teacher educators should treat teachers as they expect teachers to treat students. Drawn upon current perspectives in science teaching and learning, teacher educators should provide prospective teachers with opportunities to learn science as inquiry. An approach to this challenge, as the literature illustrates, is the use of technology tools in science teaching and learning. According to Hannafin, Land,

and Oliver (1999), technology tools provide the means through which individuals engage and manipulate both resources and their own ideas, and they also provide vehicles for representing and manipulate complex, abstract concepts in tangible, concrete ways (p. 128). Jonassen (1996) refers to computer software applications as mindtools which have the potential to engage learners in a variety of critical, creative, and complex thinking, such as evaluating, analyzing, connecting, elaborating, synthesizing, imagining, designing, problem solving, and decision making. This kind of software application has been recently defined as software *scaffolds,* which enable learners to do more advanced activities and to engage in more advanced thinking and problem solving than they would do without such help (Bransford, Brown, & Cocking, 2000).

Software scaffolds may allow learners to organize and annotate a collection of evidence associated with a specific project, develop scientific arguments and share them with others (Bell, 1997); provide prompts for learners' reflection on their ideas (Linn, 2000); support integration of informal learning settings and formal school-based science education (Margulis et al., 2001); engage learners in inquiry-based investigations (Edelson, 2001); support learners in creating mental models (Jackson, Krajcik, & Soloway, 2000); and engage learners in critical reflection and the development of evidence-based explanations (; Land & Zembal-Saul, 2001; Loh, Radinsky, Reiser, Edelson, & Gomez, 1998).

Growing evidence from a number of studies supports the argument that technology tools have the potential to engage prospective teachers in scientific inquiry (Haefner, Zembal-Saul, & Avraamidou, 2002; Loh, Radinsky, Reiser, Edelson, & Gomez, 1998). A study by Haefner, Zembal-Saul, and Avraamidou (2002) examined the nature and development of prospective elementary teachers' scientific explanations within the context of an innovative life science course that used Progress Portfolio to structure the task of designing and implementing an inquiry-based investigation and the development of evidence-based explanations. This software scaffold was developed by researchers in Northwestern University as a tool to support reflective inquiry (Loh, et al., 1998). The results of this study illuminated that, while engaging in these investigations, Progress Portfolio assisted prospective teachers in developing more complex explanations that were grounded in evidence and that explored alternative hypotheses associated with experimental design.

Research by Edelson (2001) explored technology-supported inquiry learning as an opportunity for integrating content and process learning using a design framework called the Learning-for-Use model. In this study, the researcher provided a description of the use of WorldWatcher, a geographic visualization and data analysis environment, as a means of engaging students in open-ended Earth science investigations. The findings of this study illustrated the significant role of technology tools (i.e., WorldWatcher, Progress Portfolio) in supporting Learning-for-Use. In particular, according to the researcher, technology tools can (a) motivate students since they allow them to design or construct artifacts and express their own beliefs and understandings, (b) support construction of knowledge since they offer students the opportunity to identify relationships through exploration of data and provide them with access to information in a wide variety of media, and (c) support refining of knowledge and engaging in discussions, and communicate their results through presentations, which also supports reflection.

The significant role of technology in science education has been illustrated in the *National Science Education Standards* (NRC, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993). In specific, the Science and Technology Standards (NRC, 1996), emphasize the development of students' skills and abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology (p. 106).

Conclusions

Herein, I have illustrated that significant change in the elementary science curriculum in Cyprus is needed if we are interested in a reform drawn upon contemporary perspectives on how people learn and current trends in science education in the USA and UK. However, for these changes to occur, a reconstruction of the curriculum alone is not enough; rather targeting prospective teachers' knowledge and beliefs about teaching and learning, identifying critical aspects of their development and supporting their learning to teach based on current views about teacher development is also needed.

An approach of learning to teach science as inquiry that emphasizes learning science as argument and situates scientific knowledge within specific sociocultural contexts could provide prospective teachers with the opportunities to construct meaningful and personalized understandings about the teaching and learning of science.

This approach could be empowered with the use of technology both as a means of supporting learning science as inquiry and learning to teach science as inquiry as well.

However, the use of technology tools implies a challenge associated with the need for materials resources and teacher training in learning to use specific tools. Gray (1999) states that the availability of adequate human and material resources greatly affects the quality of the delivery of science curriculum. Zembylas (2002) notices about the Cypriots teachers who are not adequately prepared for their demanding task to implement changes in the curriculum: "The lack of systematic in-service training of teachers to implement new approaches creates skepticism, tension, unease and reluctance from the teachers' part to adopt to new ideas…" (p. 515). Therefore, providing substantial and ongoing support to Cypriot teachers in using technology tools to enhance their own learning and also support their students' learning through university coursework, seminars, and workshops is essential.

Applying these recommendations for reform in practice faces the challenge of considering ways in which these recommendations can be applied in the unique educational settings of Cyprus without neglecting the traditional, societal, and cultural beliefs that hold the community together. As Gray (1999) notices, "It is important for science educators to recognize that traditional beliefs provide some *glue* that holds the community together, enabling individuals to operate in, and make sense of their world" (p. 263).

In an attempt to respond to the calls for reform in science education in Cyprus, a systematic and critical examination of the research associated with current trends in science teaching and learning is needed, as well as research associated with curricular implementation in developing countries with special attention on implementing changes that are contextually relevant to the Cypriot societal needs and with respect to the country's history, values, and traditions.

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VITA

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In 1998, I graduated from the University of Cyprus with a Bachelors of Arts in Elementary Education. After graduation I taught third grade at a small rural elementary school in Cyprus for one year. In 2001, I earned a Masters of Science degree in Curriculum and Instruction with emphasis in Science Education from the Pennsylvania State University. At the end of my masters, I continued to work on my Phd. The framework that characterizes my research agenda is that of elementary teachers' learning and development. Specifically, I am interested in how prospective and beginning elementary teachers develop their pedagogical content knowledge for teaching science in light of current recommendations for reform emphasizing teaching science as inquiry.