STANDING ON THE PATH: AN EXPLORATORY STUDY OF PRESERVICE SCIENCE TEACHERS' SCHOOL SUBJECT MATTER KNOWLEDGE DEVELOPMENT DURING THEIR PRACTICUM SEMESTER

by

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(Under the Direction of Julie A. Luft)

ABSTRACT

One of the challenges that beginning teachers face is adapting the content knowledge that they know to the content knowledge they will teach. Beginning teachers often leave traditional science education programs unprepared to think about content in the context of teaching. These programs fail to integrate content into the learning of pedagogy. This exploratory case study investigates how an intervention incorporating content into a methods class influences how preservice teachers (PSTs) think about the content they will teach. For the purposes of this study the content knowledge for teaching is called school subject matter knowledge (SMK).

The findings of this study indicated that the intervention as implemented was unsuccessful and had no impact on how the PSTs thought about content when planning and implementing a lesson. Suggestions were made to better facilitate content integration into the methods class.

It was also found that the priorities that the PSTs held influenced how they thought about content as they were planning their teaching experiences. One participant prioritized teaching life skills, another prioritized lesson structure. Both of these participants were inhibited in adapting SMK to teaching because their priorities held their attention at the expense of content. The last participant prioritized student understanding and exhibited a precocious ability to think about content as school SMK.

The intervention in the methods class was unsuccessful in providing integration of content with pedagogy. As a result the priorities of the PSTs played a significant role in lesson planning with content playing a lesser role. It was suggested that if the methods class provided more explicit incorporation of content, content could become a priority in lesson planning. Research in this area could aid teacher education programs better prepare PSTs with the ability to adapt their content knowledge for teaching and therefore be better prepared as beginning teachers.

INDEX WORDS: Preservice science teachers, Subject matter knowledge, Science teacher education, Priorities, Content knowledge

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DEDICATION

“It is good to have an end to journey toward; but it is the journey that matters, in the end.**”**

— Ernest Hemingway

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CHAPTER 1

INTRODUCTION

Teaching is becoming a profession dominated by beginners (Ingersoll & Merrill, 2012). In 2008 the most common teacher was in his or her first year of teaching making beginners the largest group within the population (Ingersoll & Strong, 2011). The dominant factor driving this demand for new teachers is teacher retention and turnover (Ingersoll, 2001; Darling-Hammond & Berry, 2006). As a result the number of experienced and skilled teachers available to support beginning teachers is limited (Darling-Hammond & Berry, 2006; Davis, Petish, & Smithey, 2006; Ingersoll & Strong, 2011). Furthermore, these beginners are learning to teach while facing the challenges of the high expectations laid out for them in the current reform documents (Davis et al., 2006).

In addition to the expectation that new teachers do the same sorts of things as experienced teachers, they also face the challenge of the *Next Generation Science Standards* (NGSS) (Achieve, 2013). These standards call for a new way to teach science, one that focuses on core ideas, crosscutting ideas, and scientific practices. Those involved in the initial certification of science teachers are changing their certification programs in order to ensure that new teachers are successful in the field.

Teacher preparation programs are also facing reform challenges. The *Our Future, Our Teachers* report (U.S. Department of Education, 2011) includes a plan that calls for assessment of teacher preparation programs. For those educating science teachers, there

have been many responses. Some educators emphasize the cultivation of instruction practices (e.g., Windschilt, Thompson, Bratten, & Stroupe, 2012), while others create teacher education programs that are housed in Colleges of Arts and Sciences (e.g., UTeach). One change, that has been called for is to build the content knowledge of science teachers (National Research Council, 2013). This area has been recognized as important, but noted as underconceptualized and poorly understood among those in education.

Kennedy (1990) tells us that since the beginning of schools there have been doubts about the adequacy of teachers' subject matter knowledge (SMK). Evidence has been mounting that college level subject matter courses are not providing students with opportunities to gain deep understanding of their subject matter. Later studies have confirmed that the SMK acquired through the academic discipline is fundamentally different from the SMK of the school subject of the same name (Zeidler, 2002; Deng, 2007). Although SMK is probably the most self-evident kind of knowledge needed to teach (Ball, 2000a; Kind, 2009) there is a distinction to be made regarding the unique character of SMK needed by teachers (Darling-Hammond, 1998; Kennedy, 1998).

In the area of mathematics education Ball, Thames and Phelps (2008) agree with the idea that the SMK needed for teaching is unique and that academic subject matter courses may not be adequate preparation for teaching content. In their words, "Unfortunately, subject matter courses in teacher preparation programs tend to be academic in both the best and the worst sense of the word, scholarly and irrelevant, either way remote from classroom teaching" (p. 404). Ball (2000b) identifies three problems

facing teacher educators that, if they were solved, would bridge the gap between SMK learned in the academic discipline and the SMK needed to teach.

- First, we would need to reexamine what content knowledge matters for good teaching. Subject matter knowledge for teaching has too often been defined by the subject matter knowledge that students need to learn (p. 244).
- A second problem we would have to solve concerns the assumption that someone who knows content for himself or herself is able to use that knowledge in teaching (p. 245).
- A third problem we would have to solve is how to create opportunities for learning subject matter that would enable teachers not only to know, but to learn to use what they know in the varied context of practice (p. 246).

The goal of teacher preparation is to facilitate the development of preservice teachers (PSTs) from students of science to teachers of science. With that transition comes the necessity to develop their SMK from that of a student of science to that of a teacher of science. The pure SMK that is special to teaching is pedagogically useful but not dependent on knowledge of students or the context of the classroom (Ball et al., 2008). Despite the fact that SMK is central to teaching it rarely figures predominantly in teacher education (Ball, 1990). In the words of Ball and McDiamid (1989), "Yet to ignore the development of teachers' subject matter knowledge seems to belie its importance in teaching and learning to teach" (p. 1).

The transition of the understanding SMK as a student to that of a teacher is subtle and often attributed to its integration with pedagogy and labeled as PCK (Bertram &

Loughran, 2014; Shulman, 1986). However, the way experienced teachers *know* and *understand* their SMK is unique (Ball et al., 2008). I am labeling that *knowing* "school SMK." Teachers use their PCK to implement their unique understanding of school SMK. School SMK is the knowing of content in a way that recognizes the pedagogical potential. It is not dependent on the context of the classroom.

Ball and associates (2008) have documented examples of the special school SMK held by experienced mathematics teachers. An equivalent example of school SMK in science may clarify the difference between academic SMK, school SMK, and PCK. Because natural selection is a topic that is fundamental to evolution and deceptively difficult to teach (Shulman interview in Berry, Loughran, & vanDriel, 2008), it is a good example to illustrate the differences.

The following selection of examples provides a representation of the knowledge base of academic SMK. The students of science, among other factual information, can give an accurate definition of natural selection. They can use their knowledge to describe how natural selection contributes to the theory of evolution. They can give examples such as antibiotic resistance of bacteria and explain how natural selection relates to carrying capacity and other ecological concepts. They can also clarify the conceptual differences between Darwinian and Lamarkian theory.

This knowledge base is a reflection of the purposes of the Colleges of Arts and Sciences where the student of science acquires disciplinary knowledge. Those purposes include production of subject matter specialists as well as successful scientists thus focusing on how knowledge can be applied (Deng, 2007; Zeidler, 2002).

This academic knowledge base must be transformed into the content knowledge of instruction (school SMK) to initiate "the transition of expert student to novice teacher" (p. 8, Shulman, 1986). This transformation represents an important distinction between knowing SMK and knowing it in ways that enable use in practice (Ball & Bass, 2000). The knowing of school SMK includes the ability to recognize the pedagogical usefulness of a repertoire of examples, metaphors, and analogies. The examples represent ideas in multiple ways. They are pure content knowledge and free of any specific context. However, the knowledge is useful because it can be called on to flexibly address students' ideas and ascertain opportunities for learning (Ball & Bass, 2000). In order to develop school SMK, PSTs must be able to think about content in its "less polished form, where elemental components are accessible and visible" (p. 98, Ball & Bass, 2000).

Examples of school SMK illustrating natural selection can be as varied as the pepper moth color change during the industrial revolution, how brown bears evolved into polar bears, or as complex as how domestic dog breeds evolved (with the caveat that it is not natural selection but useful because it is familiar and can be attributed to Darwin's logic). It would include a metaphor such as how the size of Hershey bars have changed as a result of economic pressures or how the image of Mickey Mouse changed with the norms of social pressure and technology. School SMK would also include knowledge of Darwin's religious background and how he was conflicted in making his discoveries known.

These, along with a multitude of other examples, contribute to school SMK. School SMK provides a variety of resources to draw on that are pedagogically useful but not dependent on knowledge of students. This is pure science knowledge but not

necessarily the kind that would be useful in settings other than teaching. It is diverse, flexible and not situated in a specific context. When the teacher selects which example or metaphor to use in the classroom it is driven by the needs of the students and the context of the classroom. It is therefore PCK. As such the school SMK must precede PCK, a step that is ignored in traditional teacher education programs that depend on learning academic discipline knowledge and learning pedagogy separately.

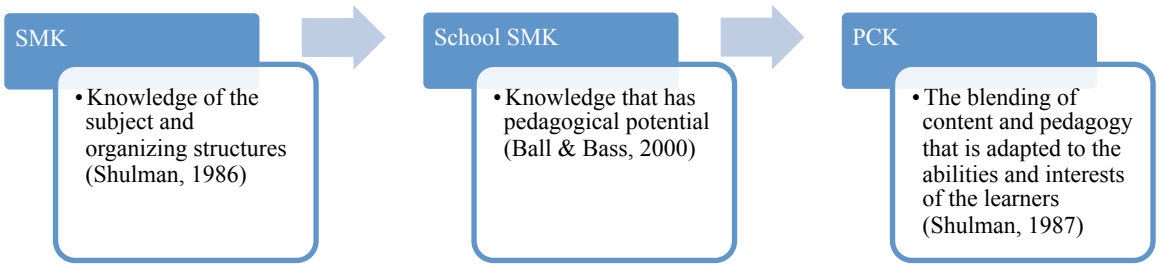

Figure 1.1. Transition of SMK to PCK

Ball and associates (2008) identify the need for this depth of understanding by describing it in the context of the work of teaching. They tell us that a teacher must not only know that an answer is wrong, but why it is wrong. They must be able to identify the reason a student made a mistake, understand the rationale that lead to the mistake, and have a depth of understanding and resources to correct it aside from the algorithmic response that leads to the correct answer but does not correct the mistake. In Ball's (2000a) words, "They need to understand the subject flexibly enough so that they can interpret and appraise students' ideas, helping them to extend and formalize intuitive understandings and challenging incorrect notions" (p. 458).

An example of this kind of thinking and depth of understanding in science, again using the natural selection example, would be reasoning about why penguins can't fly.

Students often can repeat all the "rules" and logic of natural selection but they still answer that penguins cannot fly because they don't need to or because they haven't flown and as a result their wings become unnecessary. This is a typical Lamarckian interpretation (Shulman interview in Berry et al., 2008). Implementation of school SMK would first require a determination of why the student answers this way. Is it because they don't understand the mechanism of natural selection or because they haven't recognized the advantages of having smaller wings? The teacher would use school SMK, which would include having a flexible understanding of natural selection and a repertoire of examples and/or metaphors, to put the student on the right path. In order to develop the school SMK with pedagogical potential a PST must think about the concept of natural selection in ways that are not necessary outside of teaching.

Obviously the knowledge of specific analogies and metaphors is fueled by experience in the classroom. A PST will not have the experience to create these diverse resources in their minds without being challenged by classroom experience. However, it can grow roots when the PST begins to *think* about content knowledge in ways that can make it accessible to students and *understanding* it in ways that are needed only in teaching. This is in contrast to the academic SMK that they know.

The understanding may begin with thinking about the "Big Ideas" behind concepts. Windschitl, Thompson, Bratten, and Stroupe (2012) define a Big Idea as the relationship between a natural phenomenon and its underlying causal explanation. A Big Idea unpacks a topic emphasizing what the teacher should target, what processes are involved, and what is worth studying because it is a fundamental process that the students should understand. In other words, thinking about the topic as school SMK rather than

just labeling the topic (e.g. natural selection) without delving into it in depth. They found that beginning teachers were not skilled in identifying such ideas. Because the teachers were not thinking in these terms, they could not focus instruction on the underlying concepts that helped students make sense of the curriculum. The beginning teachers could not make the shift from the propositional SMK they learned to the school SMK needed in the classroom. Without that shift, PCK cannot be developed.

It is acknowledged that the borders between SMK and PCK are fuzzy and that SMK is the foundation for PCK (Gess-Newsome, 1999). We know that the integration of SMK with pedagogy depends largely on the experience of teaching which PSTs lack (Abd-El-Khalick, 2006; Arzi & White, 2008; Bertram & Loughran, 2014; Gess-Newsome & Lederman, 1993; Hauslin, Good & Cummins,1992; Lederman, Gess-Newsome & Latz, 1994). However, there is little said about the pedagogical usefulness of the SMK learned through the academic discipline and how it can be nurtured to facilitate the growth of PCK. The traditional initial certification programs have done little to facilitate that nurturing.

The predominant structure of traditional certification programs separates the learning of SMK (delegated to the College of Arts and Sciences) and the learning of pedagogy (delegated to the College of Education) (Cochran & Jones, 1998; Darling-Hammond, 2000; Feiman-Nemser, 2001) and the tension between how much time should be spent learning each (Kennedy, 1998). Conventional teacher education programs are not designed to promote the complex learning required to integrate SMK and PK (Feiman-Nemser, 2001). Nilsson (2008) laments that:

> The structure of teacher education may not always offer opportunities for student-teachers to transfer the knowledge they acquire during course work into the type of knowledge they might need to teach in a (primary) school context. Different knowledge bases such as subject matter and pedagogy are often taught separately, thus inadvertently creating a situation in which student-teachers need to find ways, by themselves, of transforming their various 'knowledges' to useable and meaningful forms within the context of teaching (p. 1282).

Although there are initial certification programs that are non-traditional, the traditional structure remains predominant (Windschitl, 2005). Exploring how intentional, explicit instruction of school SMK in the methods class may influence how PSTs think about the content they know may be useful in the potential development of PCK. This would address Ball's (2000b) third problem (see above) creating an opportunity to develop school SMK in PSTs. It would also be instructional to know what other factors may be influential in the transition of the way PSTs think about content. With this in mind my research questions are:

1. How does explicit instruction of school SMK impact how preservice teachers think about the content knowledge that they will teach?
2. What are the specific factors that contribute or inhibit the development and/or acquisition of school SMK while learning to teach during the practicum semester?

Findings of this research have implications for future research and for preservice educators.

In the next chapter I will present a brief literature review outlining studies concerned with the character of SMK, the acquisition of SMK, the documentation of SMK, the development of SMK, as well as a view of the special school SMK that experienced teachers have. Chapter 3 describes the conceptual and theoretical frameworks that provide structure for the study as well as the data collection and analytical methods undertaken. The findings are presented in Chapter 4 as well as the narrative describing the three case studies including analytical comments and the themes found within each case. A cross-case comparison provides the analysis that proposes three themes. Chapter 5 discusses the findings, implications for teacher educators, and suggestions for future research.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Because teaching is becoming a profession dominated by beginners (Ingersoll, 2001; Ingersoll & Strong, 2011) the education of teachers and the challenges new teachers face has become the subject of considerable research (Davis, Petish, & Smithey, 2006). The complexity of learning to teach is influenced by multiple factors (Friedrichsen, VanDriel, Abell, 2011). Among those factors is the challenge of developing knowledge in the subject area that a teacher will be responsible for teaching (Davis et al., 2006). This knowledge, SMK, is an essential component of the knowledge needed for teaching (Abell, 2007; Baumert et al., 2010; Darling-Hammond, 1998; Gardner & Gess-Newsome, 2011; Mundy, Russell, & Martin, 2001; vanDriel, Berry, & Merrick 2014).

The discussion of teacher knowledge, including SMK, has been ongoing for the last 25 years (Banks, Leach, & Moon, 2005). The roots of that knowledge have been found in a variety of origins including formal schooling, both disciplinary and teacher education, as well as practical experiences occurring in the day-to-day teaching practices (Banks, et al., 2005; vanDriel et al., 2014) and the beliefs held by the teacher (Fletcher & Luft, 2011; Pajares, 1992). The development of SMK through formal schooling has been investigated primarily from a policy perspective using quantity, GPA and number of courses, as a proxy. The effect of the experience of teaching on the development of SMK

in new teachers has been investigated from the perspective of the quality and character of the SMK. Research on quantity and quality of SMK will be discussed in the first two sections of this chapter.

Shulman (1986, 1987) brought the subject of content knowledge for teachers to the forefront of discussion with his proposal that there was a knowledge base that combined content and pedagogy, PCK. Some research on PCK has sought to explore the role that SMK plays in PCK (Gess-Newsome, 1999) while others have used SMK as a starting point to making PCK explicit (Berry & Loughran, 2010; Loughran, Mulhall, & Berry, 2004; Mulhall, Berry & Loughran, 2010; vanDriel et al., 2014). These studies are discussed in the third section.

The last section of this chapter asks "Where are we now?"

Quantity of SMK

Teachers acquire their content knowledge through undergraduate and graduate studies. As such SMK has been equated to the number of content courses taken or GPA which then is used as a proxy for measurement of SMK for entrance into the profession (Abell, 2007; Ball, 2000a; Feiman-Nemser, 2001; vanDriel et al., 2014). Some states also require a subject area test for licensure, however most tests have been described as "too weak to guarantee that teachers have the content they need to teach students to high standards" (Mitchell & Barth, 1999, p. 3).

The measurement of SMK by quantity of disciplinary courses has been tied to policy and measured against the yardstick of student achievement. Studies of the quantity of SMK necessary for effective teaching have produced elusive and sometimes contradictory results. One of the largest studies was Monk's (1994) analysis of data

collected from 2,829 students. Monk analyzed the effect of subject matter preparation of secondary mathematics and science teachers on student achievement. His findings suggest that teacher content preparation in mathematics and science is positively related to how much a student learns at the secondary level. However, the magnitude of the relationship may suggest diminishing returns or a threshold effect. Because there was also found to be a positive relationship between course work in pedagogy and student achievement "it would appear that a good grasp of one's subject area is a necessary, but not sufficient condition for effective teaching" (p. 142).

Darling-Hammond (1999, 2000) offers a similar perspective. Her study of individual state policies regarding teacher qualifications relates subject matter preparation to student achievement by comparing multiple studies. She found that "it makes sense that knowledge of material to be taught is essential to good teaching, but also that returns to subject matter expertise would grow smaller beyond minimal essential level which exceeds the demands of the curriculum being taught" (p. 7).

A more recent study of South African teachers (Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, 2008) offered a different perspective. Unlike the previously mentioned studies that relate subject matter preparation to student achievement, their study measures the SMK of the teachers by their ability to represent their knowledge through questionnaires, interviews and observations as data sources. Because licensure of teachers in South Africa differentiates between how teachers are prepared in their academic discipline the study could compare teachers with differing discipline preparation. The teachers in the study had teaching degrees from various sources. The differing backgrounds of the teachers resulted in some teachers having limited

opportunities to formally develop their understanding of science although there was an assumption of adequate SMK for teaching. The findings suggest that the teachers were constrained in their teaching by their limitations of the understanding of the concept challenging the idea that minimal SMK preparation is sufficient.

Kind (2014) also challenged the sufficiency of academic preparation of potential science teachers. When probing PSTs on their knowledge of chemistry she found that "graduates may have mastery over their degree subjects, but these backgrounds do not form the everyday 'stuff' of a school science curriculum" (p. 1339). Therefore, "recruiting highly qualified, academic graduates is not an automatic precursor to ensure high-quality teachers, as weakness in their understanding of basic concepts … is apparent" (p. 1315). She found that when the PSTs teach concepts in which their content knowledge is weak, they rely on rote-learned phrases for their conceptual framework. This in turn encourages their students to learn the appropriate phrases rather than to ask challenging questions or develop an understanding of the concept. Failure to understand basic concepts means that students will struggle to comprehend inter-connecting, more advanced ideas.

Kennedy (1998) discusses this disparity between findings regarding the quantity of SMK needed for teaching. She begins her review of literature on SMK with a discussion of quantity. In her words, "Although knowledge of the subject matter is probably the most self-evident kind of knowledge needed to teach, the amount of subject matter really needed to help children learn is a contested issue" (p. 253). She continues with contradictory arguments that range from teachers need only to be able to read and follow directions because students learn from curriculum materials to teachers must have

knowledge far beyond the formal curriculum in order to answer student questions. In addressing this disparity she suggests that another issue may be more relevant. She adds, "Separate from questions about the volume of knowledge needed to teach a subject is a growing interest in the character of subject matter knowledge" (p.253). Grossman and Stodolsky (1994) agree as stated in their review of literature on SMK:

> Although heated debates occur regularly on the relative strengths and weaknesses of prospective teachers' subject-matter knowledge, they focus more on the number of courses taken in an academic major than on the character of those courses or how those courses affect prospective teachers' approaches to teaching (p 200).

Kind (2009) agrees, "Although many successful science teachers are academically well qualified in their specialist subjects, possession of a good Bachelor's degree in a science subject is not a *de facto* guarantee that someone will teach that subject effectively" (p. 169).

The primary source of SMK for the prospective teacher is the academic discipline (Shulman, 1987). The discipline courses taken in pursuit of their degree in education are usually the same academic courses taken by the subject matter major. However, the previously mentioned studies have found that SMK acquired through the discipline is necessary, but insufficient for teaching. One approach to resolving this issue is to draw a distinction between the academic discipline (an academic discipline is referred to as a branch of learning with a particular department of science at the university) and the high school subject that bears the same name (Deng, 2007).

Beginning with the epistemological roots of the academic discipline Zeidler (2002) addresses this question from the standpoint of the differing philosophies of the subject matter specialists of the Colleges Arts and Sciences whose purpose is to produce successful scientists and the teacher educators of the Colleges of Education whose purpose is to prepare teachers. He suggests that the differing philosophies and the differing educative roles explain why SMK delivered through the subject matter specialists is insufficient preparation for teachers. He acknowledges that the traditions of the two colleges are historically different and therefore unlikely to change. The conflicting philosophies of the scientist and of the educator constrain the formation of a bridge between the two. The scientist is applying the knowledge while the teacher is transforming the knowledge.

Deng (2007) adds to the discussion by analyzing the differences in what is learned through the academic discipline and what is taught in secondary school science. His comparison aids in "clarifying the distinction between a secondary-school science subject and its parent discipline" (p 504).

Research shows that the quantity of SMK accumulated from the academic discipline has an inconsistent relationship with effective teaching and that the academic discipline may form the foundation of SMK but is insufficient to inform the teaching of the school subject (Ball 2000a; Darling-Hammond, 1999; Kennedy, 1998; Monk, 1994). In addition it is fundamentally different from the school subject that it inspires (Deng, 2007; Zeidler, 2002).

A second line of research on the SMK preparation for future teachers relates to the character of the content knowledge. If there is no consensus on the question of the

quantity of content required, perhaps looking at the quality or character of the knowledge acquired through the disciplinary preparation will reap better results. This opens a discussion that targets the question of *what* is learned rather than *how much* is learned during the academic discipline classes.

Quality of SMK

> *"Of the four topics of education – the learner, the teacher, the milieu, and the subject matter – none has been so thoroughly neglected in the past half century as the last" (Schwab, 1967, p. 2).*

There is still considerable truth in Schwab's observation from 1967. However, current educational reform measures, policies, and new standards have cast a fresh light on the question of what teachers need to know about the subject they are teaching. Almost twenty years after Schwab's statement, the subject matter of teachers was moved to the forefront of interest that persists today.

It begins with Shulman's 1985 presidential address to the annual meeting of the American Educational Research Association (AERA) that critiques the body of research on teacher effectiveness dominated by "process-product studies" or "teacher behavior" research. These studies treat teaching more or less generically as if the subject matter was relatively unimportant. The assumption was that pedagogy was a content-free skill. He and his colleagues labeled the absence of focus on content as the "missing paradigm" of research (Shulman, 1986).

In his discussion of the missing paradigm Shulman (1986) considers how content knowledge grows in the minds of teachers. He initially distinguished three core categories of content knowledge: subject matter content knowledge, pedagogical content

knowledge and curricular content knowledge. His introduction of the idea of pedagogical knowledge specifically related to content (PCK) has been discussed, researched, and restructured multiple times in multiple ways in the last 25 years (Abell, 2008; Nilson, 2008; Settlage, 2013). Of apparently less interest to the research community (Arzi & White, 2007) has been the first component of the teachers' content knowledge, subject matter content knowledge. Shulman elaborates on the structure of this component, "To think properly about content knowledge requires going beyond knowledge of the facts or concepts of a domain. It requires understanding the structures of the subject matter in the manner defined by such scholars as Joseph Schwab (See his collected essays, 1978)" (p. 9). In Shulman's words (emphasis in the original):

> We expect that the subject matter content understanding of the teacher be at least equal to that of his or her lay colleague, the mere subject matter major. The teacher must not only understand *that* something is so; the teacher must further understand *why* it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened or denied. Moreover, we expect the teacher to understand why a given topic is particularly central to a discipline whereas another may be somewhat peripheral. This will be important in subsequent pedagogical judgments regarding relative curricular emphasis (p. 9).

With these words Shulman introduces the idea that the SMK of the teacher and the SMK of the academic discipline may be structured differently. In doing so he and his colleagues distinguished the specialized knowledge for teaching from that of subject

matter specialists (Abell, 2007). “The notion of ‘why’, is, for a teacher, as significant as ‘what’” (Kind, 2014, p. 1315).

As discussed in the previous section, teachers learn their SMK from the academic discipline. The SMK learned through the academic discipline differs from school SMK (Deng, 2007; Kind, 2009). Some studies have produced evidence that teaching experience may stimulate the development of teacher’s school SMK (vanDriel et al., 2014).

As an example, in their often-cited study, Hauslin, Good and Cummins (1992) compared the cognitive structures of biology majors, preservice biology teachers, novice biology teachers, experienced biology teachers, and scientists. They used a card sort that consisted of 37 biology terms. The participants were asked to sort the terms into categories based on their understanding of the relationship among the concepts. The participants were asked to think aloud during the sorting task. The verbal process was audiotaped. The subjects were sometimes prompted with direct questions or to request an explanation as they made decisions in their sorting task.

The card sort data was analyzed using statistical analysis. The results of the statistical analysis were supported with the audiotaped verbal responses. The findings showed that the scientists and the experienced teachers both had a deep understanding (versus surface understanding) of the concepts. It was also noted that despite the fact that they both had deep conceptual understanding, the cognitive structures of the scientists and the experienced teachers were quite different. The difference was attributed to how the concepts were used by both. However, comparing preservice, novice and experienced

teachers produced the most compelling result. It was found that the teachers restructured their thinking as they become more experienced.

The card sort method was criticized (Gess-Newsome & Lederman, 1993) because the concepts to be organized were provided by the investigators rather than originating with the participants. Gess-Newsome and Lederman (1993) also noted that there was a hierarchy and chronology associated with the resulting relationships in the Hauslein et al. (1992) study that begs the question of whether the results were really reflecting conceptual relationships. This was also questioned within the study itself. The study acknowledged that the teachers were verbally referencing state curriculum and textbooks as they arranged their concepts.

Gess-Newsome and Lederman (1993) developed a method to qualitatively evaluate the subject matter structures (SMS) of preservice biology teachers. They define SMS as "an individual's conceptions and/or organization of a specified area of knowledge (i.e., biology)" (p. 26). Using a multiple case study method in an open-ended investigation of PSTs' SMS they asked the teacher candidates to diagram the topics in the content area that would be their primary teaching area. By asking the participants to create the topics, rather than sort topics (card sort) that were chosen by the researcher, it was anticipated that a more accurate measure of the participants' SMS would result. The participants completed this task in phases. One phase was previous to their student teaching experience, the next was once midway through their student teaching, and the last was at the completion of their program. In addition to creating the diagram of topics, they completed a questionnaire that inquired if they had ever previously been asked to think about their content area in this way.

In the last phase of the study, the participants were again requested to complete the same topic diagram and questionnaire as they had in the first two phases. However, this time they were also interviewed to describe and clarify the meanings of their diagrams. The participants were then given their previous diagrams and questionnaires and asked how their responses were the same or different and how their responses were influenced by and reflected in their student teaching.

Findings of this study (Gess-Newsome & Lederman, 1993) indicated that the PSTs were unable to articulate their SMS. Their diagrams reflected the organization of the university biology courses they had previously taken. The findings suggest that as biology students, these PSTs "were not being provided with a readily accessible explicit or implicit structure of biology as part of their content preparation" (p. 35).

In a later project, Lederman, Gess-Newsome and Latz (1994) continued the study of SMS with a larger group of PSTs. The teachers were divided into two groups. The cohort group was followed throughout the three terms of their professional science education courses and their SMS was analyzed as they progressed through the program using the same methodology as the Gess-Newsome and Lederman (1993) study. The noncohort group was analyzed only once after their student teaching experience. The purpose of analyzing and comparing the results of the two groups was to corroborate findings. The data collection itself was similar to the previous study. Findings of the cohort group again suggested that their SMS was linear. Members of the noncohort group, without exception, provided representations of subject matter that were integrated and simplified to address the perceived needs of students. This suggests, "the act of

teaching and/or thinking about how one will teach subject matter appears to have had a significant influence on the way subject matter was conceptualized" (p. 141).

Abd-El-Khalick (2006) used the Gess-Newsome and Lederman (1993) methodology as a frame to compare preservice and experienced biology teachers' global and specific SMS. Photosynthesis was used as the specific SMS because of its centrality to the discipline. His purpose was to elucidate the relationship between these structures and the experience of the teachers. Using semi-structured individual interviews and open-ended questionnaires Abd-El-Khalick (2006) collected data from two preservice and two experienced biology teachers. The questionaires were similar to the Gess-Newsome and Lederman (1993) questionnaire asking: 1) What topics make up your primary teaching area? If you were to use these topics to diagram your content area, what would it look like? and 2) Have you ever thought about your content area in the way that you were asked above? The same questions were then asked about the topic of photosynthesis.

His findings were similar to the earlier findings of Gess-Newsome and Lederman (1993) and Lederman et al. (1994). However, the global SMS formed a continuum from preservice to experienced teachers with no distinct demarcation between the two groups while the specific SMS for photosynthesis clearly separated the participants into two groups based on their experience. The implications of the results may indicate that experience alone is not responsible for development of sophisticated SMS.

Arzi and White (2008) asked the question "How does teachers' knowledge of subject matter change over their professional careers?" (p. 221). They followed participants over a span of 17 years, collecting data in two waves. The first data collection was begun during the teachers' preservice education courses and continued

through their first two years of teaching. The data collection second wave was 17 years later. The data consisted of intensive interviews that included a word association method to construct a longitudinal concept profile of selected topics.

The word association method began with the interviewer presenting a card (by the interviewer) that had a concept label printed on it. The oral question "Can you spell out what comes to mind when you think of [label]?" The interviewer moved on only when there was evidence that the participant was no longer able to add any further information. The interviewer wrote down the responses that were used immediately for a retrospective self-evaluation of where the teacher had gained in knowledge understanding or for self-rating of understanding. The responses were analyzed by the ability of the teacher to explain the concept. The researchers justified their use of the teachers' explanations as an indicator of SMK by clarifying that, although explaining the concept can be categorized as PCK, it is nonetheless an indicator of SMK (Arzi & White, 2008).

The concept profile produced from the word association data along with other interview data resulted in the following: 1) Change in content knowledge is multifaceted, including forgetting of unused knowledge along with improved understanding, structure organization and integration; 2) Development is facilitated by a critical mass of content knowledge and interest, and therefore more likely to occur when teachers teach within their chosen areas of study; 3) The required school curriculum is the single most powerful factor affecting teacher content knowledge, serving as both knowledge organizer and source (Arzi & White, 2008).

These studies exemplify how teachers' SMK changes over time by directly documenting the teachers' SMK and comparing the cognitive structures of varied

educative backgrounds and experience (Hauslin et al.,1992), the SMS of PSTs (Abd-El-Khalick, 2006; Gess-Newsome & Lederman, 1993; Lederman et al., 1994), and the change in SMK longitudinally from preservice to experienced teachers (Arzi & White, 2008). They document "moving about thinking of science as a subject which they learned at a high level to realizing how the subject is interpreted for school contexts" (Kind, 2009, p. 186) and suggest that the changes involve adaptation of SMK for school use.

Relationship Between SMK and PCK

Although there remains much discussion around the ongoing debate about the relationship between SMK and PCK (Gess-Newsome, 1999) in their review of research on science teacher knowledge vanDriel et al. (2014) conclude that recent studies provide support that SMK and PCK are separate types of teacher knowledge. Nevertheless there is a significant group of studies centered on the identification of the 'what' of PCK that also involves SMK. Although the purpose of these studies is the documentation of PCK, they inform how teachers think about SMK in the context of teaching.

Significant within these studies is the use of Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaPers) as instruments for identifying and documenting PCK. Loughran, Mulhall and Berry (2004) queried how to make the PCK of experienced teachers explicit. The result of their studies was the creation of these instruments.

The CoRes focus on subject matter content as it relates to the teachers' practice. The PaPers focus on the teacher's pedagogical reflections centered on specific sections of the CoRe. The CoRe itself is a framework that is structured around elements of Shulman's knowledge bases, particularly the teachers' understandings of specific aspects

that represent and shape content for teaching (Berry & Loughran, 2010; vanDriel et al., 2014). CoRes offer a detailed description tabulating the "Big Ideas" or concepts relating to a topic being taught. To describe a CoRe succinctly it is "an overview of the particular content taught when teaching a topic" (Mulhall, Berry, & Loughran, 2003, p. 6). In their studies the researchers documented how these teachers think about their work (Kind, 2009). As such the teachers articulated how they were thinking about the topic as school SMK.

The development of the CoRe was influenced by multiple factors but at its heart was the knowledge that "PCK develops through coming to understand concepts/content differently as a result of attempting to teach those concepts/content and recognizing the inherent incongruities in the knowledge and developing an understanding of it in practice" (Loughran, Gunstone, Berry, Milroy, & Mulhall, 2000, p. 7). The CoRes represented a line of questioning that was hoping "to help recreate in the teacher's mind the way they had come to know the content" (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001, p. 292).

The initial focus of Loughran and colleagues' research was to document the PCK of expert science teachers in a way that might be useful and applicable in their practice and usable to others. Essentially making their tacit knowledge explicit. Unforeseen at the time was that the teachers saw the value in their experience of working with the instruments as a learning tool rather than the making of the end product (Berry & Loughran, 2010). Focusing on the implication that CoRes could be used as a learning tool, Bertram and Loughran (2014) explored using it to introduce or "plant the seed" of PCK in PSTs. What they found in relation to the content aspect was "the difficulty

student teachers face with the conceptualization of Big Ideas" (p. 122). The task of completing the CoRe illustrated that "coming to see a Big Idea as conceptual rather than propositional is an indication of a beginning point in 'seeing into' the topic differently…" (p. 122). For Bertram and Loughran (2012) the construction of CoRes

> 'forced' them to think differently about their teaching and learning in ways they felt enhanced their approach to teaching. In doing so, they became more focused on not only *what* they were teaching but also the *how* and *why*. As a consequence, they examined their understanding of the content in ways that went beyond acquisition of propositional knowledge, explored how their students learnt and, most importantly, came to see their own personal and professional development as science teachers (p. 127, emphasis in original).

Loughran and associates delved into the specific nature of thinking about and understanding SMK that can be found in the work of teaching through the eyes of teachers. In the mathematical community, Ball and associates investigated the knowledge and the skills distinctive to teaching mathematics by looking at the work of teaching rather than the teachers themselves. Like Loughran's group, they focused on the SMK specific to teaching, but instead of using the construct of PCK they separated the "special" SMK from PCK.

Ball and Bass (2000) begin by discussing the inadequacy of the understanding of what and how mathematical knowledge is used in practice. Although teachers' academic background prepares them with knowledge of mathematics there is an important distinction between knowing how to do math and knowing it in ways that enable use in

practice (Ball, 2000b; Ball, Lubienski, & Mewborn, 2001). A bridge between content and pedagogy appeared to be built with Shulman's introduction of PCK as a domain of content knowledge unique to teaching. However, after two decades of work PCK, is still inadequately understood (Ball, Thames, & Phelps, 2008) with no universally accepted definition or conceptualization (Nilsson, 2008).

The mathematical community has taken a different approach to the investigation of PCK and content knowledge needed to teach by focusing on how it is used in practice. Ball and Bass (2000) consider PCK as "a special form of knowledge that bundles mathematical knowledge with knowledge of learners, learning, and pedagogy" (p. 88). They also identify a flexible type of knowledge lying outside of pedagogy that allows a teacher to puzzle about a student's idea, analyze textbook presentations, and be able to judge appropriateness of representations. This knowledge "[they] argue, requires a kind of mathematical understanding that is pedagogically useful and ready, not bundled in advance with other considerations of students or learning or pedagogy" (p. 88).

> It is not just what mathematics teachers know, but how they know it and what they are able to mobilize mathematically in the course of teaching. Though less easily quantified than other indices such as courses taken, it is this pedagogically functional mathematical knowledge that seems to be central to effective teaching (p. 95).

In order to explore this flexible knowledge lying outside of pedagogy, Ball et al. (2008) examined numerous studies that focused on both the teaching of mathematics and the mathematics used in teaching. They found the following:

> These studies have led us to hypothesize some refinements to the popular concepts of pedagogical content knowledge and to the broader concept of content knowledge for teaching….To our surprise we have begun to uncover and articulate a less recognized domain of content knowledge for teaching that is not contained in pedagogical content knowledge, but yet – we hypothesize – is essential to effective teaching. We refer to this as *specialized content knowledge* (p. 390, emphasis in original).

To test their hypothesis, Ball and associates addressed the question of what subject matter is important from a perspective based on but differing from Shulman (1986). They focused on *how* teachers need to know the content by analyzing practice. They found that the mathematical demands of teaching are substantial. In their words:

> Perhaps the most interesting to us has been evidence that teaching may require a specialized form of pure subject matter knowledge – "pure" because it is not mixed with knowledge of students or pedagogy and is thus distinct from the pedagogical content knowledge identified by Shulman and his colleagues and "specialized" because it is not needed in settings other than mathematics teaching. This uniqueness is what makes this content knowledge special. (p. 396).

Ball and associates continue their discussion by identifying the structure of the mathematical knowledge for needed for teaching (MKT). Within MKT they segregate SMK from PCK. In their definition, SMK is considered a knowledge that is separate from knowledge of students or learning of pedagogy (Ball & Bass, 2000). The separation is an elaboration on, not a replacement of the construct of PCK. They see their work as

"developing in more detail the fundamentals of *subject matter knowledge for teaching* by establishing a practice-based conceptualization of it (Ball et al., p. 402, emphasis in original).

In their conceptualization SMK is divided into three domains. The first domain is common content knowledge (CCK). This refers to "knowledge of a kind used in a wide variety of settings – in other words, not unique to teaching" (Ball et al., 2008, p. 399). The second domain is specialized content knowledge (SCK). SCK "is the mathematical knowledge and skill unique to teaching…. [It] is mathematical knowledge not typically needed for purposes other than teaching" (p. 400). This "special" knowledge is needed for the work of teaching because "this work involves an uncanny kind of unpacking of mathematics that is not needed – or even desirable – in settings other than teaching. Many of the everyday tasks of teaching are distinctive to this special work." (p. 400). The last domain, horizon content knowledge, "is an awareness of how mathematical topics are related over the span of mathematics included in the curriculum (p. 403).

Other researchers have used the concept MKT to frame their studies. As an example, Silverman and Thompson (2008) propose a framework for studying the development of MKT. In their discussion they "see a person's MKT as being grounded in a personally powerful understanding of particular mathematical concepts and as being created through the transformation of those concepts from an understanding having pedagogical *potential* to an understanding that does have pedagogical power" (p. 502, emphasis in original).

Hill et al., (2008) explore the relationship between a teacher's MKT and the quality of their instruction. They found that there is a "powerful relationship between

what a teacher knows, *how* she knows it and what she can do in the context of instruction" (p.496, emphasis in original). Findings in studies such as these reinforce the value of exploring the special way of *how* teachers know SMK for teaching.

Although an adaptation of the MKT model for science education is yet to be published (vanDriel et al., 2014) there have been several studies describing its use in its nascent form. Building on the mathematics model of the SMK domain of MKT, the science education community has developed categories of science knowledge for teaching (SKT). Luft, Hill, Weeks, Raven and Nixon (2013) use components similar to Ball et al. (2008). Core content knowledge (CCK) is defined as the knowledge a well-educated citizen (not a teacher) should have about science content, specialized content knowledge (SCK) is the knowledge that a teacher needs to size up a student error and progressional content knowledge (PrCK) replaces the MKT horizon knowledge. PrCK represents an understanding of the connections between science concepts. A fourth category, not investigated by Ball and associates, was added. Representational Content Knowledge (RCK) was defined as knowledge about instructional approaches to represent the concept. However, during the analysis of the data it was decided that RCK was too closely aligned to PCK and so it may not be a relevant measure of SMK.

Other studies have shown promise in the use of SKT to measure and analyze SMK. Nixon et al. (2014) compared the CCK, SCK, and PrCK of preservice, beginning and experienced teachers teaching in and out of field using a multi-method study in an effort to establish a relationship between SKT and practice. DuBois, Jurkiewicz, Brennan, Campbell, and Luft (2014) used the same categories to investigate the influence of SKT on classroom instruction of early career biology teachers.

Where Are We Now?

SMK is acknowledged to be a central component of teacher knowledge (Schwab, 1967; Shulman, 1987) and a challenge to new teachers (Davis et al., 2006). The acquisition of SMK has been allocated to the academic discipline (Abell, 2007; vanDriel et al., 2014) even though the SMK acquired through the academic discipline is fundamentally different from SMK for teaching (Deng, 2007; Zeidler, 2002).

There is evidence that a teacher's SMK develops into "school SMK" over time and through the act of teaching (Abd-El-Khalick, 2006; Arzi & White, 2008; Gess-Newsome & Lederman, 1993; Hauslin et al., 1992; Lederman et al., 1994), and that school SMK is unique to teachers (Ball & Bass, 2000; Ball et al., 2008; Hill et al., 2008; Silverman & Thompson, 2008).

Investigations into this special school SMK have been mainly descriptive. Many of these studies include documentation of how participants thought about the content they were teaching. Beginning with the Hauslin et al. (1992) study using the card sort method and supplementing it with "think aloud" evidence to support their data. Studies of the SMS of teachers of various experience levels asked the question "have you ever been asked to think about content in this way?" (Abd-El-Khalick, 2006; Gess-Newsome & Lederman, 1993; Lederman et al., 1994). Arzi and White (2008) asked their participants what they thought about specific concepts. Descriptions of the development of CoRes emphasized how the teachers thought about content emphasizing its pedagogical potential. Ball and associates used interview data as well as observation to describe how teachers thought about their teaching of various concepts. As Kind (2009) acknowledged,

the change from discipline SMK to school SMK begins with *thinking* about content in the context of school SMK.

New teachers must evolve from students of science to teachers of science. Studies of the special science knowledge that teachers hold include evidence that teachers think about content uniquely. It appears that thinking about the content as a teacher may be the beginning of the transition from student to teacher. There is a need for teacher education to take notice of the transformation of academic SMK to school SMK, what influences the transformation, and how it can be facilitated.

CHAPTER 3

METHODS

Introduction

This chapter begins with a description of the conceptual and theoretical frameworks that form the foundation of this research. It then continues to describe the context of the study along with the selection and description of the participants. It concludes with research methodology, data analysis, and review of methods employed to ensure trustworthiness.

Conceptual Framework

According to Maxwell (2005) a conceptual framework is something that is *constructed* and not found. "It incorporates pieces that are borrowed from elsewhere, but the structure, the overall coherence, is something that *you* build, not something that exists ready-made" (p. 35, emphasis in original). It is the "researchers map of the territory being investigated" (Miles, Huberman, & Saldana, 2014, p. 20).

This research is framed around the assumption that science teachers hold a unique understanding of science that differs from the content knowledge held by scientists and students of science. This knowledge is tacit by nature but its existence is implied by past and current research (Ball, Thames, & Phelps, 2008; Loughran, Mulhall, & Berry, 2004).

The current discussion of the content knowledge that teachers hold began with Shulman (1986). Shulman categorized three core areas of content knowledge: subject matter content knowledge (SMK), pedagogical content knowledge (PCK), and curricular

content knowledge. The novel idea of PCK immediately caught the interest of researchers initiating much attention that continues today (Nilson, 2008; Settlage, 2013). At the time Shulman's category of SMK garnered less attention (Arzi & White, 2007).

Shulman's introduction of PCK began a deluge of research focused on defining and capturing it (Abell, 2007; Gess-Newsome, 1999). SMK became of interest as a component of PCK. Despite much investigation, the relationship between the two is still a matter of discussion. The borders between SMK and PCK remain blurred (Gess-Newsome, 1999; Kind, 2009). However, there is agreement that SMK is crucial to the development of PCK (e.g. Abell, 2007; Baumert et al., 2010; Gardner & Gess-Newsome, 2011; Rollnick, Bennett, Rhemtula, Darcy & Ndlovu, 2008; Shulman, 1986) initiating shifts by a few researchers to a focus on the unique characteristics of SMK for teaching.

The mathematical community leads this shift. Ball et al. (2008) have delved into the relationship between SMK and PCK and developed a model of mathematical knowledge for teachers (MKT). Their model defines SMK as separate from PCK. Their initial model found that within SMK there is common content knowledge (CCK), "knowledge of a kind used in a wide variety of settings – in other words, not unique to teaching" (p. 399), and a specialized content knowledge (SCK), "…an uncanny kind of unpacking of mathematics that is not needed – or even desirable – in settings other than teaching" (p. 400). This knowledge is a "pedagogically useful mathematic understanding" (Ball & Bass, 2000, p. 89), a way of knowing mathematical knowledge that is unique to teachers.

Luft and colleagues (2013) have used the MKT model to isolate and begin to define the content knowledge that science teachers hold that is relevant only to teaching.

Although research in this direction remains in the nascent stage, the implication is that there is a special science content knowledge that is unique to science teachers that resembles the MKT model. This science knowledge for teaching has been labeled SKT. It can be described as the content knowledge that has the potential for the development of PCK and is unique to teachers. It is separate from PCK.

Rollnick et al. (2008) have also investigated the content knowledge that teachers hold. They did not separate that content knowledge from PCK as Ball et al. (2008) and Luft and colleagues (2013) did but instead explored the dependence of a teachers' understanding of content knowledge on the development of PCK. They focused on how the teachers' understanding of science influenced their ability to allow a PCK-rich approach to teaching. By using CoRes and PaP-ers (Loughran, Berry, & Mulhall, 2004, 2006) as methodological tools to assist in analysis of data they were able to "focus on teachers' understandings of the aspects that represent and shape the content and contribute to the content-specific nature of PCK" (Rollnick, et al., 2008, p. 1369) thus tacitly looking at the PCK potential of the teachers' SMK.

Research suggests that science content knowledge is essential for teachers and that teachers hold knowledge of their subject that is unique to teaching. This knowledge is a way of understanding and thinking about content that is situated in the act of teaching, not in the academic discipline (Shulman, 1986). It can be described as *how* a teacher knows the content rather than *what* a teacher knows (Ball et al., 2008). Although there is a relationship between this unique knowledge and PCK the borders between the two remain blurred.

My research is not designed to identify nor define the specific nature of this unique knowledge or to investigate its relationship to PCK. Instead it seeks to explore if this knowledge, this way of thinking about content, is or is not being developed in PSTs during their final semester before student teaching. Development will be evidenced by a shift from thinking about content as factual and propositional to tacitly thinking about the pedagogical potential of content.

Other researchers have explored how the content knowledge of teachers changes with experience (i.e., Abd-El-Khalick, 2006; Arzi & White, 2008; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome. & Latz, 1994). I am investigating a more tacit characteristic, *how* these PSTs think about the content they are teaching as they progress through their practicum semester. The study is framed conceptually around the existence of this unique knowledge that I am calling 'school SMK'. This study seeks to explore the development of this way of thinking in PSTs by exploring how PSTs consider the content that they know.

As the PSTs enter their final semester before student teaching they are transitioning from students of science to teachers of science. How they think about science content should also transition from thinking about science as a student of science to thinking about science as a teacher of science: from SMK that is factual and propositional to SMK that will enhance their student's understanding.

Theoretical Framework

The theoretical perspective "is a way of looking at the world and making sense of it" (Crotty, 1998, p.8). The framework that the theoretical perspective provides functions

as a scaffold that supports the study. The framework guiding this study is interpretivism, which is supported by the constructivist epistemology.

Epistemology is "how we know what we know" (Crotty, 1998, p. 3). The constructivist epistemology follows Vygotsky's theory that knowing develops in a social context. It recognizes that knowledge is a social construction. Constructivism considers knowledge to be relative to the context in which it is being viewed and is contingent on convention, human perception and social experience. It recognizes knowledge as being created by the individual within the context of their background and social forces (Kuhn, 1970). This study focuses on how the experiences of three preservice teachers mold their understanding of science content as they progress through their practicum semester. The context of their personal backgrounds, the context of their teaching experiences, and the dynamics of conforming to external forces all contribute to the way the participants consider or think about their own content knowledge.

Interpretivism

The interpretivist paradigm frames the theoretical perspective of my study and will provide the methodological foundation to view and interpret the experiences of these students as they progress through their methods class and practice teaching. From the perspective of the interpretivist researcher, the goal is to understand the complex world of lived experience through the point of view of those who live it by interpreting their perspectives. There is an understanding that there is openness to whatever emerges and a lack of predetermined constraints on the outcomes. The purpose is sense making (Erickson, 1986).

> Interpretive, participant observational fieldwork research, in addition to a central concern with mind and with subjective meaning, is concerned with the relation between meaning-perspectives of actors and the ecological circumstances of action in which they find themselves (Erickson, 1986, p. 127).

Interpretivism is the appropriate choice for my study because the study concerns itself with the meaning-perspectives of the students as they learn how to use the content knowledge that they know. However, the meaning-perspectives do not stand alone. They are located within the contexts that surround their experiences.

Interpretivism has methodological implications that the world is very complex, events are the result of multiple factors coming together and interacting in complex and often unanticipated ways. Interpretivism portrays the world in "which reality is socially constructed, complex, and ever-changing (Glesne, 2011, p. 8). As such my research includes interacting with the participants and talking to them about their perspectives through interviews. It includes their interaction within the methods class and their written viewpoints as recorded in their assignments. It embraces an open-minded, exploratory mind-set that is open to a variety of perspectives and any issues that might arise (Glesne, 2011). It describes phenomena from the perspective of the participants but involves the meaning making of the researcher.

Setting and Participant Descriptions

Setting.

The study took place during the first semester of the PSTs final year of a teacher education program at Southern State University (SSU). SSU is a large, public university

with an undergraduate student population of approximately 26,500. The university graduates between 15 and 20 secondary science teachers a year. The majority are undergraduate students majoring in science education with a few acquiring a Masters of Teaching (MAT) that requires completion of an undergraduate degree in a science discipline. The undergraduate students have completed or are in the process of completing their discipline-specific academic coursework. The science discipline coursework includes 9 - 12 hours in core classes followed by at least 39 hours in upper division classwork with at least 21 of the hours in their area of concentration. Prior to student teaching all students are required to complete the coursework referred to as Block I. It includes a 3-hour curriculum class, a 3-hour methods class and a 3-hour practicum (teaching experience). This study was centered on the methods class where the intervention, the explicit instruction of school SMK, occurred. Artifacts from both the methods and curriculum classes were collected.

The syllabus of the methods class described a format of lecture, small and large group discussion, reflection, and activities and stipulated a close association to the practicum. The objectives of the class are to be met by four broad areas addressed throughout the semester: designing a learning environment, student/teacher interactions, encouraging student interactions, and methods of effective science teaching. Among the resources discussed and emphasized throughout the semester were the *Next Generation Science Standards* (Achieve, 2012) and the *National Science Education Standards* (National Academy Press, 1996).

The syllabus of the practicum described the purpose as providing an opportunity to make structured classroom observations and to plan and implement science lessons.

Written assignments included reflections on their teaching experience. The teaching experience consisted of teaching with a partner twice during the semester. The first was a one-day lesson and the second was a three-day lesson. The students were informed that using a lesson plan obtained from their coordinating teacher was acceptable. Taking an existing lesson plan and adapting it for themselves would be desirable and removed the pressure of creating a lesson on their own.

Content instruction during methods class.

The explicit instruction of school SMK (also referred to as intentional instruction) was incorporated into the existing curriculum of the methods class. The intentional instruction, which occurred four times through the semester, consisted of questions intended to provoke discussion and encourage the PSTs to think about SMK in the context of teaching providing a tension between what they know and how they will use that knowledge.

The school SMK model chosen was SKT. This model, in the nascent form, has been used in studies that seek to identify SKT in new teachers (DuBois, Jurkewicz, Brennan, Campbell, & Luft, 2014; Luft, Hill, Weeks, Raven, & Nixon, 2013; Nixon, DuBois, Jurkiewoc, Toerien, Campbell, & Luft, 2014). It was modified to provide provocative questions to begin discussion in the methods class and in the interviews that followed.

The intervention took place in the methods course and consisted of adding instruction and discussion of content knowledge at various points during the course with the use of probes. The instructor explicitly discussed content instruction with attention to CCK, SCK, and PrCK, the components of SKT (Nixon et al., 2014). CCK is common

content knowledge and includes the knowledge a well-educated citizen may have about the topic. The instructor asked, "What was the content goal of this lesson?" followed by asking, "What is the core idea for this lesson?" SCK is the unique knowledge needed only by teachers including what may make this topic difficult. The instructor asked, "What makes this content difficult to understand?". PrCK is the knowledge of where the topic fits into the "Big Picture" (what precedes and what follows this topic) relating the topic/concept to the big ideas and crosscutting concepts. The instructor asked, "What do the students need to know before this lesson? What can I follow this lesson with?". This model of instruction strived to make the utilization of SMK explicit, articulating what the PST should *do* with the content rather than just *knowing* the content. This was done four times during the semester with the purpose of highlighting the content in the lesson. The probes were asked after a pedagogical strategy had been introduced.

Content was introduced indirectly while demonstrating specific methods as well as directly with the use of probes. An example was a lesson on the cell membrane. Students were given the information available when scientists first began to explore the structure of a cell membrane. The students designed a model that fit the information they were given. Following the historic path, more information became available and students were asked to modify their models to accommodate it. The students modified their models in steps following the historical availability of information. While completing this task, content information was informally being presented along with the teaching strategy. When the activity was complete the instructor explicitly asked the students the SKT probes.

Participants.

The participants were drawn from the science methods class during the Fall 2014 semester at SSU. The class consisted of 15 students, 11 undergraduate and 4 graduate students. The methods class was purposefully selected (Creswell, 2003) because it was specifically designed to teach future middle and high school teachers the "methods" for teaching science and was the last instructional class for the students before they embarked on their student teaching in the following semester. Participation was voluntary and represented a heterogeneous sample. The heterogeneity ensured that the common patterns that emerged were of interest and value and contributed the development of themes (Patton, 2002).

During the first meeting of the methods class I addressed the class and asked for voluntary participation. I described the purpose of the study as seeking to document how the participants were thinking about content as they progressed through the semester. An example was given that represented how thinking about content as a student of science differs from thinking about content as a teacher of science. It was explained that participation would involve three interview sessions and access to their written assignments as well as being observed during the methods classes. Participation would have no impact on their course grade. The participants would have access to their analyzed data at the end of the study.

Two participants volunteered after the first class, Kim and Max. A second invitation was extended after the second class meeting and James volunteered at that time. Kim was an MAT student with an undergraduate degree in molecular biology. Both Max and James were undergraduate science education students with a concentration in

biology. All three signed consent forms and their first interviews were scheduled. Further descriptions of the participants and their backgrounds will be discussed in Chapter 4. Although invitations for participation were extended in the next few class meetings no other students volunteered.

Research Design

Case study.

Stake (1998) states that a "case study is not a methodological choice but a choice of object to be studied" (p. 86). It is "a detailed examination of a single example" the value lying in the case itself (Flyvbjerg, 2001). The case is the unit of analysis, a bounded and integrated system (Merriam, 2002). As such, the methodological choice for this research could be none other than case study. It is the study of three PSTs as they completed their final semester prior to student teaching, the practicum semester.

The study of these three PSTs was bounded temporally by the semester and limited to the activities of the participants within the methods class and their teaching experiences thus fitting the description of an instrumental case study (Stake, 1994, 1995, 1998). Extending it to a collective case increased understanding. According to Stake (1998):

> Individual cases in the collection may or may not be known in advance to manifest common characteristics. They may be similar or dissimilar, redundancy and variety having a voice. They are chosen because it is believed that understanding them will lead to better understanding, perhaps better theorizing, about a larger collection of cases (p.89).

The analysis of the cases was also limited methodologically by the research questions focusing on the participants' acquisition of school SMK during this semester. Studying this specific issue within these cases provided insight by focusing on understanding it (Creswell, Hanson, Clark, & Morales, 2007).

Data Collection

Interviews.

Each participant was interviewed three times during the semester. The interviews were all digitally recorded and transcribed by the researcher. The interviews were semi-structured and in-depth providing a framework for the participants to express their own understandings in their own terms (Patton, 2002) while maintaining the flexibility to probe for deeper understanding (Legard, Keegan & Ward, 2003). The semi-structure also provided a guide to center the questioning on the research focus while allowing the addition, replacement or expansion of the established questions as interaction with the participants progressed (Glesne, 2011). This flexibility allowed me to be an active player in the development of data and in the negotiating of knowledge creation as viewed through the constructivist frame (Legard et al., 2003).

The interview questions were formulated to gain understanding. The initial question was designed to open up a subject and the spontaneous probes that followed focused on widening the dimensions of the topic while clarifying and amplifying the responses (Legard et al., 2003). The interview protocols can be found in Appendix A.

The timeline of the interview schedule followed the structure of the methods class and the practice teaching schedule. There were three key places where the consideration of content knowledge was probed. The first interview was scheduled early in the

semester. Kim and Max were interviewed previous to the second methods class. James was interviewed in the week between the second and third classes. This was important to establish a "baseline" of their content knowledge consideration so that a comparison to later interviews could be made. This baseline was implicitly explored by asking how each participant would prepare to teach a class on heredity and a class on chemical equilibrium. Attention was focused on the role content played in their planning. Max and James could not answer the chemical equilibrium probe. Kim did and this answer became relevant in the analysis. This initial interview also collected background information to establish context.

The second interview was scheduled after their one-day practice teaching experience. Practice teaching was a test of using content knowledge in the act of teaching. As such, the consideration of content knowledge through the planning and implementing of the lesson was probed to investigate whether the experience induced any changes. The interview questions indirectly included the probes used in the methods class, this time in reference to the lesson that they planned and taught.

The last interview was structured to compare the way the participants were thinking about content knowledge at the end of the semester as compared to the beginning of the semester along with the factors that were instrumental to any changes. It occurred at the end of the semester, after the three-day teaching experience and the completion of the methods class. The last interview again included questions about planning lessons on heredity and for Kim only, chemical equilibrium.[1] This time the questions centered on the big picture to be constructed for the students: What would be

[1] Kim was the only participant who answered the chemical equilibrium question initially.

the core idea of the lesson? What would make the concept difficult? What would precede and follow the topic? These were the same probes that the instructor used in the methods class. This interview also asked direct questions about how the participants' were now thinking about their content knowledge.

The last interview also included a series of questions that had been used by SKT researchers to identify the SKT that new teachers hold (Nixon et al., 2014). These questions were more in-depth than the previous probes and included a scenario.

Observations – Participant Observer.

The first data source was the observation of the methods class and of the participants' participation in class discussions. As a participant observer I was fully engaged in experiencing the setting while at the same time observing and talking to the participants about what was happening. The field notes were recorded from recall after the class to prevent distraction (Patton, 2002). Following the Corbin and Strauss (2008) scheme the field notes included detailed observations concerning participants and described the events. Theoretical notes denoting my thoughts about those events were included in my notes.

Participants' Written Assignments – Artifacts.

The methods class and the curriculum class required written assignments. Copies of these assignments were collected by the researcher and examined for evidence of how the participants' consideration of content knowledge changed during the semester. The artifacts were used mainly to verify themes found in the interviews (Glesne, 2010). Although all written assignments were examined only six were deemed relevant and subsequently used. The assignments that were evaluated are listed in Table 3.1

Table 3.1: Class Assignments

Assignment	Class making assignment	When assigned	When due
Concept map defining science teacher	Methods class	First day of class	First day of class
1 day lesson plan	Methods class	Syllabus	After one day teaching experience
3 day lesson plan	Methods class	Syllabus	After three day teaching experience
Unit lesson plan	Curriculum class	Syllabus	End of semester
Reflections on teaching experience (paper)	Methods class	Syllabus	December – after teaching experiences
Rationale paper	Methods class	Beginning of semester – Drafts due periodically during semester	Final draft due at end of semester

Data Analysis

In this study, data analysis involved making sense of multiple forms of data including observation data in the form of field notes, interview data, and artifact data. The preliminary analysis began during data collection and included the process of transcribing the interviews and recording field notes of observations. Coding initiated the comprehensive analysis and was started after all the data were collected. According to Miles et al., (2014) "Coding *is* analysis….coding is deep reflection about and, thus, deep analysis and interpretation of the data's meaning" (p. 72, emphasis in original).

Coding began with the open coding of the interview transcripts. Open coding was used because of its emphasis on the interplay between the researcher and the data (Patton, 2002). It is appropriate to this exploratory study because open coding requires a brainstorming approach to analysis that opens the data to all the potentials and possibilities within them. Corbin describes her method of open coding. In her words "I'll

take a piece of raw data. That piece of data will be used as a springboard for analysis. What I am thinking as I analyze the data will be presented as a memo. Each memo will be labeled with a concept….Any conceptual label reflects my interpretation of what is being said…" (Corbin & Strauss, 2008, p. 163).

Following Corbin's methodology (Corbin & Strauss, 2008) first the interview data were broken down into manageable pieces and the pieces were interpreted through memo writing. The memos generated codes reflecting my interpretation of what the interviewee said. The codes often included the participants' own words. By using this method of memo writing a link was formed between the analytical interpretation and the raw data (Charmez, 2007).

Following the first cycle of coding was axial coding linking related conceptual labels. As Corbin explains (Corbin & Strauss, 2008) "we break data apart, and identify concepts to stand for the data, we also have to put it back together again by relating those concepts" (p. 198). At this point all the artifacts, including documents collected and field notes, were reviewed and parts that confirmed the conceptual labels were included in the supporting data for comparative analysis and validation trustworthiness. The documents and field notes were also examined for conflicting data. None were found.

Matrices were constructed to condense, organize, and reflect on the conceptual labels (Miles et al., 2014). In order to address the research questions the matrices were organized both temporally (Table 4.1) and by the apparent influences to the way the participants were considering their content knowledge (Tables 4.2).

I then composed a narrative description to elaborate each case and identify themes (Miles et al., 2014). The stories were constructed around the organizational matrices and

intended to weave together the conceptual labels produced through coding. They interweave the participants' quotations with my interpretations thus validating the findings (Creswell, 2003). In each story themes emerged. Saldana (2012) describes themes as "*an extended phrase* or *sentence* that identifies what a unit of data is *about* and/or what it *means*" (p. 175, emphasis in original). The narrative stories followed by the themes can be found in Chapter 4. They represent the findings of the individual case studies.

A cross-case analysis was then completed. Metasynthesis was used to systematically compare the cases in order to draw cross-case conclusions (Saldana, 2012). To accomplish the metasynthesis, matrices were prepared comparing the themes of the three individual cases (Table 4.3) as well as salient points from the three narratives (Table 4.4). Three cross-case themes emerged. The findings of the cross-case analysis can be found in Table 4.5 and are discussed in Chapter 4.

Quality

Freeman and colleagues (2007) tell us that validity is generally understood by educational researchers as the trustworthiness of inferences drawn from the data. Trustworthiness can be determined with context rich, meaningful and thick descriptions, triangulation of different data sources of information, member checking of specific descriptions or themes, and clarification of the bias the researcher brings to the study (Cresswell, 2003). Each of these methods of ensuring trustworthiness was employed in this study.

Thick descriptions.

Lincoln and Guba (1986) tell us that naturalistic inquiry must be studied holistically since all the pieces are interrelated and influence the other pieces. In their words, "Moreover, the pieces are themselves sharply influenced by the nature of the immediate context" (p. 75). Therefore the findings of this study are presented as stories that interweave the pieces and consider the context.

Each case is described in the findings through a narrative story. The story is told through my own voice as researcher as I describe my interpretations of the data and the voices of the participants as they describe what they have experienced and what they know. Using both voices adds clarity and authenticity (Patton, 2002). Incorporating the voices of the participants, allowing them to tell their own story, offers a means to stay close to the data and a powerful means to tell the story (Janesick, 1998).

The initial focus of the stories was the participants' thinking about content in order to address the research questions. However as the data analysis progressed it became apparent that the participants' background needed to be included in the case narratives. It was important to know what shaped their views (Patton, 2002). The relevant background information, the participants' responses to their teaching experiences, their perspectives of the methods class instruction, and their perceptions of content knowledge all contribute to the story. The interweaving of the participants' words into the case narrative provides a robust description supporting the developed themes.

Member checking.

Each of the participants was given the opportunity to review the transcripts of their interviews along with my interpretations of what their responses represented as a check for trustworthiness (Saldana, 2012). James responded first with an affirmation that the transcripts were accurate and my interpretations correct. He added, in response to my quest for clarification, an email describing his perspective of how his commitment to influence the lives of his students.

Max also affirmed the accuracy of the transcription and my interpretations. He added an additional comment that he has changed many of his views since his experience student teaching. He suggested that an additional interview would be insightful.

Karen chose not to respond to repeated requests to review my interpretations of our interviews.

Triangulation.

"Triangulation is supposed to support a finding by showing that at least three independent measures of it agree with it or, at least, do not contradict it" (Miles et al., 2014, p. 299). The three sources of data collected during this study were interviews, documents, and field notes from observations. The interview data served as the main source in the analysis. Documents (class assignments) were searched for supporting and refuting evidence. Although much of the supporting evidence was implicit within the participants' assignments it supported the themes found in the interview data corroborating those interpretations. Much of the information found in the documents was implied. Examples are the lack of discussion of content in Max's assignments, the focus of pedagogy and structure over content in Karen's lesson plans, and James' choice of

strategy for a unit lesson plan that supported his focus on student understanding. There was no contradictory evidence found.

Observations of the participants during the methods class tacitly confirmed that the students viewed the class as pedagogical in nature. Filtered through the lens of pedagogy, the content introduced did not elicit a consideration of content knowledge differing from factual and/or conceptual understanding.

Subjectivity Statement.

Peshkin (1988) describes subjectivity as virtuous because it is the basis of the unique configuration of the researcher's personal qualities joined to the data they have collected over time. His admonition is to be aware of the "I" that is present throughout the study from design to the collection and interpretation of the data. In his words:

> I can consciously attend to the orientations that will shape what I see and what I make of what I see. By this consciousness I can possibly escape the thwarting biases that subjectivity engenders while attaining the singular perspective its special persuasions promise (p. 21).

Subjectivity is invariably present in qualitative inquiry (Peshkin, 1988). Patton (2002) tells us "the perspective that the researcher brings to a qualitative inquiry is part of the context of the findings" (p. 64), while Wolcott (1990) describes subjectivity as a strength of the qualitative approach. However personal backgrounds should be revealed that may influence interpretation. As such it is important for me to describe the lens through which I conducted the study.

My undergraduate degree is in medical technology, a field in which I worked on and off for around 20 years while following my husband to various countries as he served

in the Air Force. When finally settling back in the United States, with two children in tow, I began a graduate degree in science education. The impetus for the change was two fold. The first was practical, as I could not find a job as a medical technologist without undergoing another round of certification testing. The second was my lack of confidence in the education that my children were getting. Like many parents I thought, "I can do better than that." And so I went back to school to earn a master's degree in science education.

My first teaching position was a learning experience, as much for me as for the students. By year two I was assigned to teach AP biology. Having been out of school for 20+ years I had to work hard to learn what I had to teach. I studied two college texts and several other books before I taught every topic. I was blessed with some truly gifted students who asked me questions that I had to really think about and research before answering. Their questions were insightful and beyond factual knowledge. I think that this experience taught me to think like a teacher.

Thinking like a teacher required not only knowing the topic in depth and thinking about what the students need to understand, but also how the topics eventually will interweave into a big picture. This way of thinking about content overflowed into my 9th and 10th grade classes and I found myself focusing on what the students needed to understand instead of just propositional facts. I was also thinking about how that understanding related to understanding the next topic. I welcomed the "is that like…" questions that were generated by the students from media (movies and TV) and life stories. The questions revealed where the students were in their understanding and allowed me to lead them to where I wanted them to be.

I undertook the task of National Board Certification for the personal challenge as well as the financial reward being offered. The process increased my awareness of the relationship between *what* I was teaching and *how* I was teaching through the requirement of both documentation and reflection. The implicit knowledge that I gained could later be labeled as PCK. I found that the process of developing PCK, although implicit, first required a consideration of the content before it could be married to pedagogy.

Having established myself as a "good" teacher I was often asked to mentor struggling teachers. I knew that the ability to be a good teacher depended on more than knowledge of facts and more than pedagogy, even the pedagogy that was linked to content. The knowledge that I had was tacit, difficult to convey, and developed through experience. It was more than content knowledge and more than pedagogy. It was *how* I thought about the content.

My experience did not help me specifically identify why some teachers were experts while others just never could understand why their students didn't "get it" no matter how hard the teacher tried. The problem apparently did not reside with their content knowledge or their depth of understanding. They sought and used pedagogical strategies, activities, and resources from various sources without success. What they seemed to lack was the ability to transition what they knew conceptually and factually to pedagogical strategies and explanations. Although they knew the content knowledge, they could not use it for effective teaching.

Retiring from teaching was a difficult decision. However, the challenge of graduate school made it easier. During my studies I was introduced to the concept of the

existence of a content knowledge that was unique to teachers. The research of Ball and associates (2008) resonated with me. I began to consider the relationship between *what* a teacher knows and *how* the teacher considers that knowledge. Relating that concept to my experience mentoring teachers, I decided to investigate what influences the development of that special way of knowing of content in prospective teachers.

CHAPTER 4

FINDINGS

Introduction

This chapter reports the experiences of three PSTs as they progressed through their practicum semester. The cases are bounded temporally by the semester and methodologically by the research questions. The narrative begins with a general contextual description of the study. Further contextual factors significant to each participant are discussed as background within their own stories (Corbin & Strauss, 2008). The stories are organized to represent each case as a coherent whole using the participants' own words to tell the story of their experiences (Fossey, Harvey, McDermott & Davidson, 2002). Each story is developed around four sections. Each of these sections includes the researchers analytical thoughts as well as the participants' own words. The sections are organized as follows: (1) The participants' background and prior experiences both academically and contextually; (2) The change in each of the participants' consideration of content knowledge through the semester; (3) The effect of the explicit and informal discussions of content during the methods class on how they thought about content knowledge; (4) The effect of the experience of teaching on the way they thought about content knowledge. Pseudonyms were used throughout the narratives to hide the participants' identities. Generic terms were used to mask the identification of locations that could potentially identify the participants.

Each section addresses either one or both of the research questions:

1. How does explicit instruction of school SMK for teaching impact how preservice teachers think about the content knowledge that they will teach?
2. What are the specific factors that contribute or inhibit the development and/or acquisition of school SMK while learning to teach during the practicum semester?

The stories are followed with a section summarizing the salient points gleaned from the narratives. Included in the summary are tables comparing the three cases.

The last section is the cross-case analysis. This analysis compares the similarities and differences of the three cases in search of patterns and themes. The salient data from the three cases is summarized in Table 4.4. The findings of the cross-case analysis is described in the three themes that emerged. Table 4.5 summarizes the emerged themes with supporting data from each case.

Three Cases

Setting

This study followed three PSTs through their practicum semester. The study is centered on the methods class but includes artifacts from both the methods and the associated curriculum class. I observed and participated in discussions during the methods class and conducted interviews with the three participants three times during the semester. The first interview was conducted within the first two weeks of the semester. The second was mid-semester and the last at the end of the semester.

The instructor of the methods class discussed content in two different ways during class. One way involved directly questioning the students on the core idea of a particular topic, the difficulty of the topic, and what would precede and follow the topic. At the

time these were the probes used in questioning new teachers to identify their SKT (DuBois, Jurkiewicz, Brennan, Campbell, & Luft, 2014; Luft, Hill, Weeks, Raven & Nixon, 2013). (It should be noted that the instructor for the methods class was the advisor for this study.)

The second way was indirect references to content while demonstrating specific methods during the class. An example was a lesson on the cell membrane. Students were given the information available when scientists first began to explore the structure of a cell membrane. The students designed a model that fit the information they were given. Following the historic path, more information became available and students were asked to modify their models to accommodate it. The students modified their models in steps following the historical availability of information. While completing this task, content information was informally being presented along with the teaching strategy. When the activity was complete the instructor explicitly asked the students the SKT probes.

The practicum included teaching with a partner twice during the semester. The first was a one-day lesson and the second a three-day lesson. The students were informed that using a lesson plan obtained from their coordinating teacher was acceptable. Taking an existing lesson plan and adapting it for themselves could even be desirable by removing the tension of creating a lesson on their own.

Case 1, Max

Background.

Max grew up on a barrier island. He attributed his interest in science to these childhood experiences. The combination of organized activities at the 4H center on a neighboring island and spontaneous, informal observations of marine life is

enthusiastically described as “I soaked it up. I loved it” (interview 1). His childhood experiences led to his interest in ecology “because that’s one thing that I can see, where I’m from I can see so many different factors that go into ecology happening. I think that, you know, I’m such a science geek too …” (interview 1).

Because of his interest in ecology he began his university education as a triple major. That was short lived as the reality of the course load set in. “Actually for a week I was a triple major in science education, biology concentration, biology and ecology and quickly realized that was too much and then I went to ecology double major with science education and then I figured, I just said, I figured I don’t want to do an extra semester, I want to get done in four years” (interview 1). Despite his ambitious start at the university he found classes difficult and he described his lack of academic success in a self-effacing manner. He repeatedly referred to himself as “not that great of a student” who has “taken every class like twice” (interview 1).

Consideration of content throughout the semester.

At the beginning of the semester Max described how he would plan a lesson on heredity. In his description he was focused on finding an activity, not on the content he would be teaching. He talked about looking for the appropriate activity. He said “you’ve got to do something interesting like, spark their interest, immediately. You can’t just go teaching, hey this is DNA and this is what it does. So, I would probably find some activity….either show them like something in real life that’s happening like, not a case study, but, umm, something that’s happening right now in genetics we can always relate to” (interview 1). He went on to describe the sought after activity as something age appropriate, especially vocabulary, something not confusing, something not boring. “I

don't want it to be confusing because then students aren't going to want to learn it. I would look for something that's engaging. Something that the students can kinda get hooked into" (interview 1). He felt that a good hook would lead students through the unit and serve as a reference along the way. He based this planning on allowing the students "to see how it works" followed by "learning how it works".

Max felt that he had sufficient knowledge of content related to heredity since he was taking a genetics class concurrently with the practicum. As such he said, "I feel like I will have it just because what I am learning now is fresh on my mind and everything I've learned since" (interview 1). With that statement he dismissed the idea of any further content preparation. During his extensive, although rambling and disjointed, description of how he would select an activity, he never linked the activity to what he wanted his students to know. He centered his planning on the activity, not the content.

Later in the semester Max made it clear that he prioritized knowing how to teach over knowing what to teach. "I think it's important that we have that content knowledge but I think the most important thing is learning how to be a teacher. And so I would have rather sacrificed content knowledge for the ability, learning how to teach." He continued "…I always thought that we should be spending more time in the classroom and more time learning how to be teachers than learning the content." He defended this position with "I think you can know all the content in the world but that doesn't mean you know how to teach the content or the strategies to teach with individual students…" (interview 2). Interestingly this is contradictory to comments he made informally during the interview sessions. He remarked that he prioritized his genetics class over the practicum and complained that the methods class was too demanding. His expectation of the

practicum semester was that it would not require much work. It was observed that he often came to the methods class unprepared for class discussions despite his informally stated concerns about his GPA.

Max clearly prioritized learning pedagogy over learning content and he saw each as a separate knowledge base with little interaction between the two. This can also be seen in his initial description of how he would plan to teach a lesson on heredity where he dismissed the need to think about content beyond the factual level and focused on finding an activity to spark the students' interest.

He also prioritized teaching process and/or problem solving skills over teaching content. At the start of the semester Max framed his discussion of process skills versus content knowledge around *Next Generation Science Standards* (NGSS) (2012). He saw a disparity between the NGSS and the State Standards. His interpretation of NGSS begins with "It looks like the content is actually being learned in elementary school and middle school and in high school it's like, hey, let's do these cool, sciencey things and apply the content they learned and then, teacher discretion, you put in content where it's needed". He compares this to the State Standards that say specifically "this is the content they need". He continued his interpretation of NGSS with "… it looks like content isn't as important, dare I say that? It's more important that the students are learning problem solving skills. How to really actually look at something, think deeper, question it…. I think that's what the new standards are really more focused on is teaching the students how to be science minded rather than knowing science content" (interview 1). This interpretation of a dichotomy between teaching content and teaching process skills continues throughout the semester. Max thinks that NGSS neglects content in the high

school standards although he said that "I still think content is important…. I mean to me content's always going to be important. So I mean, will I teach content, yes. I mean, I think everyone should be teaching content, but there's got to be a balance though" (interview 1).

His interpretation of NGSS highlights Max's confusing dichotomous understanding of content knowledge and the nature of science as separate pieces. Testing appears to be his focus on content. "… content is still important because this is a science class. You need to know the content. You're going to be tested on the content" (interview 1). But he thinks that if the class centers on teaching process skills the students will not learn the facts. He said that if "they're experiencing science but they're not learning the facts that you want them to know and that you're testing them over" (interview 1). Although most of his discussion confirmed this view he later contradicts himself as he acknowledged "through the application they're taking the content they've already learned and applying it further. Exploring it further and elaborating on it. And still learning that content but through the application process maybe they can still be tested the way they are. They'll just have a better knowledge of it" (interview 1).

In mid-semester he continued to defend his position. "The facts are good but it's more important to develop skills that are going to help you later on in life…'cause… nowadays you can look up information if you wanted to so, maybe, that's their plan is like, hey, content can now get looked up within a second" (interview 2). It should be noted that Max used the terms science process skills, life skills, and less frequently the nature of science interchangeably throughout his discussions to refer to skills to be taught that supersede content.

He reiterated this view at the end of the semester. The students were required to write a rationale paper. In his rationale Max said, “The most important parts of teaching science is incorporating the nature of science and implementing the practices of science within the classroom. This is my first goal for the development of my classroom.”

Max’s consideration of content remained pretty consistent, although blurred, throughout the semester. To put it bluntly he didn’t think about content because he didn’t think it was important beyond the factual level needed to pass tests. This is implicitly stated in his reflections paper where he primarily discussed classroom management with mentions of county policies (credit recovery) and student motivation. He did not talk about either content or pedagogy.

Max repeatedly used the terms content knowledge and factual knowledge interchangeably although at the end of the semester he appeared to include factual knowledge and process skills within content. It is clear that Max does not have a well-defined definition of what he thinks content knowledge is and its importance in teaching. At times he sees it only as factual knowledge and at other times, less frequently, he included scientific process. His perception is that they are separate but vaguely related. He did not waiver on his interpretation of NGSS as elevating scientific process over content knowledge.

Impact of content discussions during class.

Max felt like the content discussion in class taught him that “the content knowledge is important but you’re teaching so much more than just the content” (interview 3). Despite the class discussions he did not waiver on his view of content knowledge as being factual and a secondary knowledge base for teachers. “Factual

knowledge like that is important because you know you're in a biology class and it's required for you to know. You know to get down to graduate high school and all that fun stuff. But after that, it's not important unless you're either going to go either go into science or be on Jeopardy or something. So, I don't know. I feel like process, the practices of science and stuff are more important" (interview 3).

Impact of the teaching experience on consideration of content knowledge.

Max and his partner Anna did their one-day teaching in a middle school science extension class. They created an original lesson plan that targeted the ability of students to determine whether a web-based source was good or bad, credible or not credible. His description of their goal for the lesson was "…we won't be teaching content. We'll be teaching you something that goes onto something you'll actually need in life" (interview 2). This goal reflected his previously expressed view of content as secondary to teaching science process and/or life skills.

The three-day lesson that Max and Anna taught was based on that of their coordinating teachers. The experience of planning the lesson and teaching did not change the way that Max thought about content. He continued to think about content as factual. "…doing our practicum experience has definitely helped me with my content knowledge realizing how much I know, how much I don't know about certain things. Um, I don't, really, realizing how much has stuck throughout the years. You know being through these courses, because I didn't make the greatest grades in these classes but you know, the content, the knowledge is still there which is good, I guess" (interview 3).

His account of his three-day experience is a confusing at best. He and Anna taught together as planned but Anna submitted her lesson with only her name and Max

added his name to the lesson plan of another group. His discussion of how the teaching experience contributed to how he thinks about content reflected his view of content as secondary. He felt "like it's nice to have the understanding for yourself but having that deep content knowledge doesn't necessarily help you explain it to other people" (interview 3).

Theme 1: Content is factual, easily forgotten and can be looked up.

Max's own words reflect his mindset about content. He refers to content only as "facts" and that "nowadays you can look up information if you wanted to… (interview 2). At the end of the semester he is still stating that content is merely factual and needed only to pass tests. After that, it's only necessary if you're "going to be on Jeopardy" (interview 3).

Theme 2: Content is less important to teach than problem solving skill and other life skills.

Max repeatedly refers to teaching content as secondary to teaching skills. Sometimes he refers to teaching life skills while other times it is teaching science process skills. This is evidenced in his one-day lesson plan, his rationale, and his words.

For their one-day lesson plan Max and his partner chose to teach the students how to determine whether an Internet source was credible or not credible. He defends the goal of the lesson with "The facts are good but it's more important to develop skills that are going to help you later in life" (interview 2).

At the end of the semester content is still deemed secondary to skills. In his rationale paper he echoes his belief with "the most important parts of teaching science is incorporating the nature of science and implementing the practices of science".

Theme 3: Content is less important for a teacher to learn than pedagogy.

This theme is reflected throughout the semester in his words. In the first interview he makes it clear that his priority is learning to teach. He says, "I think it's important that we have content knowledge but I think the most important thing is learning how to be a teacher."

Although he directly states the importance of learning to teach throughout the semester, his actions contradict his words. He was unprepared for class multiple times and there is evidence that his participation in lesson planning was minimal. However, his inattention to the methods class does not appear to be because of its lack of importance. By his own admission he struggled with content classes also.

Case 2, Karen

Background.

Karen is a MAT student with an undergraduate degree in molecular biology. She has a strong content background in both biology and chemistry and thinks that she would like to teach both. Her answers during the interviews indicate that she attends to details and focuses on "getting it right." This was also exemplified in her meticulous preparation of class assignments and her contributions to class discussions. She is a conscientious student who strives to please. This striving to please along with the need to get it right was demonstrated by her hour-long discussion with her instructor after teaching her one-day lesson.

Karen attended a small, private school. Her first experience in a public school setting was during the practicum semester. In her reflections paper she spent a significant amount of time talking about the behavior of the students in the public school compared

to her own school experiences. She sees herself as different from the students she will be teaching. “And, I went to … [a] small, private school. And so obviously we were a completely different batch of students than you might get in a public school. Because, you know, we’re not necessarily forced to be there as some public school students might be” (interview 1).

Karen was obviously a student who was successful in what she calls the traditional classroom and recognizes that it will be difficult for her to teach in a different way. “I think that, umm, thinking about, you know, breaking the lecture traditional classroom type of thing. I think that’s going to be, I think that’s going to be one of the hardest things for me because that’s what I grew up with. Umm, and like looking back at my science teachers and stuff. We basically, it was like the same thing, lectures, practice problems, examples, demonstrations, labs, and like, I enjoyed all of my science teachers” (interview 3).

Karen had the unique experience of tutoring her younger brother in chemistry, specifically in chemical equilibrium. Coincidently, chemical equilibrium was the topic of a few of the interview questions providing an interesting contrast to her responses to the biology questions.

Consideration of content throughout the semester.

At the beginning of the semester Karen methodically described how she would prepare to teach a lesson on heredity. She would begin by reviewing content and standards and what the students are expected to know. “So I actually saved a lot of my high school class notes. Probably go home and grab those and see what things you are covering because I’ve learned more than what I learned in high school in bio 1. So I

wouldn't want to like to bombard them with complicated things that they wouldn't necessarily need to know. And then I would look at the, like the standards, and see what types of things, like, the NGSS what they're calling for. Like what types of things the students should know … I would look at the State Standards and stuff like that. … I would look at all those and see what types of things I have to cover and then I would sit down and figure how I want to present it to the kids" (interview 1).

Karen described planning to teach chemical equilibrium quite differently. Her experience tutoring her younger brother gave her a different perspective on how she would plan. "He really needed to understand equilibrium and like what that meant in terms of the equation and like what was happening physically and stuff like that. So I think that really finding a way to visualize or with a demo or with a video or something to really get the idea of what equilibrium was. I think that would be very important to incorporate into a lesson about chemical equilibrium" (interview 1).

Karen's description of planning the two different topics in the two different contexts presents her divergent thinking about content for each situation. Karen described the content for heredity in terms what the students are expected to know factually to satisfy the standards and for equilibrium she described what her brother needed to understand with a broader, big picture view of content. In chemistry she described what connections need to be made in order for the student to understand equilibrium and then she went on to describe how she would teach it so that her student could see how the connecting pieces fit together and how she could relate it to their world. "And I think that another thing is like having it, having what you are doing relate back to like personal experiences, like something that the students can understand more if they've experienced

it. So I think that a demo of something that was in equilibrium compared to a demo of something that wasn't. Some sort of way for the students to really have something to latch on to. When I would like, when I would say, in chemical equilibrium. Have them have a visual or something about what that would mean in the physical world or something like that" (interview 1).

By mid-semester Karen was focused on learning how to teach. Her view of content centers mostly on the level of complexity of the content she would teach although she did hint at the big picture of the concept of multicellularity. She described her experience teaching a middle school introductory lesson on cells. "I felt like it wasn't very deep [depth of knowledge] at all. Umm, like, like multicellular, multicellular versus unicellular organisms. Unicellular organisms are made of one cell. Multicellular organisms are made of many cells. Sometimes it's many different types of cells. That was it. So like, I felt like it's unsatisfying…. It was like, it was like it almost got there, but I felt like I almost wanted to say a little bit more or I wanted to say a little bit more to kind of, I don't know…. But like why is that important, that type of thing. Yes, you have the definition as many cells. But like, big picture, hey, we're multicellular organisms. You know, we have different types of cells…" (interview 2).

At the end of the semester Karen was still viewing content from the level of the complexity that she will communicate to students. "I feel like, like having that knowledge [her own content knowledge] is good because you know, you're always going to have that student that asks like more specific question or like one who wants to know more…. I'm thinking definitely that I'm going to have to like think about like, what information is like truly important and what is just like bonus information" (interview 3). She described

how she would think about content in terms of the standards and determining the detail of content by asking experienced teachers. “I think that I’ll definitely, umm, look towards umm. First of all the standards. Like the State Standards or like the NGSS and then also, I think that, umm, talking to the other teachers in the school” (interview 3). Karen was thinking about the content she would teach coming from external sources rather than how she considered her own content knowledge.

During the interviews late in the semester the participants were asked questions designed as SKT probes. One of the probes targets SCT in terms of understanding the difficulty of a topic as understood by a teacher as compared to that of a scientist or a student of science. Karen answered the heredity probe with “I think it’s difficult because of a few things. You can’t see it. You can’t see DNA really. Umm, you can see the results of it but you can’t see actual DNA…. But also the fact that your, every single cell in your body has the exact same DNA but then. So many, you have so many differ types of cells. Like your cells in your brain, like they’re not going to do the same thing as the cells in your stomach. At least I hope not. You know like so having the students understand that each cell contains all the information but only certain information gets communicated in each different type of cell. I think that’s a big thing for students to understand as well” (interview 3). When asked the SKT probes for chemical equilibrium, she defined chemical equilibrium as the big picture. “I mean you know for chemistry you learn about like the chemical structures and stuff like that but in terms of like reactions I think that having the, you know, the chemical equilibrium is kind of like the big. I feel like chemical equilibrium is the big picture” (interview 3).

Although Karen's explicit explanations of how she thinks about content focus on detail, standards, and what the students need to know her responses to the SKT probe introduce the idea that implicitly she is looking beyond her factual knowledge and thinking about the content conceptually within a big picture.

Impact of content discussions during class.

Karen saw the class discussions of content only from a pedagogical stance. Thinking about content was thinking about how to teach the content. "I think that understanding what students already know and what misconceptions they might have is a really big portion of how you're going to go about teaching whatever topic you're dealing with" (interview 3). She also thought about how she would communicate the content knowledge, "breaking the lecture traditional classroom type of thing" (interview 3). The class discussions were viewed only as to how the content could be taught.

Impact of the teaching experience on consideration of content knowledge.

Both of Karen's practicum teaching experiences included planning around how to please her coordinating teachers and her evaluator. She and her partner adapted the coordinating teachers' lesson plans to include the 5E model. "We modified it in the sense that we added a few things to make it more of a 5E set up. Um, cause we know that what, that's one of the things that Dr. Land, Landon, cause that's who was observing us. But that's one of the things that they're looking for" (interview 2).

The practicum teaching experiences did not explicitly impact the way Karen thought about content knowledge. When discussing content knowledge in relation to her teaching experiences she focused mainly on pedagogical issues. As an example she discussed targeting terminology, "I think that being very specific and explicit and like the

terms" and also behavior "I think that this one-day experience definitely has made me think about what I need to do to get both the kids that aren't as focused and are taking longer with the notes and stuff involved as well as the kids that were twiddling their thumbs and so kind of like trying to get them all working the entire time but also speeding up the note taking process" (interview 2). Her first concern was structuring the lesson to please the evaluator. Content was considered only from the perspective of how the content would be taught.

At the end of the semester Karen again referred to content primarily in terms of pedagogy. "I definitely think that teaching has made me think about. You know if I were in 7^{th} grade or 9^{th} grade or whatever grade. Umm, what would I want to have to make me more engaged and make the lesson more meaningful type of thing. And it's difficult because I was fine with lecture" (interview 3). However, she did have a glimmer of thought about content aside from pedagogy in referring to the level of complexity as well as a big picture. "I think that it would also. I think that I would also probably have to ask myself, like, if you had to describe the organelle, let's just say mitochondria, the mitochondria's function in like one sentence. Cause I felt like the depth of knowledge that the kids knew. I felt like they were going to be getting at least. I felt like it wasn't very deep at all…. But like why is that important, that type of thing" (interview 2).

Karen also described her informal teaching experience tutoring her younger brother in chemical equilibrium. This more informal and personal experience exemplified a different perspective of how she viewed content. She was viewing content as less factual and conceptual. Later she identified the ways that make the topic of equilibrium difficult. "Umm, well, it makes it difficult because, you know, equilibrium, it's not just

like the, it's not like a see saw where you have the same amount of products and the same amount of reactants and that's equilibrium. It's the rate of forward and the rate of the reverse that makes the equilibrium. So I think that having students, when students think of equal in like math like one side equals the other. But for chemical equilibrium it's not one side is the same as the other cause like with Le Chatelier's principle like you remove some from the product it will shift to reach that equilibrium again but it's still not an equal amount it's the equal rate so I think that that's like the really confusing part" (interview 3).

The contrast between Karen's formal and informal teaching experiences is insightful. Karen's formal lesson planning was structured and reflected her desire to please the coordinating teachers and her observer rather than focusing on what the students are learning. Her thinking about content is secondary to thinking about the structure of the lesson and the procedure of implementing the lesson. In her informal teaching experience, when lesson structure was not important, she focused entirely on her student's understanding.

Themes 1: Karen's thinking about content differs depending on the context of teaching situation.

Karen's teaching experience during practice teaching was focused on pleasing the instructor and getting a good evaluation. She was confident in her content knowledge and therefore gave it little thought as she planned and implemented the lesson. She and her partner modified the existing lesson supplied by their cooperating teacher because, in her words, "We modified it in the sense that we added a few things to make it more of a 5E set up. Um, cause we know that what, that's one of the things that Dr. Land, Landon,

cause that's who was observing us. But that's one of the things that they're looking for" (interview 2).

In her effort to please her evaluator and "get it right" her concern for lesson structure overrode thinking about the content. However, when she was tutoring her brother she focused entirely on how she could make the content understandable for her student.

Theme 2: Karen is able to think about content from the perspective of teaching the content (school subject matter knowledge) when liberated from the underlying constraints of formal lesson planning.

Karen's contrasting contexts of teaching experiences demonstrate her ability to deeply understand the content and recognize the pedagogical potential of different strategies when her only concern was her student's understanding as it was when she was tutoring her brother. Her conscientious nature in this context is focused on her need to have her student understand.

In the more formal context of the practicum her major concern is lesson structure and pleasing the evaluator. Karen gives little thought to the content itself outside of what she will teach.

Case 3, James

Background.

James came to the university with a strong religious background. During informal conversations he unabashedly referred to his spiritual self and desire to influence the lives of students. He was a high school wrestler and has served as an assistant wrestling coach

in a community program during his university years. His commitment to influencing the lives of his students is best described in his own words.

> I see coaching not only as a way to build confidence and accomplishment, but I see coaching as a way to spend more time with students. I see it as an opportunity to be in less academically charged arenas. After being in the classroom for my student teaching, I have come to see that it is hard to have real, heart level deep conversations with students that are outside the content of science. They happen, but they are rare and short. Usually, those type of conversations occur in discipline contexts. But on a road trip to a tournament or before or after practices, it is a lot easier to hear about a student's story and experiences and live life with the students. More time gives greater opportunity for quality time with my students and to impact their lives in meaningful ways such as sharing the Gospel with students or walking through their daily struggles and celebrations. I want to have more time to share and care for my students in ways outside of academia. Academia is critical and important, but the classroom, only, does not give me the student contact that I believe is needed to develop truly meaningful relationships with lasting impact (at least the time for me). (personal communication, March 24, 2015)

On the academic side James is confident and articulate when talking about content and about teaching. His contributions to class discussions exemplified his precocious ability to think about content and teaching much like an experienced teacher. During class he was able to identify core ideas that were abstract to the other students and asked

questions that articulated his ability to visualize and question distinctive teaching scenarios.

When talking about the content classes that he had taken he enthusiastically described poultry science classes. “I’ve taken poultry science, I’ve taken poultry 3000 which is another poultry science class but it is a surgical class on live birds like the best class I’ve ever taken …. I highly recommend it to anybody. And then I’m currently taking poultry 4200 which is an avian slash human anatomy general anatomy course. We also, we just performed a surgery on a bird today” (interview 1). He referred to his poultry science classes frequently, especially the labs. He created a unit plan using problem based learning (PBL) and attributed the idea to these classes.

Consideration of content throughout the semester.

At the beginning of the semester James described how he would prepare to teach a class on heredity. He said he would intensely review and supplement his content knowledge. “I’d be reading a lot, I’d definitely be preparing like content knowledge cause I mean I want to feel very competent. I’d definitely, probably use the textbook that’s given for the class. I’d probably do, I’d go back over some old college notes cause I have those and some Power Points I still have. Umm, I would really want to buy a couple books that aren’t so much text books, but almost novel like I guess” (interview 1). He also referenced standards but went further than just looking at the standards. “I’d go over the standards over and over again try to unpack what each standard like piece by piece” (interview 1).

In the mid-semester interview James described how he planned for his introductory lesson on cell organelles. (James did not have a partner for his one-day

teaching experience). “The core idea was, um, teaching, introducing basically the primary, aa, the primary structures within a cell. And less focus on the structures and what they look like and more on the function of those structures. And then how they interact together so that, um, so that your basic cell can survive.… my goal was, basically, can they talk about the function of each of the structures and then talk about how they interact together…. So like less looking at them as individual isolated units and more looking at it as a whole working together” (interview 2). Even before the teaching experience, while still planning, James was trying to develop a relationship between cell structure and function for his students.

At the end of the semester James described the difference between thinking about content knowledge as a teacher compared to thinking about content knowledge as a university student. In his own words:

> I learned it best when I taught it and so teaching it requires a deeper understanding. Kind of an understanding of the things like people don’t ask questions about. And I mean it kind of fuels. I guess the way you study it when you’re looking at content when you’re teaching. You have to look at the broad picture and see where the things connect. Cause if it’s random facts in your mind you’ve got no hope of making kids, students, seeing it as more than random facts…. I think as a teacher you need to know the, quote unquote, random facts but you need to know how those random facts mesh together. And um, be able to communicate the bigger picture. If you don’t have a bigger picture understanding, it’s just random facts in your mind. You’re not going to be able to communicate with students…. If I don’t see a

> big picture in my lesson plan, if I don't see a lesson plan in the context of the unit, or the context of the class…. I can't guide them, like see like with the statements they're making and see the validity in them, and help them, kind of push them on the right path. I guess if I'm not standing on the path and know where that path's going then how it twists and turns, then I can't give them good directions…. I need to know the road map. I need to know what the road map looks like in intricate detail and also the big picture so that I can communicate clearly when a student's on the path and, you know, encourage that or when they're getting off a little bit (interview 3).

James believed that the deep content knowledge acquired through his academic content classes was necessary as exemplified in his creation of his PBL unit. "Like have the confidence to step into that method that I really didn't understand fully had I not had the background that I had in content as far as like genetics and biology here at the university. I just don't think I could have. And in poultry sciences classes I told you about" (interview 3). Even though he was confident about his academic background he considered himself to still be a learner. In his reflections paper he identified one goal as bringing professionals into the classroom because "I do not know all there is to know about content… [to] expand my own knowledge and understanding of content".

James's words expressed a significant change in how he thinks about content knowledge. At the beginning of the semester he focused on expanding his factual knowledge and he described using standards to guide his teaching. By mid-semester he was focused more broadly than the standards and looked at how he could develop a big picture to frame his lessons. By the end of the semester he clearly articulated how he

thought about content knowledge learned as a student as different than how he will think about content knowledge as a teacher.

Impact of content discussions during class.

When talking about the discussion of content during the methods class, and how it impacted the way he thinks about content he said, "my first thought was I've learned just a lot about content in general from other people's presentations" (interview 3). He acknowledged that his "first thought" may not be the answer so he added, "But I think that's what I've learned as far as content has to be. In order for it to be really meaningful to the student it's got to be. I mean they've got to have some stake in it. They have to build it somehow. I guess that's the big method I think I've picked up from Dr. Land's class" (interview 3).

James reflected the same views as the other participants. There was no reference to a change in how he considered content that could be attributed to class discussions. He learned factual content in the methods class as well as a vague reference to strategies that allow students to build their understanding.

Impact of the teaching experience on consideration of content knowledge.

James used both his one-day and three-day teaching experiences to create his own lesson rather than adapting an existing lesson supplied by the coordinating teacher. He planned and taught his one-day lesson by himself and his three-day with another student. His one-day lesson an introduction to cell organelles and planned around the essential question. He was focused less on factual information and more on developing a big picture for the students. He described the way the experience of teaching impacted his way of thinking. "Yeah, nothing like experience and so I'm just sitting there and like.

You know, I began to see the thread of, like seeing the whole picture of things working together. Like if you just know what a ribosome does, that's great but, I mean you gotta be able to. If you understand how that function interacts with other functions. Just understanding the concept that there are things that are structure and function are interacting together you incorporate that in all science. You start to see that thread, so you can pick up on things and facts come along with that" (interview 2).

By mid-semester he was beginning to think about content beyond factual information and also beyond basic relationships as exemplified by his own questioning of what the students learned. "They could talk about those functions fine but they really couldn't integrate them and talk about how they're working together. Um they really couldn't. If I had of asked what if this, what if a ribosome is messed up it can't read the RNA for example. I don't think they would have been able to compute that it won't make protein and or if, if something was messed up or mutated or something, they probably couldn't have communicated to me what would have been messed up and how it would affect the other three structures" (interview 2).

His three-day teaching experience was also original although his partner took the lead (it was a physical science class that was more in his partner's field of expertise). His description during his presentation reflected an understanding of how content is not just factual but requires a recognition of the difficulty in understanding something that cannot be seen.

Although he had limited input for his three-day lesson, his unit plan (the unit plan was a required end of semester assignment) was his own. His unit was based on a problem base lesson strategy. He described the goal of the lesson as, "The aim of this

PBL is to help students get a very deep and meaningful understanding of all Components of the Central Dogma of Biology by treating patients with different bacterial infections through the use of antibiotics" (from unit plan, Following the Path of DNA to Protein). Whether this was a conscious decision or not, the unit plan directly addressed the concerns he had after his one-day lesson. After his one-day lesson his expressed concern was that the students would not be able to relate how the malfunction of one organelle would affect the other organelles. "But like try to get them to understand…. to give students situations where one of the structures is malfunctioned and get them to justify why, why would that hurt the cell, would it hurt the cell, why or why not. Justify your answer. So getting them to think…. what would be the repercussions…. It might not have gotten them where I wanted them to answer the essential question but I think it would have gotten them thinking more in that manner and start breaking those isolated boxes and allowing them to see how everything's working together" (interview 2).

Unlike the other participants, the teaching experience made a significant impact on James's thinking. He began the semester thinking about standards as the focus of content. By mid-semester he is thinking about relationships among concepts and the big picture rather than individual isolated units. By the end of the semester he thinks about understanding content from the role of teacher rather than the role of student or science scholar.

Theme 1: James's view of content knowledge evolved throughout the practicum semester.

In the beginning of the semester James described content knowledge as coming from different sources (textbooks, college notes, standards) much like the other

participants. However, he added that he would plan around what the students need to know.

As the semester progresses, by mid-semester he is seeing content as a big picture rather than individual facts. In his words, "So less looking at them [facts] as individual isolated units and more looking how they interact together" (interview 2).

By the end of the semester he is beginning to see the necessity of knowing the content in a different way that is special to teaching. He describes how he thinks about content knowledge. "… teaching it requires a deeper understanding. Kind of an understanding of things like people don't ask questions about" (interview 3).

Theme 2: James no longer thinks about content knowledge as individual, isolated, factual units but rather as related concepts that create a thread linking them to a big picture.

Theme 3: James thinks about content knowledge learned as a student or understood as a scientist as different from how he will think about content knowledge as a teacher.

James articulates it best. "You have to look at the broad picture and see where the things connect. Cause if it's random facts in your mind you've got no hope of making kids, students, seeing it as more than random facts…. I think as a teacher you need to know the, quote unquote, random facts but you need to know how those random facts mesh together" (interview 3).

Summary of Individual Cases

In order to address the second research question there must be evidence that the participants' consideration of content changed during the practicum semester. Table 4.1 summarizes the salient data gleaned from the three cases.

Table 4.1: Consideration of Content Throughout the Semester

	Beginning semester	Mid semester	End of semester
Max	• Not concerned about knowing content • Plans around activities, not content	• Content is factual, easily forgotten, can be looked up • Problem solving skills more important than content • Content necessary so students can pass the test • Content and problem solving skills mutually exclusive	• Content useful but learning to teach more important • Knowing deep content does not necessarily help you to explain • Unclear whether content knowledge is all factual or includes scientific process skills
Karen	• Plans around what students need to know • For chemistry thinks beyond factual complexity to relationships • For chemistry chooses activities with specific content in mind	• Talks about content from viewpoint of level of complexity • Defines content difficulty differently for biology and for chemistry	• Thinks about content in terms of amount of detail students need to know • Thinks about teaching chemistry differently than the way she thinks about teaching biology
James	• Plans around what students need to know • Sees content knowledge coming from different sources	• Views content as a big picture rather than individual factual units • Attributes "seeing how things work together" to experience teaching	• Sees depth of knowledge acquired through academic classes necessary • "If you don't have a bigger picture understanding, it's just random facts in your mind, you're not going to be able to communicate with students." • "If I'm not standing on the path and know where that path's going then how it twists and turns, then I can't give them good directions."

The intervention using content probes in the methods class as well as the less formal introduction of content during the class had no impact on how the participants

were thinking about content. However, the experience of teaching did have an effect. Table 4.2 summarizes that effect.

Table 4.2: Effect of Teaching Experience on Content Thinking

	Lesson plan structure	Effect of teaching experience on content thinking
Max	One day – original plan Three day – adapted from existing plans	Views content as secondary to teaching process skills. Views his content knowledge adequate for teaching
Karen practicum	Both experiences adapted from existing plans	More concerned about the structure and procedure than content
Karen tutoring	Unstructured (tutoring)	Thinks about the big picture being created for the students and aware of why the topic is difficult
James	Both experiences based on original lesson plans	Feels that teaching requires an understanding different from factual information. It requires looking at the broad picture and seeing where things connect

Analysis of the three cases produced themes. The individual case themes are summarized in Table 4.3.

Table 4.3: Individual Case Themes

Case 1	**Case 2**	**Case 3**
• Max considers content as factual, easily forgotten and can be looked up. • Max considers content as less important to teach than problem solving and other life skills. • Max considers learning pedagogy as more important then learning content.	• Karen's thinking about content differs depending on the context of the teaching situation. • Karen is able to think about content from the perspective of teaching the content (content knowledge for teaching) when liberated from the underlying constraints of formal lesson planning.	• James's view of content knowledge evolved throughout the practicum semester. • James no longer thinks about content knowledge as individual, isolated, factual units but rather as related concepts that create a thread linking them to a big picture. • James thinks about content knowledge learned as a student or understood as a scientist as different from how he will think about content knowledge as a teacher.

Cross-Case Analysis

Analysis of individual cases is typically followed by a cross-case analysis to search for patterns and themes that cut across the individual experiences (Patton, 2002). By comparing individual cases with different outcomes the researcher can begin to form more general explanations and although findings may be ill suited for generalizability they can identify concrete, specific patterns. The "fundamental reason for cross-case analysis is to deepen *understanding and explanation*" (Miles, Huberman, & Saldana, 2014, p. 101, emphasis in original).

Based on this principle, after considering each case as a whole, the similarities and differences of the three individual cases were studied through comparative analysis. The cases were remarkably dissimilar as displayed in Table 4.4. Despite the dissimilarities the patterns found hold value in the "*seldom apparent compatibility of uniqueness and generalization"* (Stake, 1994, p. 32, emphasis in original).

Table 4.4: Summary of the Comparison of the Individual Cases

	Case 1: Max	Case 2: Karen	Case 3: James
Academic background	• Difficulty with academic content classes	• Undergraduate degree in molecular biology	• Favors poultry science classes with its problem based labs and hands-on experiences
Effects of both explicit and informal discussion of content in methods class	• Content knowledge is important but teaching students to be 'science minded' more important	• Refers only to how to teach content such as awareness of misconceptions and moving away from traditional lectures	• Refers to learning factual content and to learning that students must build their own content knowledge
Structure of teaching experience	• One day lesson was original • Three day lesson was adapted from cooperating teacher • Evidence of little participation in planning lessons with partner	• Both lessons adapted from cooperating teachers • Evidence that adaptation targeted at fulfilling expectations of observers • Tutoring experience different from practicum experience	• Both lessons plans original • Three day lesson follows partners lead • Plans unit around PBL
Impact of teaching experience on thinking about content	• Continues to view content less important than teaching skills	• In structured lessons concern remains about complexity of content and meeting criteria of standards • In tutoring thinks about how to teach content from aspect of student understanding	• Realizes teaching requires a different understanding of content outside of factual knowledge • Looks at the broad picture of content and sees relationships among concepts
Personal views on content in teaching context at semester's end	• Teaching content less important than teaching problem solving and life skills	• Meticulous and methodical when in a structured environment and in unstructured environment conceptually driven with priority on student understanding	• Precocious understanding of relationship between knowing content as a university student and knowing content as a teacher

Despite the apparent differences in the cases three themes emerged as the cases were compared.

Theme 1: Class discussions of content, including the use of probes, had no impact on thinking about content knowledge.

The discussion of content in the methods class occurred in two different forms. The first was the explicit use of probes that target a way of thinking about content as a teacher would rather than the way an academic or scientist would. This way of thinking is considering the *how* of thinking about content rather than the *what* of the content (Ball, Thames and Phelps, 2008). The probes included the core idea of the topic, what makes the topic difficult and what the students should know before the topic was introduced and what would follow the topic. The probes were used periodically four times throughout the semester. The second form of content discussion during the methods class was the indirect discussion that occurred as teaching strategies were introduced and as the students discussed and presented their teaching experiences. This more informal discussion of content was frequently interspersed with class discussions.

When the participants were asked if the methods class had influenced the way they think about content no participant referenced the direct probing. When the probes were used in the class there was little discussion. It appeared that the students were looking for a right or wrong answer rather than a discussion of what the answer could be. Because the use of probes followed lessons on pedagogical strategies, there was the appearance that the students considered the probes themselves as another "box to be checked" when planning a lesson. Additionally, no student, with the exception of James, could correctly answer any of the probes. James could only identify the core idea of a

topic. The only responses to the difficulty of a topic had a pedagogical focus such as misconceptions. All responses to what students should know before the topic and what would follow the topic referenced curriculum and sequencing.

In answering the interview question about the influence of class discussions on their thinking about content, the participants did talk about the informal content discussions. The informal discussions were precipitated initially by the instructor as teaching strategies were presented and discussed or by the students as they discussed their teaching experiences. The focus of the participants was on learning content that they were not familiar with rather than how they were thinking about the content. This is illustrated by their answers during interviews. When probed Max reiterated his view of content as having secondary importance. Karen referenced misconceptions and communication, and James referenced the factual knowledge learned as well as the students' need to construct their own knowledge. All, with the exception of Max, had a pedagogical emphasis.

The intervention of explicit instruction does not appear to have been noticed by the participants. The informal content instruction appears to have contributed to the pedagogical aspects of teaching as well as their factual content knowledge. Since the methods class traditionally is a class on learning pedagogy, their answers were reasonable.

Theme 2: Preservice teachers approach the practicum teaching experience with different backgrounds and therefore different priorities.

The three participants in the study had diverse backgrounds and diverse academic experience. All three participated in the same practicum semester and yet the priorities

that they hold for teaching are quite different. All three have priorities that can be associated with their own experiences. This suggests that their backgrounds and personalities have influenced their priorities as much as or more than the instruction received during the practicum.

Max has a love for science cultivated by his environment as he grew up. However, his academic history and lax attitude towards the methods class are contrary to his expressed enthusiasm for teaching. He has a lack of interest in content and a desire to instill in his future students an attitude of being "science-minded" rather than science educated.

Karen has an undergraduate degree in molecular biology and is articulate when discussing content. She has been academically successful and is meticulous and conscientious in completing tasks whether it is a written assignment, class discussion, or her teaching experience. When approaching her teaching assignment she is focused on the structure of the lesson and fulfilling what she feels are her observer's requirements for a successful evaluation. However, when the structure of the lesson and the evaluation are eliminated her priority is focused entirely on how to make the content understandable for her student.

James has a desire to be a positive influence on the lives of his students but is able to separate that desire from his classroom teaching in discussions. He is academically successful and has a precocious ability to see how content needs to be considered when he talks about teaching. His priority is his students' understanding and he centers that concern on his own understanding of the content.

Theme 3: The priorities the preservice teachers bring to their teaching experience influence how they think about content.

When the priorities that the future teachers bring to their teaching experience are contrasted with the way that they think about content a relationship can be noted. Max's expressed, although often muddled, priority is the teaching of skills rather than the teaching of content. He thinks about content as being factual and easy to look up if forgotten. In his words "it's not important unless you're either going to go either go into science or be on Jeopardy or something" (interview 3).

Karen is meticulous and conscientious. She brings these characteristics to her teaching experiences. When she is being evaluated, she focuses on the structure of her lesson and the implementation of that lesson. Under these circumstances, she thinks about content as what the students need to know as dictated by the standards. In the more informal setting of tutoring her brother, she focuses entirely on what her student needs to understand so that he can construct the bigger picture of, in this case, chemical equilibrium. When she thinks about content in this context she focuses on the relationships between what is happening physically with what is demonstrated algorithmically. She is also aware of the difficulty that students may have with viewing a chemical equation as opposed to the more familiar math equations. She is thinking about content as a teacher would.

James has a precocious ability to recognize that if he wants his students to see content beyond individual facts he must have that content organized in his mind as more than facts. To use his words, "Cause if it's random facts in your mind you've got no hope of making kids, students, seeing it as more than random facts" (interview 2). He begins to

think this way after his first teaching experience. It is not clear if his background is influential in this way of thinking although he is clearly influenced by his poultry science classes where content is viewed from the wider perspective of how factual information is used to understand avian physiology.

Summary

Analysis of the three cases produced themes relative to how the participants were thinking about content knowledge as the semester progressed. Cross-case analysis compared their backgrounds as well as their experiences in the practicum semester.

The cross-case analysis identified three themes relevant to the research questions. Table 4.5 summarizes the themes with the supporting data.

Table 4.5: Cross Case Themes with Supporting Data

	Theme 1 Class discussions of content, including the use of probes, had no impact on thinking about content.	**Theme 2** Preservice teachers approach the practicum semester teaching experience with different backgrounds and therefore different priorities.	**Theme 3** The priorities the preservice teachers bring to their teaching experience influence how they think about content.
Case 1, Max	Methods class reinforced his idea of science process more important than content knowledge	Prioritizes teaching skills over teaching content	Thinks about content as factual and easy to "look up"
Case 2, Karen	Learned the pedagogical strategies that impact content knowledge such as misconceptions	(structured lesson) Prioritizes structure of lesson over content of lesson	Thinks about content as what students need to know
		(tutored lesson) Prioritizes student understanding	Thinks about content as what students need to understand
Case 3, James	Learned factual knowledge and learned that student knowledge was constructed	Prioritizes student understanding of conceptual relationships	Thinks about content as big picture that students need to be guided through

These three themes can be summarized as:

1. The intervention of using content probes in the methods class had no impact on the way participants thought about content.
2. The PSTs in this study approached the practicum semester with diverse backgrounds that relate to different priorities.
3. The priorities the PSTs brought to their teaching experience influenced how they thought about content.

These themes will be discussed relative to the research questions, relevant literature, and implications for teacher educators and future research in Chapter 5.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Introduction

Chapter 4 told the stories of the four participants using their own words to describe their experiences and reflections. The narratives, along with other data, were analyzed to identify themes in each case. These themes were interpreted as they relate to the research questions.

A cross-case analysis was then performed to compare the similarities and differences of the three cases searching for patterns and themes (Patton, 2002). The three themes found in the cross-case analysis have implications for both teacher educators and the research community. A discussion of the findings and the implications of those findings hold the significance of the study and are the culminating piece of the research.

The key findings found in the cross-case analysis are:

1. The intervention of using content probes in the methods class had no impact on the way participants thought about content.
2. The PSTs in this study approached the practicum semester with diverse backgrounds that relate to different priorities.
3. The priorities the PSTs brought to their teaching experience influenced how they thought about content.

In this final chapter the key findings will be discussed relative to the research questions and framed in current literature. Suggestions for teacher educators and future research will be proposed.

Discussion of Research Questions

Research Question 1: How does explicit instruction of school SMK for teaching impact how preservice teachers think about the content they will teach?

The traditional system of teacher education requires individual courses in content and pedagogy but does not provide methods devised to utilize or integrate the information learned in each (Gess-Newsome, 1999; Kind, 2008). The explicit instruction of school SMK in this study was intended to bridge this divide encouraging the transition from academic SMK to school SMK by challenging the PSTs to think about content in a way that would support student learning.

The explicit instruction took the form of content probes that were incorporated into instruction during the methods class. The probes were intended to provide a situation in which the PSTs were challenged to think about the content in the context of teaching thus providing a tension between the content they know and how they will use that knowledge. Unfortunately the probes went without notice. When the participants were asked about content discussed in class the probes were not mentioned. Observations during the class confirmed that the students regarded the probes as another box to be checked when considering lesson planning. As such, the findings suggest that the probes did not influence the participants' thinking about content.

Although the explicit instruction was the focus of this research question, the probes were not the only initiator of content discussions during the classes. Content was

also introduced during discussion of teaching strategies, lesson plans, and incidentally during discussion of teaching experiences. However, when the participants talked about these occurrences they categorized them as new content learned rather than new understandings of content.

The findings of this study indicate that not only the explicit instruction as implemented had no impact on how the participants think about the content they will teach, no content introduced, even incidentally, during the methods class had an impact. The content – pedagogy gap was not bridged.

Research Question 2: What are the specific factors that contribute or inhibit the development and/or acquisition of school SMK while learning to teach during the practicum semester?

The complexity of learning to teach is influenced by factors other than classroom instruction (Friedrichsen, VanDriel, Abell, 2011). The second research question investigated what factors, outside of the classroom instruction, influenced the development of school SMK as exhibited by the way the participants considered content. The two factors that were identified in this study are interrelated and affected each participant in different ways, sometimes contributing and sometimes inhibiting school SMK development. The predominant influential factor was the priorities that each PST brought with them to the program. These priorities influenced the second factor, the teaching experiences of the practicum semester.

For this study I define priorities as what the PSTs gave their attention to, either consciously or unconsciously, at the expense of competing alternatives. Priorities were identified as the primary factor that influenced the way the PSTs were thinking about

content. In this study it was necessary to also consider how those priorities were established. Analyzation of the data provided evidence that the participants' priorities were related to their backgrounds and personality characteristics. Table 5.1 summarizes the relationship.

Table 5.1: Relationship Between Background and Priorities of Participants

	Background	**Priority**
Max	• Grew up in a ecologically rich environment that influenced his interest in science • Self admitted academic difficulty in content classes	• Wanted students to be "science minded" • Prioritized teaching skills
Karen	• Meticulous, conscientious, detail oriented student • Grew up with a private school education that gives her an outsiders perspective of public school • MAT student with an undergraduate degree in molecular biology • Comfortable with the traditional lecture driven classes and recognizes that she will find it difficult to change • Has experience tutoring her brother in chemical equilibrium	• In formal teaching wanted to please evaluator • Prioritized structure of lesson without concern for content • When tutoring prioritized student understanding
James	• Strong spiritual sense and desire to impact the lives of students • Confident and articulate when discussing content with a precocious awareness of content knowledge for teaching • University content classes include poultry science giving him a hands on, problem based academic experience	• Prioritized student understanding

Existing literature describes a relationship between priorities and beliefs. PSTs' beliefs are influenced by personality characteristics and backgrounds and are consistent with their priorities (e.g., Decker & Rimm-Kaufman, 2008). They are personal constructs that are developed through experiences, are value laden, and reflect personal stories

(Fletcher & Luft, 2011). While beliefs are predictors of behavior (Pajares, 1992) priorities are made explicit through behavior.

The interview protocols used in this study did not include questions guiding discussion of either beliefs or priorities nor did the artifacts or observations. However, because priorities dictated how the PSTs focused their attention they could be identified.

In this study priorities relate to the participants' backgrounds. Other studies have related backgrounds to teaching orientations (Brown, Friedrichsen, & Abell, 2013). Teaching orientations have been discussed extensively as a component of PCK as suggested by the Magnusson model (Friedrichsen et al., 2011; Magnusson, Krajcik, & Borko, 1999). However, since the publication of that model there have been multiple definitions of orientations that have led to ambiguity (Friedrichsen et al., 2011). A recent review of literature by Friedrichsen et al. has proposed a shared definition of orientations to be used in research. They define orientations as beliefs about the role of the teacher, the role of the student, views about science and goals and purposes of teaching science.

This study focuses on the development of school SMK as defined by how PSTs think about content. Although the study does not seek to define school SMK it does segregate it from PCK as Ball, Thames and Phelps (2008) segregate MKT from PCK. Teaching orientations as discussed in the Magnusson model are a component of PCK. Friedrichsen et al. (2011) define orientations by beliefs held. Both of these definitions make orientations irrelevant to discussion of this study despite the commonality of relationship to backgrounds.

Priorities as a factor influencing the development of school SMK.

In these cases priorities relate to the way the participants think about the content they are teaching therefore influencing the development of school SMK. Max prioritized teaching science skills and therefore gave little thought to content. Karen prioritized lesson structure in her formal teaching and student understanding in her informal teaching. She was confident in her content knowledge and gave it little thought when planning a formal lesson but much thought while planning tutoring when formal lesson structure was not a concern. James prioritized student understanding and as a result focused on how he must understand the content in order to facilitate his students' learning.

The findings of this study follow a tentative path from background to priorities to practice in these PSTs. Backgrounds influence teaching priorities and teaching priorities influence the role content will play in their teaching practice as expressed by how they think about content. Thinking about content has been recognized as a step in the development of school SMK as I have defined it.

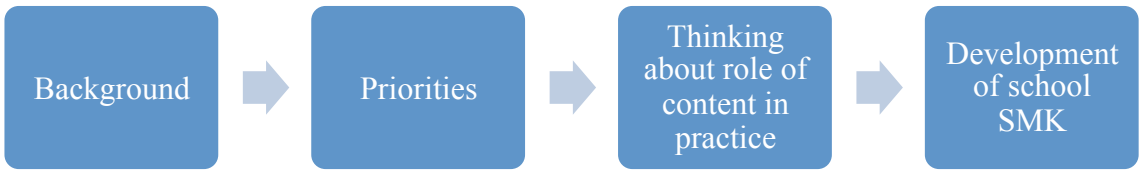

Figure 5.1: Development of School SMK

This progression is supported in part by existing literature. Banks, Leach, and Moon (2005) found that background influences the formation of school SMK. Bertram and Loughran (2014) as well as Windschitl, Thompson, Braaten, and Stroupe (2012) support the role of thinking about content in practice as a step toward the development of

school SMK. However, the question of why some PSTs develop school SMK while others struggle has remained a mystery. I contend that looking at priorities may provide evidence of the missing piece.

Background forms the underpinning for development of school SMK.

In an effort to provide a theoretical framework for discussion around the relationship between knowledge and pedagogy, Banks et al. (2005) devised a model of teacher professional knowledge that includes what they refer to as school knowledge. They define school knowledge as a transposition of subject disciplinary knowledge into the knowledge used in teaching. It lies outside of the school context. They acknowledge that school knowledge may be viewed as an intermediary between subject knowledge and the pedagogical knowledge used by teachers. However, they attribute personal constructs as lying at the heart of the process of the amalgamation of subject knowledge, school knowledge and pedagogical knowledge. Included in their definition of personal constructs are the teachers' view of the subject matter, their personal biography and educational experience, as well as their own teaching experiences.

My characterization of school SMK is a rendering of the Ball et al. (2008) model of specialized content knowledge used only in teaching (SCK). The Ball et al. model segregates SCK from PCK. Although Banks and colleagues (2005) did not focus on defining school knowledge their use of the term bears similarity to my definition of school SMK in important ways. Both school knowledge and school SMK are held outside the context of the classroom and both are knowledge used only in teaching.

The Banks et al. (2005) model focuses on the influence of personal constructs on school knowledge development. Their definition of personal constructs can be parsed to

background influence coinciding with my contention that background is an integral factor in directing the path to development of school SMK. Ball and McDiamid (1989) agree that personal biography, including everyday experiences as well as prior educational experiences, have influence on the construction of subject matter understanding.

My study's cross-case analysis provides evidence that priorities, which in these cases, relate to their backgrounds, provide a filter through which practice develops and therefore the role that content plays in their teaching.

Thinking about content as a step to development of school SMK.

Two research groups have included thinking about content as an ancillary step to their study's primary objectives. Bertram and Loughran (2014) used thinking about content through the construction of CoRes to plant the seed of PCK. Windschitl et al. (2012) included thinking about content while PSTs learn to teach ambitiously. Both of these studies acknowledge the difficulty that PSTs have in adapting their academic SMK to use in teaching. These studies and how they relate to my findings are discussed in more detail later in the conclusions and implications section.

Teaching experience as a factor influencing the development of SMK.

The limited teaching experience of the practicum semester added another dimension to the way the participants thought about content. This finding is also consistent with the Banks et al. (2005) model of development of school knowledge. In their description of personal constructs they include the influence of teaching experience.

The interview questions and interview schedule for this study were devised to follow the participants as they progressed through the methods class and also to allow them to reflect on their teaching experiences. The prompts focused their answers on

content and how the participants were thinking about the content. Each participant expressed either directly, indirectly, or by omission the role that thinking about content played as they designed and implemented their lessons. The evidence provided by the interviews and artifacts showed a remarkable relationship between the priorities of the participants and how they were thinking about content. As a result, the teaching experience factored differently into the thinking of each participant.

Max's priority was teaching his students skills and having his students be science-minded. He simply did not think about content because he viewed content with little importance. This was expressed through his discussion of his teaching that focused more on skills that content. For Max the experience of teaching had no effect on his thinking about content.

Karen was meticulous, methodical, and conscientious focusing on attention to detail. She was confident in her content knowledge. Her priority in her practice teaching was "getting it right". As such, Karen's initial priority was pleasing her evaluator and thus she focused on the structure of the lesson. However, as the semester and her teaching experience progressed she lamented that she was dissatisfied with the content that she presented to her students. Although at this point she was only puzzling over content, she was beginning to think about content as well as the techniques of teaching. In her words, "it was like it almost got there, but I felt like I almost wanted to say a little bit more… But like why is that important, that type of thing… But like, big picture" (interview 2).

Karen also had an informal teaching experience tutoring her brother. In this situation, without having to please an evaluator, her meticulous and conscientious nature prioritized her student's understanding. In this environment she thought only about

content and expressed an understanding that her academic knowledge had to be adapted to teach.

James had a strong religious background and wanted to influence the lives of his students. This desire extended to prioritizing student understanding. As he acquired classroom experience he developed a precocious ability to recognize that he had to adapt his academic knowledge to content knowledge for teaching in order for his students to understand. In addition, he was able to articulate his way of thinking. He used the metaphor of thinking about content more as a road map than as a straight line. A straight line would lead directly to the standard, the standard being the destination. A road map takes into account the twists and turns that students make on their journey to the destination of understanding. In his words "I guess if I'm not standing on the path and know where that path's going then how it twists and turns, then I can't give them good directions…. I need to know the road map" (interview 3).

The experience of teaching affects James more directly than it does the other participants. As James has more experience teaching he shifts his focus from techniques (as learned in the methods class) to purposes. This shift aligns with Dewey (1902) who divided educational perspectives into two opposing sects. In the first the road is long but straight and "subject matter furnishes the end and it determines the method" (p. 8). In the other "the child is the starting point, the center and the end" (p. 9).

The experiences of the three participants exemplify how priorities affected how they approached their teaching and how, as they worked with the students, their teaching affected their thinking about content. Karen initially did not think about the content as other than the academic content that she knew well. Her focus was on lesson structure

rather than content with the priority of getting a good evaluation. As the semester progressed and she had more teaching experience her thinking begins to shift. She noted only dissatisfaction. However, dissatisfaction can serve as a beginning of developing school SMK if she can shift her priority away from pleasing others.

James's priority was student understanding. Through his teaching experience he realized that he had to think about content differently in order for his students to learn. His metaphor of "standing on the path" and "needing to know the road map" articulates his recognition that he needs to adapt his academic knowledge to school SMK.

Max did not think about content. His priority was teaching his students to be science-minded. His teaching experience did not change the way he considered content.

Conclusions and Implications for Teacher Educators and Future Research

This study focuses on the development of school content knowledge in PSTs. PSTs begin the transition from students of science to teachers of science during their practicum semester. The practicum semester is the final classroom instruction for these prospective teachers before they will enter the profession as beginning teachers.

As we know beginning teachers are the most common teacher in the profession (Ingersoll & Strong, 2011). Therefore it is important that our beginning teachers are well prepared to enter the profession. One of the challenges new teachers face is an understanding that the content knowledge they hold as students of science differs from the content knowledge used by teachers of science (Ball et al., 2008; Darling-Hammond, 1998; Davis, Petish & Smithey, 2006; Deng, 2007; Kennedy, 1998; Zeidler, 2002).

Traditional education programs require individual courses in content and pedagogy but do not provide a method to integrate the information learned in each (Gess-

Newsome, 1999; Kind, 2008). This study attempted to provide a method of integration with the use of explicit instruction of content by the use of probes. The intervention was unsuccessful.

A second goal of the study was to identify any other factors that influenced the development of school SMK. That question yielded results.

Conclusions and Implications

The key findings of this study lead to three major conclusions:

1. Content introduced in the methods class was viewed as peripheral and factual. The content - pedagogy gap was not bridged by explicit instruction.
2. Academic and personal backgrounds influenced teaching priorities.
3. Teaching priorities influenced how the prospective teachers thought about the content they would teach.

The first conclusion reflects extant literature that has determined that the separation of classes in content as taught by the College of Arts and Sciences and the classes in education as taught by the College of Education have the effect of segregating lessons learned in each in the minds of PSTs (Gess-Newsome, 1999; Feiman-Nemser, 2001; Kind, 2008; Zeidler, 2002). With no effort to integrate the knowledge bases learned in each, the divide will remain the puzzle for PSTs to solve.

This study delved into solving the problem of bridging the two by implementing the use of content probes in the methods class. The purpose of the content probes was to stimulate discussion of content as school SMK. The intervention was not successful.

Conversely Bertram and Loughran (2014) were more successful in bridging the gap between pedagogy and content by going beyond the traditional basic approach to

planning the structure of a lesson. In addition to learning the nuts and bolts of time management and teaching strategies the PSTs in their study produced CoRes to provoke an awareness of PCK. The CoRes provided a way to unpack a Big Science Idea. The development of a CoRe initiated "coming to see a Big Idea as conceptual rather than propositional as an indication of a beginning point in 'seeing into' the topic differently" (p. 122). Bertram and Loughran argue that this way of thinking may be a central aspect of recognizing what PCK 'might be' and how it might be understood by beginning teachers and developed over time, thus bridging the content - pedagogy gap.

Although the CoRe intervention proved to be successful in promoting thinking about the pedagogical potential of content, the process was time consuming and cumbersome. The gap between content and pedagogy was bridged but the process may not be practical in a traditional teacher education programs.

Windschtl et al. (2012) are also critical of the current traditional teacher education programs describing them as instruction about instruction. Clearly this description depicts the separation of content instruction from pedagogical instruction. In order to develop what they term ambitious teaching in prospective teachers they propose a core set of tools to provide an organizing framework for model-based inquiry. They distill ambitious teaching into four core subject-specific high-leverage practices (HLP) that could be articulated and taught during teacher preparation. The HPLs then were linked to tools that provide a method of discourse and reflection on practice as novices are learning to teach.

The first priming tool in their core set of tools is referred to the Big Idea Tool. It is the single tool that guides planning rather then enactment. In using this tool the PSTs focus on shifting their thinking about the scientific phenomena from propositional to

conceptual. Windshitl et al. (2012) found that most of their participants initially took curricular topics at face value as Big Ideas. The tool was designed to "help participants develop an explicit understanding of the target ideas that they were to teach from the curriculum" (p. 889). With that understanding the PSTs were able to reconstruct the curriculum around Big Ideas.

Both the CoRes and the Big Idea tool build pedagogy around content therefore melding the two as the PSTs learn to teach. Both ideas require training for both the teacher educators and the prospective teachers to facilitate their use. Although they both bring content front and center their implementation would require a restructuring of the traditional education programs which may not be a practical solution.

The less intrusive solution of using probes was not successful. In this study the probes were introduced after the pedagogy was discussed. As such the students appeared to view the probes as an afterthought, a box to be checked while planning. The methods class was viewed as being content free leaving the PSTs to integrate content into their lesson planning by themselves. As a result their backgrounds played an important role in that integration.

The CoRes study and the Big Idea tool both begin with content and build the pedagogy around it. Using this strategy, they encouraged their PSTs to "see into the topic differently" (Bertram and Loughran, 2014, p. 122). The success of this approach suggests a possible alternative to the restructuring of traditional education programs. The alternate could be to center pedagogical instruction around content rather than the current method of instruction on instruction. If the methods class instruction was pedagogy built around

content it could encourage PSTs to consider content a priority when planning a lesson and background could play a lesser role.

Returning to Shulman's basic argument of finding the missing paradigm of content could be a solution to bridging the content – pedagogy gap. Research in this area could help traditional teacher education programs develop ways to make content knowledge more explicit in their methods classes.

The second conclusion concerning the influence of academic and personal backgrounds on teaching priorities is supported by the evidence produced in this study as well as what we know about learning. PSTs do not enter their practicum semester *tabula rasa.* The teaching priority that the prospective teachers bring with them to their education classes filters how they view the instruction offered in those classes (Pajares, 1992).

The PSTs' priorities were a complex integration of their backgrounds. The part of that background that included their own experience with education had been acknowledged to be a significant factor in how they will teach. As noted by Feiman-Nemser (2001), "Conventional programs of teacher education… are not designed to promote complex learning by… students. The typical preservice program is a weak intervention compared with the influence of the teachers' own schooling and their on-the-job experience" (p. 1014).

Although prior education experience is a factor, there are other aspects of background to consider as this study served to illustrate. Max had academic difficulty but grew up in an environment in which he explored the science of his surroundings. His priority was to have his students be "science-minded" and he had little interest in

developing their academic knowledge. Karen was confident in her content knowledge and had a meticulous, detail-oriented nature. Her priority was fulfilling the requirements of lesson structure to get a good evaluation and was initially unconcerned with thinking about content. James's desire to impact the lives of his students extended to his need to be assured they understood the content. He had a precocious awareness of how he needed to understand the content in order to teach it and he had the ability to articulate his concerns.

The last conclusion addresses the heart of this study. The transition of student of science to teacher of science must include understanding that the content the prospective teacher has learned must also transition to the content that the teacher must teach. That transition of academic SMK to school SMK content is fueled by how the prospective teacher thinks about the content. The findings of this study imply that priorities filter how the prospective teachers think about the content they will teach thus codifying the role that priorities can play in future practice. Although academic and personal backgrounds cannot be changed, teacher educators may be able to address how those backgrounds influence teaching priorities. Teacher educators should be asking prospective teachers to examine the nature of their own priorities.

Summary

This study investigated what factors may contribute or hinder the transition of academic content knowledge to school SMK in PSTs. An intervention was introduced in the methods class to stimulate the transition. The intervention was not successful but, as in many cases, the result of the lack of success has provided insight into the problem. The findings, without exception, revealed the teaching strategies introduced were viewed as

content free. In the context of the methods class the content was viewed as propositional and did not stimulate development of school SMK. This finding suggests that more can be done to develop the school SMK of a teacher and it needs to have a more explicit focus.

This exploratory study cast a wide net to find other factors that may influence the way the PSTs thought about content. Although teaching experience was an expected outcome (Abd-El-Khalick, 2006; Arzi, & White, 2008), the influence of priorities was unexpected. Although priorities have been discussed in literature as an expression of beliefs (Pajares, 1992), they have not previously been discussed directly as an influence on practice. Identifying the priorities that PSTs display in planning and implementing plans may be a way of making those priorities explicit. Making them explicit would open discussion about the role that content plays or does not play in their developing practice.

One Last Thought

My study focused on three volunteer participants who, by serendipity, had diverse backgrounds. The diversity itself became significant as data were collected and analyzed in the study. Although diversity played the central role, it would be unconscionable to overlook the contribution that James made as he articulated his journey in understanding *how* he had to understand the content as a teacher. A review of his words is an appropriate finish to this study.

> If you don't have a bigger picture understanding, it's just random facts in your mind. You're not going to be able to communicate with students…. If I don't see a big picture in my lesson plan, if I don't see a lesson plan in the context of the unit, or the context of the class…. I can't guide them, like see

like with the statements they're making and see the validity in them, and help them, kind of push them on the right path. I guess if I'm not standing on the path and know where that path's going then how it twists and turns, then I can't give them good directions…. I need to know the road map. I need to know what the road map looks like in intricate detail and also the big picture so that I can communicate clearly when a student's on the path and, you know, encourage that or when they're getting off a little bit (interview 3).

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APPENDIX A

INTERVIEW PROTOCOLS

Interview 1

1. Questions related to academic background and interest in science.
2. What science content courses in biology have you taken or are currently taking?
3. Is there one particular area of biology that interests you more than any other area?
4. What science content courses outside of biology have you taken?
5. You will be teaching a class on heredity. How will you prepare to teach this class?
6. You will be teaching a class on chemical equilibrium. How will you prepare to teach this class?

Interview 2 – After practice teaching

1. Questions related to background information on lesson taught, school (middle of high), grade level, class, and partner.
2. What was the topic, core idea, of the lesson you taught?
    - Includes description of lesson itself
3. How did the content knowledge in the lesson that you taught compare to the content knowledge described in the curriculum/ standards and the textbook?
4. Did you find that the students were having difficulty in ways that you did not expect?
5. Did you refer to previously learned topics or upcoming topics?
6. Did anything occur during the lesson that was unexpected?
7. Would you change anything if you taught this lesson again?
8. Has teaching this lesson changed the way you think about the science content?

Interview 3 – At the end of the semester

1. Do you think that the content knowledge that you learned in your subject matter classes is useful for teaching?
2. How will you consider content when planning a lesson in the future?
3. I'm going to ask you the same questions about content that I did in the first interview. (The topics from the first interview will be used)
4. Why is this important to the "big picture" that you hope to construct for your students?
    a. What is the core idea behind this concept?
    b. Why is this important to the "big picture" that you hope to construct for your students?
    c. What makes this idea difficult?
    d. What topics should precede this topic and what should follow?
5. What have you learned about content knowledge from discussions during the methods class?
6. What has the experience of teaching contributed to your consideration of content knowledge?

This next set of question is about your understanding of some topics in science. Please be as detailed in your responses as possible. (Students will be asked to answer either Mendelian Genetics or Photosynthesis depending on which topic was previously discussed.)

MENDELIAN GENETICS

1. Can you describe why some traits are expressed in organisms and why some traits are not?
2. I'd like you to give your next responses based on this scenario:

You are in the middle of a series of lessons in which you are teaching students about Mendelian Genetics. You move to a group of students, who are working on a series of genetic problems that you have posed. Most of the problems involve determining the phenotypic outcome of the individuals, from parents who have heterozygous alleles for a trait. The students consistently conclude that the first and second-generation offspring will inherit the dominant characteristic 100% of the time.

3. Why do you think the students are having a problem with this idea?
4. What would you do next, knowing what you know about the students understanding of this topic?
5. What knowledge should students have before this topic is taught, and what could you follow this topic with?

PHOTOSYNTHESIS

6. Can you describe photosynthesis and respiration, and how they are related to one another?
7. I'd like you to give your next responses based on this scenario:

You have been teaching about respiration and photosynthesis for quite a few days. In order to assess your students' knowledge of these processes, you are going to present your students with a drawing that shows a mouse in an airtight container with unlimited food and water, and a plant in a different airtight container with unlimited light and

water. You ask your students to describe what will happen over time. Most of the students respond that, both will live, as both have enough resources for life.

8. Why do you think the students are having a problem with this idea?
9. What would you do next, knowing what you know about the students understanding of this topic?
10. What knowledge should students have before this topic is taught, and what would follow this topic?