

INVESTIGATING SCIENCE TEACHER KNOWLEDGE OF LEARNERS AND
LEARNING AND SEQUENCE OF INSTRUCTION IN AN ALTERNATIVE
CERTIFICATION PROGRAM

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Dedicated to my grandfather Herbert Goldstein. I hope one day my stories will influence someone as much as yours have impacted me.

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INVESTIGATING SCIENCE TEACHER KNOWLEDGE OF LEARNERS AND
SEQUENCE OF INSTRUCTION IN AN ALTERNATIVE CERTIFICATION
PROGRAM

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ABSTRACT

Alternative certification programs (ACPs) have been designed to address the teacher shortage and still meet the goals of science literacy by creating highly qualified teachers. However, science education researchers know little about the development of teacher knowledge during an ACP. The purpose of this study was to investigate how science teacher knowledge of learners and lesson structure develops in an ACP. Data sources included a lesson planning task at the beginning of the program, interviews after the first summer of ACP coursework, and an interview-observation cycle during the teacher's first semester teaching. I constructed profiles of four individuals and generated a set of assertions from a cross-case analysis.

The four prospective teachers developed knowledge of learners from their experiences in the Secondary Science Methods courses, from their mentor teacher, and from working with students. Their ideas about the requirements for learning science and areas of student difficulties expanded from teaching and experiences in the Science Methods courses. The teachers consistently sequenced instruction in ways that gave priority to "inform" types of instruction. They used lectures and teacher-led discussions during inform types of instruction to transmit knowledge to students. Over time, teachers

integrated their knowledge of learners and sequence of science instruction. For the teachers, the integration of knowledge of instructional sequences and learners meant that they purposefully added “practice” types of activities to help students learn terms and concepts. ACP teachers’ science teaching orientations were complex, consisting of multiple dimensions. Although each teacher added goals and/or views of the teacher’s role, their science teaching orientations were highly resistant to change. Prospective teachers’ science teaching orientations acted as a filter for making sense of experiences in the ACP. Three of the teachers embraced experiences and knowledge that aligned with their incoming views that were traditional, and teacher-centered in nature. The other participant drew from multiple experiences and began to restructure his knowledge of teaching to better meet the needs of his students.

CHAPTER ONE: INTRODUCTION

The ultimate goal in science education is that all students achieve science literacy. Science literacy means students leave the K-12 classroom with a broad knowledge and appreciation of science so that they are able to be critical of science, analyze science, and relate new science knowledge to their daily lives (American Association for the Advancement of Science [AAAS], 1989; Bybee, 1997). A scientifically literate person can evaluate science information based on the source and by understanding the evidence, can ask and seek answers to scientific questions derived from curiosity, and can apply knowledge to solve problems (National Research Council [NRC], 1996). Achieving higher levels of science literacy is important because understanding science makes it possible to comprehend the natural world.

Unfortunately, students are not attaining high levels of science literacy. Evidence from many sources, including national and international tests, indicates that students are not scientifically literate. The research on students' images of science and misconceptions emphasizes that students are not gaining an understanding or ability to do science. For example, many K-12 students view the methods used to generate science explanations in science class as separate from everyday life (Driver, Leach, Millar, & Scott, 1996). Even though students are taught science concepts (e.g., phases of the moon, forces of motion, photosynthesis), they leave high school with deeply held misconceptions about many natural phenomena (Driver, Squires, Rushworth, Wood-Robinson, 1994).

Not only are students not achieving science literacy, but numerous reports about the United States educational system and students' achievement in science are distressing. Over 20 years ago the National Commission on Excellence in Education published *A Nation at Risk: The Imperative for Educational Reform* (1983). This publication declared that if a foreign power had imposed the then current state of American education on the U.S., it would have been considered an act of war. This report called for higher education standards and wide scale school reform. More recently, the results of the 2003 Trends in International Mathematics and Science Study (TIMSS) indicated that while U.S. fourth- and eighth-grade students scored above the international average, they were outperformed in science by students from many Asian and European countries (National Center for Educational Statistics, 2003) (see Table 1).

Table 1

U.S. fourth and eighth graders performance in science on the 2003 TIMSS¹

Fourth grade	Eight grade
In 2003, fourth-graders in the United States scored 536, on average, on the TIMSS science assessment, which was higher than the international average of 489	In science, U.S. eighth-graders exceeded the international average and outperformed their peers in 32 of the 44 other participating countries
Of the 24 other participating countries, fourth-graders in 16 countries demonstrated lower science scores, on average, than fourth-graders in the United States, while students in three countries—Chinese Taipei, Japan, and Singapore—outperformed their peers in the United States.	U.S. eighth-graders performed lower, on average, than their peers in seven countries and were not found to perform measurably different from students in five countries.

¹ Note. From “Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003”. By National Center for Educational Statistics. (2005). Washington D.C.: <http://nces.ed.gov/pubs2005/timss03/science1.asp>

Concerns about U.S. students being outperformed by students in other countries have escalated with a changing world economy that demands a workforce with greater education and technical knowledge (National Science Board, 1996). Globalization and the state of the U.S. economy emphasize the need to reform education so that American students are prepared to compete with students from Asian and European countries for knowledge-based occupations.

Research consistently shows that what students learn is greatly influenced by how they are taught (Brophy & Good, 1986). The U.S. Department of Education (2002) described highly qualified teachers as individuals with a bachelor's degree, teacher certification, and a major in the field that they teach. In science education, the *National Science Education Standards* (NSES) [Standards] defines what it means to be highly qualified to teach science. The NSES were developed in part to address the fact that: (1) most science teachers use didactic, traditional methods, and as a result (2) students master sets of disconnected facts instead of gaining a broad conceptual understanding of science (NRC, 1996). The Teaching Standards provide a vision of what science teachers need to know and be able to do to assure that adequate learning experiences take place for all students.

A major component of teacher quality is teacher preparation. Recently, teacher preparation has become a target of reform efforts intended to promote science literacy and challenge current practices. Reforms in teacher preparation emphasize instruction that is active and student-centered. In science education, becoming highly qualified encompasses the changes in teaching outlined in the NSES (see Table 2).

Table 2

Teaching Standards Changing Emphasis (NRC, 1996, p. 52)

Less Emphasis On	More Emphasis On
Treating all students alike and responding to the group as a whole.	Understanding and responding to individual student's interests, strengths, experiences, and needs.
Rigidly following curriculum.	Selecting and adapting curriculum.
Focusing on student acquisition of information.	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes.
Presenting scientific knowledge through lecture, text, and demonstration.	Guiding students in active and extended scientific inquiry.
Asking for recitation of acquired knowledge.	Providing opportunities for scientific discussion and debate among students.
Testing students for factual information at the end of the unit or chapter.	Continuously assessing student understanding.
Maintaining responsibility and authority.	Sharing responsibility for learning with students.
Supporting competition.	Supporting a classroom community with cooperation, shared responsibility, and respect.
Working alone.	Working with other teachers to enhance the science program.

The aim of the standards is to prepare teachers to use instructional strategies that promote environments where students think critically, carry out investigations, and develop scientific explanations. In other words, the focus is on preparing teachers to use instructional strategies that promote student understanding and application of major scientific ideas and fundamental concepts to increase science literacy.

Preparing teachers to teach to the vision of the standards is complicated by the nationwide shortages of highly qualified teachers. The projected need for teachers is greater than the number of teachers who gain teacher certification through traditional teacher education programs (Johnson, Birkeland, & Peske, 2003). Feistritzer, Harr, Hobar, and Scullion (2005) reported that as many as 2.2 million K-12 teaching positions will need to be filled by 2015. Demographic studies describe that the greatest teacher

shortages are in urban and rural areas (Ingersoll, 1999) and in the subject areas of mathematics and science (Abell Foundation, 2001).

A major policy issue at national, state, and local levels is how to address the teacher shortage while preparing teachers to be highly qualified. Some groups seek to significantly reduce college and university-based teacher education to simplify the teacher certification process and alleviate teacher shortages (Cochran-Smith & Fries, 2006). Reducing college and university-based teacher education by shortening the pedagogical preparedness and the fieldwork component of teacher education has been termed the “deregulation” agenda. The deregulation agenda is a push to reform teacher education by decreasing the certification requirements necessary to become a highly qualified teacher.

In response to the deregulation agenda, many educators have designed a new type of teacher education program. Alternative Certification Programs (ACPs) address the teacher shortage and meet the goals of science literacy by creating highly qualified teachers. ACPs have been described by Adelman (1986) as, “Those teacher education programs that enroll non-certified individuals with at least a bachelor’s degree offering shortcuts, special assistance, or unique curricula leading to eligibility for a standard teaching credential” (p. 657). ACPs provide a faster route to obtaining science teacher certification than traditional teacher preparation programs for individuals who have an undergraduate science degree. However, not all ACPs are equivalent in terms of duration, coursework, and fieldwork. One question that remains is whether or not teachers who go through these alternative routes become highly qualified to teach in their subject area.

We can reasonably assume a link exists between teacher preparation, teacher knowledge, and student achievement. However, there is little agreement, and even less evidence, about what knowledge will enable teachers to teach so that students learn science with understanding. The past 30 years mark a shift in educational research from identifying aspects of effective teacher training to understanding the development of teacher knowledge (Cochran-Smith & Fries, 2006). Studies of teacher knowledge aim to better understand the sources of attitudes, beliefs; how teacher preparation influences knowledge; and how teachers learn to teach over time. This study seeks to understand the development of teacher knowledge in an ACP.

Rationale for the Study

The rationale for research conducted within the context of ACPs is twofold. First, securing highly qualified science teachers in public schools is a national concern because students are not obtaining science literacy. Second, the effectiveness of teacher preparation remains mired in debates regarding the ability to improve teacher quality and alleviate teacher shortages. Thus, researching teacher knowledge within an ACP is needed now more than ever before (Zeichner, 2005).

To make sense of teacher knowledge development, it is necessary to break down the conceptual and contextual complexities of professional knowledge. Shulman (1986) proposed that, “scholars must necessarily narrow their scope, focus their view, and formulate a question far less complex than the form in which the world presents itself in practice” (p. 6). Taking this advice, an overarching question and five sub-research questions guide this study.

Overarching Research Question

How does science teacher knowledge of learning and sequencing of instruction develop in an ACP?

Sub-Research Questions

1. What knowledge of learners do teachers have at various points during an ACP (entry, end of summer, end of first semester, end of first year)?
2. How do ACP teachers sequence science instruction at various points of their program?
3. In what ways do ACP science teachers integrate their knowledge of learners and sequence of instruction?
4. What is the nature of ACP teachers' orientations to science teaching at various points of their program?
5. In what ways do the following factors contribute to the development of teachers' knowledge of learners and sequencing of instruction: background experiences, science teaching orientations, and school context?

Conceptual Framework

What is missing from many of studies of secondary teachers' knowledge within a teacher education preparation program is research situated in relation to a well grounded conceptual framework (Zeichner, 2005). The present study is concerned with a type of professional knowledge for teaching called Pedagogical Content Knowledge (PCK). The following sections describe the construct and components of PCK as well as ideas about instructional sequences in science.

Pedagogical Content Knowledge

In 1986, Lee Shulman first proposed a model of teacher knowledge emphasizing that teaching requires more than just subject matter knowledge. Teaching is a complex process that requires teachers to transform and apply knowledge from multiple domains. Shulman (1986) described 7 domains of teacher knowledge to include: “(a) content knowledge; (b) general pedagogical knowledge; (c) curriculum knowledge; (d) pedagogical content knowledge; (e) knowledge of learners; (f) knowledge of educational contexts; (g) knowledge of the purposes, philosophy, and historical grounds for education” (p. 227). Shulman emphasized that effective teachers blend both content and pedagogical knowledge, and transform them into knowledge specific to teaching called Pedagogical Content Knowledge (PCK). According to Shulman (1986), PCK is “teachers’ cognitive understanding of subject matter content and the relationship between such understanding and the instruction teachers provide for students” (p. 25). Thus, PCK is a form of teacher knowledge, distinct from other domains of teacher knowledge, but defined by its relationship to those other domains. Shulman’s view of teacher knowledge emphasized that teaching requires individuals to draw from many sources to develop knowledge for teaching. Additionally, this view stresses the importance of teacher preparation because teacher knowledge is learned through educational courses and developed through experiences with students. Many studies on teacher knowledge have shown that knowledge of content and pedagogy influence how teachers teach (Ball, 1991; Davis, Petish, & Smithey, 2006).

Grossman (1990) built on these ideas to highlight the relationship among three knowledge domains that influence a teachers' PCK. These knowledge domains include: (1) subject matter knowledge and beliefs, (2) pedagogical knowledge and beliefs, and (3) knowledge and beliefs about context. A description of these three knowledge domains follows:

- Subject matter knowledge and beliefs include teachers' substantive knowledge and beliefs and their syntactic knowledge and beliefs. Shulman (1986) described teachers' substantive knowledge to include understandings of facts, theories, concepts, principles, within and between science topics. Shulman (1986) described teachers' syntactic knowledge and beliefs to include teachers understanding of how knowledge is discovered, organized, tested, and debated in the field.
- Pedagogical knowledge and beliefs include teachers' knowledge of classroom management, instructional principles, learners and learning, and educational aims.
- Contextual knowledge and beliefs include teachers' knowledge about the community, students, school and district (Grossman, 1990).

According to Grossman, PCK is a type of knowledge that is transformed from these three knowledge domains (i.e., subject matter knowledge, pedagogical knowledge and contextual knowledge) and is more powerful than its constituent parts (see Figure 1).

Three of the rectangles, subject matter knowledge, pedagogical knowledge, and contextual knowledge use two-way arrows to point to PCK. This means a reciprocal relationship exists between PCK and these three knowledge bases. PCK is transformed from subject matter knowledge, pedagogical knowledge, and contextual knowledge. Furthermore as PCK develops, it influences teachers' subject matter knowledge, pedagogical knowledge, and contextual knowledge (Grossman, 1990). Grossman (1990), in her study of beginning teachers, reported that PCK is developed from the following sources: (a) observation of classes as a student and teacher, (b) specific courses during teacher education, and (c) classroom teaching experience.

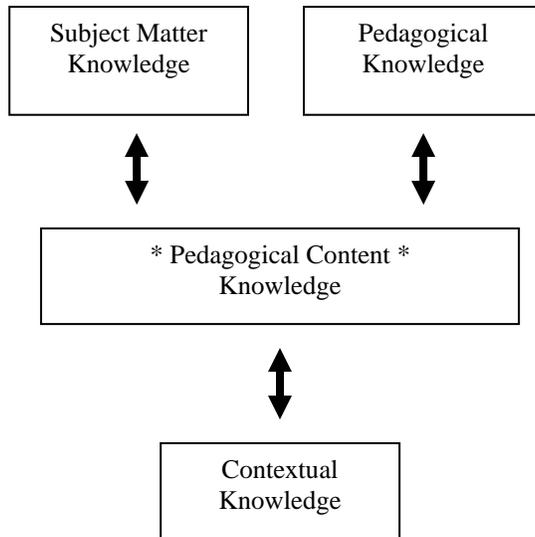


Figure 1. Transformative model of PCK².

Magnusson, Krajcik, and Borko's work (1999) further elaborated on Grossman's model of PCK. Magnusson et al. (1999) described PCK as:

A teacher's understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. (p. 96)

Teachers who can draw on multiple domains of knowledge will have greater ability and effectiveness than those whose knowledge is limited (Magnusson et al., 1999).

Magnusson et al. (1999) conceptualized PCK as consisting of five components: (1) orientations toward science teaching, (2) knowledge of curriculum, (3) knowledge of assessment, (4) knowledge of students' understanding of science, and (5) knowledge of instructional strategies (see Figure 2). A description of the five components of PCK follows:

² Note. From Pedagogical content knowledge: An introduction and orientation (p.12), by J. Gess-Newsome. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education*. Boston: Kluwer. Copyright 1999 Kluwer Academic Publishers.

- Orientations toward teaching science are, “teachers’ knowledge and beliefs about the purposes and goals for teaching science at a particular grade level” (Magnusson et. al., 1999, p. 97).
- Knowledge of curriculum includes: (1) knowledge of goals and objectives for students at and across grade levels, (2) knowledge of curricular resources.
- Knowledge of assessment includes knowledge of methods to assess students’ understanding.
- Knowledge of students’ understanding of science includes: (1) knowledge about students’ prior learning experiences in science, and (2) knowledge of students’ difficulties.
- Knowledge of instructional strategies includes: (1) knowledge of general strategies and approaches to teach science, and (2) knowledge of strategies and approaches used to teach specific topics.

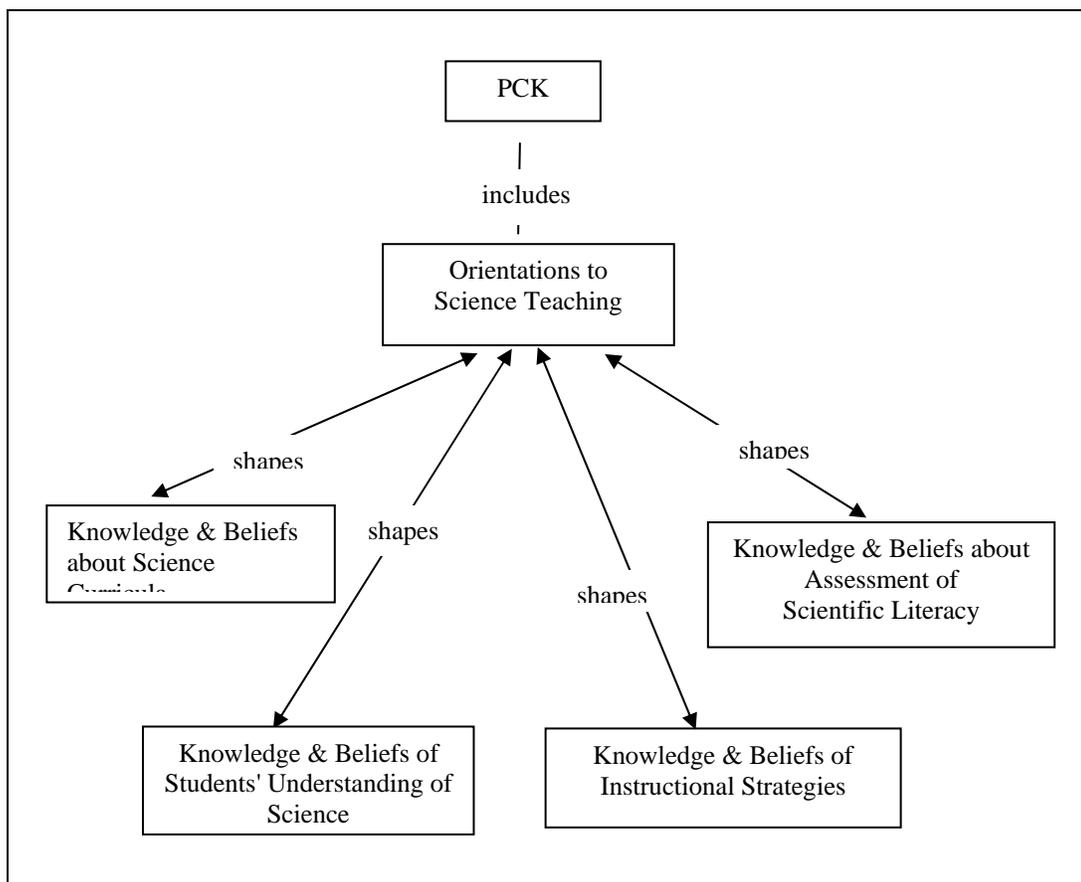


Figure 2. Magnusson et al. (1999) model of PCK3.

³ Note. From Nature, sources, and development of pedagogical content knowledge for science teaching (p.99), by S. Magnusson, J. Krajcik, & H. Borko, 1999. In J. Gess-Newsome & N. G. Lederman (Eds.),

According to the Magnusson et al. model, four of these knowledge components (curriculum, students, assessment, and instructional strategies) influence and are shaped by a teacher's orientation to teaching science. A teacher's orientation guides all of his/her instructional decisions. All five of the components of the Magnusson et al. model are influenced by teachers' subject matter knowledge, pedagogical knowledge, and knowledge of context.

As a researcher, I define PCK as the transformation of subject matter knowledge, pedagogical knowledge, and contextual knowledge into a special type of knowledge unique for science teaching. This view aligns with the one originally proposed by Shulman (1986) in his American Educational Research Association (AERA) Presidential address. This view also aligns with Grossman's (1990) and Magnusson et al. (1999) PCK models. The Magnusson et al. description of knowledge of learners and instructional strategies served as the interpretive lens for examining how teachers' knowledge developed in the ACP under study.

I have modified the Magnusson et al. description of science teaching orientations based on the mathematics education literature (Ernst, 1989; Handal, 2003), science education literature (Koballa, Glynn, Upson, & Coleman, 2005), and research on college science faculty members conceptions of teaching and learning (Samuelowicz & Bain, 1992). I describe science teaching orientations to include teachers' goals and purposes for teaching science, views of teaching and learning, and views of teacher/student roles in the science classroom. I have labeled goals/purposes, views of teaching and learning, teacher/ student roles "dimensions." Both Samuelowicz & Bain (1992) and Koballa et al.

Examining pedagogical content knowledge: The construct and its implications for science education.
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(2005) used this term when referring to teacher/student roles and goals and purposes for teaching science. I use the term “additions” if and when teachers gain views of teaching and learning and/or views of the teacher/student roles and goals. By broadening my definition of orientations to include dimensions and additions, I believe I can better understand how science teaching orientations contribute to the development of PCK.

Sequence of Science Instruction

The second piece of the conceptual framework for this study is concerned with instructional sequences used to teach science. Instructional sequence can be described as the arrangement and combination of activities designed to achieve educational outcomes (Abraham, 1992). The sequence of instruction used to teach is important because it impacts how and what students learn about science (Abraham & Renner 1986; Purser & Renner, 1983; Renner, Abraham, & Birnie, 1988). Recent reforms of science curricula emphasize improving science literacy through the use of instructional strategies that promote active, student-centered learning (NRC, 1996). In order to illustrate the difference between student-centered and a teacher-centered instructional strategy, I describe three instructional sequences that are commonly used to teach science.

Inform-Verify-Practice. The inform-verify-practice (I/V/P) sequence is a teacher-centered strategy that divides instruction into three phases of instruction (Abraham, 1992). The sequence begins with an initial phase where students are *informed* about what they are to know. Often, this is accomplished through lecture or textbook readings. Then students *verify* new knowledge learned from lectures and readings through laboratories or demonstrations. The purpose of verification laboratories and demonstrations are so students can confirm knowledge of concepts, theories, and facts with data. Lastly,

students answer questions or work problems to *practice* their new knowledge in other circumstances. The V/I/P sequence is primarily concerned with the transmission of correct content and information to students. Thus, the I/V/P sequence is teacher-centered in nature and aligns with a traditional science teaching orientation that views teaching as telling and learning as listening.

SCIS Learning Cycle. The learning cycle is a student-centered strategy that was designed to help teachers improve their instructional practices (Bybee, 1997). The learning cycle comes from the *Science Curriculum Improvement Study* (SCIS) curriculum, a primary school science curriculum project that began in the late 1950s (Karplus & Their, 1967). The rationale for the learning cycle followed Piaget's developmental theories and was based on constructivist learning theory (Bybee, 1997). The learning cycle approach divides instruction into three phases: 1) *exploration*, 2) *concept introduction*, (3) *concept application* (Karplus & Their, 1967). The exploration phase is a time to challenge, expose, and make students' ideas explicit. The teachers' role is to provide firsthand experiences to investigate science. Explorations involve laboratory experiences or demonstrations that allow students to collect data. Collecting data is central to science instruction because the experiences provide the basis to later introduce new concepts and terminology. The concept introduction phase is an opportunity for the student and teacher to derive concepts and new terminology from the data (Abraham, 1992). This is a time for students to explain their ideas and for the teacher to provide new ideas that students cannot discover on their own. Finally, the application phase allows students to elaborate and verify their new knowledge in other contexts. This is a chance for the student to explore the usefulness of new ideas in other

circumstances. In contrast to the I/V/P sequence, the SCIS learning cycle is student-centered in nature and aligns with a reform-oriented science teaching orientation that views teaching and learning as the construction of knowledge based on students' firsthand experiences collecting data.

5E Instructional Model. Since Karplus and Their (1967) introduced the learning cycle, several variations have been invented. However, each new version retains the essence of the original learning cycle—exploration before concept introduction. One popular contemporary learning cycle is the 5E instructional model--Engage, Explore, Explain, Elaborate, Evaluate (Bybee, 1997). The middle three phases of the 5E instructional model, Explore, Explain, and Elaborate, parallel the 3 stages of the SCIS learning cycle, exploration, introduction, application. Like the SCIS learning cycle, the sequencing of the phases of the 5E instructional model mimics a natural learning process. During the Engage phase, the teacher provides meaningful and relevant science activities to capture students' interests in learning (Bybee, 2002). This phase engages students in science and provides the teacher the opportunity to assess preconceptions. Engage activities should make connections between past and present learning experiences, and anticipate activities and organize students' thinking toward the learning outcomes of current activities. Next, the explore phase affords opportunities for students to conduct "hands-on" and "minds-on" activities. During this time students explore new science ideas and collect data. Often students begin to realize their prior conceptions are unsatisfactory and seek new understandings. In the explain phase students draw on the engage and explore activities to construct explanations of the phenomenon. The teacher introduces language that is unique to science and different forms of representations

(analogies, diagrams, formulas) to increase student understanding. This process of providing scientific terminology and new representations helps students restructure their prior conceptions. During the explain phase, the teacher “Focus (es) students’ attention on a particular aspect of their engagement and exploration experiences, and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors” (Bybee, 1997, p.178). In the elaborate phase students draw on their experiences in the engage, explore, and explain phase to test and verify new understandings in other contexts, affirming that their new science ideas are valid in other situations. Finally, the evaluation phase is an opportunity for students to reflect on their new conceptions of science and an opportunity for the teacher to evaluate student learning. The evaluation phase is the culminating experience for the learner and is metacognitive in nature meaning that the student has the opportunity to reflect on his or her own learning. The beginning phase of the 5E instructional model, engage, and ending phase, evaluate, are an addition to the 3-stage, SCIS learning cycle instructional model. The 5E instructional model is emphasized in the ACP under study.

Learning Cycle and 5E Instructional Model versus I/V/P Science Instructional Sequence. The key aspect of the learning cycle/5E instructional model is that instruction is sequenced so students have the opportunity to collect data and investigate science before they are introduced to new terminologies and concepts. Thus, the fundamental difference between the learning cycle/5E instructional model and I/V/P sequence of instruction is the positioning of data collection phase in relation to when and how concepts are introduced. In the learning cycle and 5E instructional model approach, the data gathered in the Explore phase are used to formulate concepts in the concept

introduction (learning cycle) or Explain phase (5E). The learning cycle and 5E instructional model are inductive approaches to science learning where students generalize concepts and theories from data collected during laboratory experiences or other direct observation of phenomena.

In contrast, in the I/V/P sequence students are introduced to concepts, theories, and facts first. Then, students generalize these new ideas to their data. The I/V/P sequence is deductive in nature and focuses on students mastering a set of ideas that are disconnected from empirical evidence. In other words, teaching in an I/V/P sequences requires that students attach meaning to what they have been told by carrying out “experiments.”

Sequences like the I/V/P have predominated in science teaching in spite of being incongruent with how students naturally learn science (Cosgrove & Osborne, 1985). Cognitive scientists report that students need to relate new ideas to their experience and place new ideas into a framework for understanding (Bransford, Brown, & Cocking, 2001). Thus, exploring phenomena before explaining them is critical for learning. If teachers start lessons by telling or giving students information, through lecture or textbook readings, students are denied the opportunity to show what they already know and figure out how to find answers for themselves. In this study, the SCIS learning cycle and 5E instructional model served as an interpretive lens for examining how ACP teachers’ sequence science instruction.

Significance of the Study

The U.S. Department of Education (2002) predicts that 1 million K-12 grade teachers will retire in the next 5 to 6 years. More than 2 million teaching positions will

need to be filled (Feistritzer et al., 2005). To address teacher shortages, 48 states have created alternative certification programs (Feistritzer, Harr, Henry, & Ulf, 2006).

Alternative certification programs (ACPs) have been designed to address the teacher shortage and still meet the goals of science literacy by creating highly qualified teachers. These programs require applicants to hold an undergraduate degree and typically move them quickly through teacher preparation into classrooms. Under Federal legislation, *No Child Left Behind* (NCLB), teachers are required to be highly qualified. Additionally, under NCLB teachers are also being held accountable for student achievement. Scores that compare student achievement on mandated state tests to local and national standards are printed in local newspapers. Despite meeting NCLB's credentials for being highly qualified relative to content knowledge, many ACP teachers feel their pedagogical preparedness is inadequate and they need additional support and mentoring (Roehrig & Luft, 2006). Science education researchers know little about the development of teacher knowledge during an ACP. Understanding future teachers' knowledge about science learners and their sequencing of science instruction is critical for improving science teacher education. Within the current accountability context, this study is significant. It addresses the policy issue of alleviating teacher shortages while preparing highly qualified science teachers. The results from this study contribute to what we know about teacher PCK at the beginning of a teacher preparation program and how teacher knowledge develops during an ACP. This study informs the design and/or redesign of ACPs that promote high quality science teaching.

Organization of the Dissertation

This study is divided into six chapters. Chapter One provides a brief overview of the study including the rationale, research questions, theoretical framework, and significance. The theoretical framework includes Pedagogical Content Knowledge and the learning cycle and 5E instructional model. Chapter Two elaborates on these concepts by discussing how they are described in the research literature.

Chapter Three outlines the qualitative approaches used in this study. This includes a description of the research tradition, research methodology, and the design of the study. I included details of the context of the study including the design of the ACP and school demographic data. I also describe data collection strategies and data analysis methods. The chapter concludes with a brief description of the trustworthiness of the design and implementation of the study.

Chapter Four and Five describe the findings of the study. In Chapter Four I provide 4 case profiles of the participants in the study. The purpose of Chapter Four is to provide details for the assertions made in Chapter Five.

In Chapter Five I provide a cross-case analysis and assertions that emerged from the data. Throughout this chapter I refer to the profiles presented in Chapter Four. Additionally, I synthesized data from Chapter Four into tables that are representative of the research participants' knowledge at different points in the ACP.

Chapter Six is the final chapter. This chapter includes a summary of the findings in relation to the research questions and a discussion of the findings relative to the research literature. The chapter concludes with implications for practice and recommendations for future research.

CHAPTER TWO: REVIEW OF THE LITERATURE

In chapter two, I elaborate on the concepts in chapter one, by aligning the research literature to the research questions. These research areas include: (a) PCK for learners and learning, (b) preservice and beginning teachers' PCK for instructional strategies, (c) science teaching orientations, and (d) factors that contribute to teacher development.

PCK for Learners and Learning

This component of the Magnusson et al PCK model refers to teachers' knowledge of the requirements for learning science and areas of student difficulty. Research conducted about prospective teachers' knowledge in this area indicates that their knowledge is limited, but improves over time.

Some studies show that secondary preservice teachers recognize that students' ideas about science are important for learning and teaching (Davis et al., 2006; Russell & Martin, 2007; van Driel, de Jong, & Verloop, 2002; van Driel, Verloop, & de Vos, 1998). Two studies by Van Driel and colleagues aimed to understand how prospective teachers use their PCK for learners. Van Driel et al. (2002) researched how PCK developed in preservice teachers who were learning to teach the chemistry topic of "corpuscular characteristics" on the micro and macro levels. The researchers found that through the act of teaching this content, 10 of the 12 preservice teachers became aware that high school students had difficulty with this relationship. Additionally, half of the preservice teachers were more effective teaching this content when they varied their instructional approaches to include visualizations and models to represent the phenomenon. Van Driel et al. (1998) were interested in how 12 prospective chemistry teachers use both their subject-matter knowledge, and what they learned about students' understanding of

chemistry, to teacher chemical equilibrium. Van Driel et al. (1998) found many chemistry teachers held misconceptions and struggled with teaching chemical equilibrium as a dynamic process. These teachers chose instructional strategies that were ineffective and used metaphors that students found confusing. Through reflection, the teachers' understanding of students' learning difficulties and reasoning improved, and they were able to challenge students to explain the phenomenon.

Even though some studies show that preservice teachers acknowledge that learners have incoming ideas about the content, the research demonstrates that preservice teachers do not consider students' ideas extensively in their teaching practices. In a study of beginning teachers by Simmons et al. (1999), participants believed that students learn science the same ways they learned in school. Tabachnick and Zeichner (1999) investigated how an action research seminar influenced prospective science teachers' knowledge of students' prior conceptions. They found that, over time, prospective teachers were able to elicit students' prior knowledge, but did not know how to use this information to plan their instruction. Geddis, Onslow, Beynon, and Oesch (1993) investigated two secondary preservice teachers' ideas about transforming their science content knowledge about the topic of isotopes into practice. The authors reported that the two participants were surprised that students did not have the necessary prerequisite science knowledge to understand the concepts they were planning on teaching. Their students did not know how to calculate average atomic mass, which was a fundamental concept for teaching the lesson. In Lemberger's, Hewson's, and Park's (1999) case study of three teachers, one of the teachers, Cora, was surprised that students wanted to know the theoretical basis for molecular bonding and were not satisfied just memorizing when

a double bond versus a single is needed. De Jong (2000) reported that prospective teachers were concerned about their own knowledge and how they would teach the relationship between concepts of bond-energy and temperature change. Very few of the preservice teachers voiced a concern with student learning. Similarly, Geddis and Roberts (1998) reported that their participants' strong commitment to transmitting the content to students through lectures and left little room for the consideration of student learning. In a study of 12 prospective Malaysian physics teachers' PCK, Halima and Meerah (2002) reported that many participants were unable to identify misconceptions students might have learning physics concepts and thought that students would have few difficulties with the lesson they had planned.

The studies reviewed in this section suggest that prospective science teachers develop more sophisticated knowledge of learners over time. However, they struggle to put what they know about learners into practice. It is reasonable to assume that as prospective teachers encounter different experiences in teacher preparation, that their knowledge of learners and learning will change. However, the factors that facilitate and constrain this change are not well understood. More studies are needed that investigate the experiences that influence the development of knowledge of learners during their teacher preparation program.

Beginning and Preservice Teachers' PCK for Instructional Sequence

The category of knowledge of instructional sequences strategies within the Magnusson et al. model includes subject-specific instructional sequences like the learning cycle and conceptual change approach. Some researchers have investigated beginning teachers' knowledge of the learning cycle, 5E instructional model, and conceptual change

approach. However, Anderson & Mitchener's (1994) review of the literature on science teacher education indicated that teacher knowledge of specific strategies to teach science is limited.

Most of the research I found on teachers' knowledge of the learning cycle and 5E instructional model was with prospective elementary teachers. Odom and Settlage (1996) assessed preservice elementary teachers understanding of the 3 phases of the learning cycle using a two-tiered test called the Learning Cycle Test [LTC]. The researchers concluded that despite students learning about the learning cycle in methods classes, they lacked understanding of the purposes and activities used in the phases of the learning cycle. In a follow-up study, Settlage (2000) investigated preservice elementary teachers' confidence using a pre/post Self Efficacy Test and the LTC. The preservice teachers in this study experienced, watched, and taught lessons using the learning cycle. Settlage found that preservice teachers self efficacy increased and their anxiety about teaching science decreased. Additionally, he found a positive relationship between preservice teachers' performance on the Learning Cycle Test and their beliefs about their abilities to influence their future students' learning.

Marek, Laubach, and Pedersen (2003) administered the LTC in an elementary science methods course. The authors reported that the preservice teachers learned about the phases of the learning cycle and answered correctly on 80% (exploration), 64% (concept introduction), and 47% (concept application) of the items. However, through conversations with the preservice teachers they found many participants were frustrated by the two-tiered design of the LTC because the responses did not correspond with their

own beliefs and understanding of the phases of the learning cycle. Thus, findings from the LTC should be viewed with caution.

Flick (1996) investigated elementary teachers' knowledge of the Generative Learning Model (GLM). The GLM is a four stage instructional model that begins with the teacher assessing students' knowledge. Next, students have experiences to explore their conceptual understanding and compare and contrast different ideas with evidence. Finally, students apply newly refined ideas in another context. Flick found that elementary teachers had difficulty planning instruction in a GLM and differentiating the GLM from direct instruction.

I found one study that looked at middle level teachers. Duran, McArthur, and Van Hook (2004) investigated 25 preservice students' perceptions of a newly designed, reform-oriented physics course. Duran et al. (2004) found that students struggled with the constructivist nature of the course because it sequenced instruction differently from their prior experiences learning science. Students thought the workload was much greater than in traditional courses and wanted the instructor to give them answers rather than learn through 5E instructional model and inquiry. Additionally, the participants believed that they would not be able to design 5E instructional model from this experience alone. They thought they needed more specialized courses that blended content with pedagogy in order to be able to design and implement 5E instructional models. These findings suggest that the change from lectures to the 5E instructional models takes time and a commitment on behalf of both preservice teachers and science educators.

A number of studies have investigated teacher knowledge of conceptual change approaches. Hewson and colleagues indicated that both prospective secondary and elementary teachers learned about conceptual approaches in teacher preparation course work, but had difficulty implementing a conceptual change approach in practice (Hewson, Tabachnick, Zeichner, & Lemberger, 1999; Lemberger et al., 1999; Marion, Hewson, Tabachnick, & Blomker, 1999). Halim and Meerah (2002) reported that secondary prospective teachers had limited subject matter knowledge and their knowledge of students impacted their ability to implement conceptual change approaches to teaching physics. Yip (2001) studied 16 prospective secondary biology teachers' abilities to implement a conceptual change approach. Yip indicated that preservice teachers' abilities to implement conceptual change approaches improved overtime; however, the participants had difficulty mastering how to respond and teach to students' alternative conceptions so that students developed more accurate scientific understanding.

It seems that prospective teachers have limited knowledge of instructional sequences; however, their knowledge of instructional sequences can improve over time. Marek et al. (2003) addressed the issue of implementing survey techniques to evaluate teachers' understanding of the learning cycle. Researching how and why teachers sequence instruction, and their rationales for their instructional practices through observations and interviews, might deepen our understanding of the relationship among the teachers' understanding of instructional sequences and learning and their practice. Due to the lack of studies with secondary preservice teachers, more research is needed to better understand teachers' knowledge and beliefs about sequencing instruction and how this knowledge develops.

Science Teaching Orientations

It has been recognized that teachers enter teacher preparation programs with beliefs about teaching grounded in their experiences (Calderhead, 1986; Kagan, 1992; Nespor, 1987; Pajares, 1992). These beliefs are thought to act as a “conceptual map” that guide teachers’ instructional decisions (Borko & Putnam, 1986). Within the domain of teachers’ beliefs, researchers have used the labels such as “science teaching orientations” and “conceptions of teaching science” to describe teachers’ thoughts about teaching and learning. A majority of the studies I reviewed acknowledged that “conceptions” and/or “orientations” are types of beliefs.

Anderson and Smith (1987) used the term “orientations” to describe teachers’ “general patterns of thought and behavior related to science teaching and learning” (p. 99). They identified four orientations that describe different approaches to science teaching: (1) activity-driven, (2) didactic, (3) discovery, and (4) conceptual change.

Hewson and Hewson (1987) described “conceptions of science teaching as a:”

Set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature of content of science and the learners and learning which the teacher uses in making decisions about teaching, both in planning and execution. (p. 194)

Hewson and Hewson (1987) suggested that prospective teachers’ “conceptions of science teaching” are reflective of their experiences as students. As part of their work, Hewson and Hewson (1989) designed a task analysis tool to elicit teachers “conceptions of science teaching.” Although Anderson and Smith (1987) used the term “orientation,” and Hewson and Hewson (1989) used “conceptions of teaching science,” their definitions both describe set of beliefs teachers have about science teaching and learning.

Grossman's (1990) included "conceptions of purposes for teaching subject matter" in her PCK model (p. 5). She described this component of PCK as reflective of teachers' goals and purposes for teaching particular subjects. In her study of beginning English teachers, her terminology is comparable to Anderson and Smith's label "orientation."

Magnusson et al. (1999) used the term "orientation" to refer to, "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97). Although they drew on Grossman's (1990) work, they chose the label "orientations." Magnusson and her colleagues identified nine different science teaching orientations: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5) activity-driven, (6) discovery, (7) project-based science, (8) inquiry, and (9) guided inquiry. Magnusson suggested that teachers' science teaching orientation shape all other components of PCK.

One of the difficulties I faced in reviewing the literature is that various researchers have used different terminologies and descriptions for the construct. Additionally, a number of researchers expand the construct of orientations to include nature of science ideas. When possible, I identify how researchers define "conceptions" and/or "orientations" in their study. In studying "conceptions" and/or "orientations," researchers have investigated prospective elementary (Anderson, Smith, & Peasley, 2000) and secondary teachers (Koballa et al., 2005; Mellado, 1998); beginning teachers (Simmons et al., 1999); beginning teachers with professional work experience (Greenwood, 2003); and experienced teachers (Friedrichsen, & Dana, 2002). Researchers have also looked at how a more complex set of "conceptions" influences

prospective teachers' practice (Lemberger et al., 1999), and how a more complex set of conceptions changes over time (Da-Silva, Mellado, Ruiz, & Porlan, 2006; Lotter, Harwood, & Bonner, 2007).

Two studies investigated the relationship among prospective teachers' "conceptions of teaching and learning science" and classroom practice. Koballa et al. (2005) identified five "conceptions" about science teaching held by secondary science teachers in an ACP. These conceptions included: (a) presenting science content to students, (b) providing students with a sequence of science learning experiences, (c) engaging students in hands-on science activities, (d) facilitating the development of students' understandings about science, and (e) changing students' science-related conceptions. They drew on Hewson and Hewson's (1989) description of "conceptions for science teaching" and noted that the terms can be used interchangeable with "beliefs" and "orientations." Koballa et al. argued that ACP teachers' conceptions about science teaching and learning were formed by their prior experiences and acted as barriers because the teachers were reluctant to change them. When the ACP teachers attempted to implement reform-oriented instruction, it created tension with their existing conceptions about science teaching.

Anderson et al. (2000) studied three prospective elementary teachers' development of "conceptions of teaching" during a teacher preparation program. They viewed the terms "orientations," "dispositions," and "conceptions," as interchangeable. They used a metaphor using the terms "trajectory" and "forces" to describe the development of teachers' conceptions of learners and learning and reported that participants in their study came into the program "already moving along a particular

trajectory, seeking to learn about certain aspects of teaching that were congruent with each one's own current conceptions of good teaching and learning" (p.567). The teacher preparation program along with other factors served as "forces" that acted upon individuals' initial orientations. Two of the participants, Mindy and Joanna, entered the program with different trajectories, but left with goals similar to those of the program. Thus, the program influenced these teachers' trajectory towards the orientation of the program. Although the other participant, Greg, realigned his trajectory, his goals were less congruent with the program than Mindy and Joanna.

I found two studies demonstrating that a partial relationship exists between educational "conceptions" and/or beliefs and classroom practice. Mellado (1998) studied the relationship among four prospective secondary science teachers' "conceptions of teaching and learning science" and their classroom practice. Mellado used the terms "conceptions," "beliefs," and "orientations" interchangeably and described that "conceptions" imply a "conviction or value judgment" (p. 198). He reported that the teachers held "constructivist orientations" toward learning. This meant they viewed learning as active and building on and confronting students' prior science knowledge. However, these teachers primarily used transmission types of instruction. Overcoming a transmissionist view of instruction is difficult for preservice teachers. Mellado concluded that he could not establish a clear relationship between teachers' conceptions and/or orientations and their instructional practices. Although not studying orientations explicitly, a number of researchers also concluded that beginning secondary teachers view teaching as transmitting knowledge to students (de Jong, 2000; Geddis & Roberts, 1998; Geddis, 1993; Halim & Meerah, 2002).

Simmons et al. (1999) studied perceptions, beliefs, and classroom performances of beginning secondary science teachers. The authors found that teachers who initially espoused student-centered beliefs actually demonstrated teacher-centered actions. As teachers gained experiences their beliefs and actions became more congruent. Beginning teachers often “wobbled,” or shifted, between student-centered, conceptual, and teacher-centered beliefs about teaching.

Although “orientations” is included in the Magnusson et al. PCK model, very few studies explicitly investigate science teaching orientations. Friedrichsen and Dana (2002) studied the unique contextual influences of the school and teaching setting on four highly regarded biology teachers’ orientations. The researchers used the Magnusson et al. (1999) description of goals and purposes as a starting point for understanding science teaching orientations. However, they cautioned that the theoretical categories of orientations proposed by Magnusson and her colleagues may not match those of prospective science teachers. As part of their work, Friedrichsen and Dana (2003) also developed a card sorting task to elicit and clarify science teaching orientations. They found that the orientations held by these teachers were complex in nature, and included central and peripheral goals. The authors reported that biology teachers’ orientations to science teaching shifted based on the course, topic, and grade level of the student, and informed their implementation of specific instructional strategies. This study points to the complex interaction that takes place between teachers’ science teaching orientation and their instructional decisions.

One study investigated how long-term professional work experiences influenced prospective teachers' orientations. Greenwood (2003) investigated factors influencing the development of three career-changing teachers' orientations. She reported that these individuals held "conceptions of science" that were based on their prior experiences. She interpreted "conceptions of science" as, "reflective of 'science as experienced' rather than the broader and more philosophical ideas about science encompassed in NOS" (p. 230). Thus, her study of orientations also included teachers' views of the nature of science. Greenwood reported that teachers "conceptions of science," derived from their professional experiences, acted as filters for making sense of their experiences in the teacher preparation program. Additionally, the authors reported that teachers' "conceptions of science" strongly influenced their science teaching orientation. Although Greenwood drew on Hewson and Hewson's (1989) work, she did make connections between how her research on orientations is connected to, or builds on, previous studies of science teaching orientations.

Some researchers identified a more complex set of "conceptions" to better understand how prospective teachers' "conceptions" influence practice. In a case study of three secondary preservice teachers, Lemberger, et al. (1999) studied the relationship between "teachers' conceptions of science and science teaching" and their classroom practice. They also included teachers' views of the nature of science in their description of "conceptions of science." The three participants believed that science "truth" is discovered by scientists and the facts of science are described in textbooks. According to this view, they believed that a goal of teaching science is to ensure students receive factual information. The teachers in this study used metaphors like "throwing out" or

“taking in” information. They talked about the responsibility that teachers have in transferring knowledge to students who received the facts of science (p. 369). Thus, the participants’ beliefs about the nature of science knowledge influenced their conceptions of science teaching

Two studies investigated the development of more complex set of “conceptions” with experienced science teachers. Da-Silva et al. (2006) studied how an experienced science teacher named Consuelo held “conceptions of the nature of science” and “conceptions of science teaching and learning” that developed over a 9-year time span. Consuelo’s began her teaching career believing that science teaching was mainly transmitting knowledge, based on her experiences as a student observing her teachers. As a result of teaching experience, Consuelo’s “conception of the nature of science” shifted from a view that science follows a prescriptive science method void from subjective and emotional aspects to a more open-view of a flexible science method that includes both social and emotional factors. With time, her “conceptions of science teaching” also shifted from a teacher-centered, traditional-transmission view, to a more constructivist model that focused on procedures and student learning rather than stressing concepts as a result of working with students. Lotter et al. (2007) investigated the relationship between experienced teachers’ core “conceptions of science,” “conceptions of the purposes of education,” “conceptions of students,” and their “conceptions of effective teaching,” on their implementation of inquiry-based approaches after a professional development experience. All three teachers added inquiry lessons as a result of the PD. However, their enactment of inquiry was related to their 4 core conceptions that acted as filters for their experiences in the PD. The researchers reported that

although two of the teachers' core conceptions changed slightly over time, their core conceptions limited the type of inquiry they used from the PD. These two individuals tended to view science mostly as facts, the purpose of education as transmitting knowledge, students' as having limited abilities, and effective teaching as transmitting information. Meanwhile, the third teacher's core conceptions were characterized as process-oriented, aimed at developing students' problem solving skills, and encouraging independent thought. This participant's core conceptions allowed him to embrace more of the inquiry strategies presented in the PD.

Although the terms "conception," "orientation," and "belief" have been used interchangeably by some researchers, the research indicates: (1) "orientations" and/or "conceptions of science teaching" influence practice (Anderson et al., 2000; Koballa et al., 2005; Lemberger, et al., 1999); (2) prospective teachers come into teacher preparation with strongly held "conceptions of science teaching and learning" that are resistant to change (Anderson et al., 2000; Koballa et al., 2005); (3) prospective secondary teachers view teaching as telling (de Jong, 2000; Geddis & Roberts, 1998; Geddis, 1993; Halim & Meerah, 2002; Mellado, 1998); (4) experienced teachers' "orientations" consist of multiple central and peripheral goals (Friedrichsen & Dana, 2005); (5) "conceptions of science teaching" can change over time (Da-Silva et al., 2006; Lotter et al., 2007); and (6) investigating a more complex set of "conceptions" is useful in understanding teacher practice (Da-Silva, et al., 2006; Lemberger, et al., 1999; Lotter, et al., 2007).

Although orientations are theorized to play a pivotal role in the Magnusson et al. PCK model, few studies explicitly set out to understand the role that science teaching orientations play in PCK development. Thus, investigating the relationship between

science teaching orientation and PCK could shed light on how beginning teachers interpret and assess ideas and experiences that they encounter during teacher preparation.

Factors that Contribute to Teacher Development

Because teachers greatly influence student learning, the quality of secondary science teaching preparation has been a national concern. The Center for Science, Mathematics, and Engineering Education (CSMEE) (1999) put forward a vision of science teacher preparation intended to ensure that teachers are highly qualified. The CSMEE proposed, “All post secondary institutions that prepare teachers will develop and implement mechanisms that encourage collaboration among departments, among postsecondary institutions, and among postsecondary institutions and K-12 schools” (p. 2). The NSES (1996) described science teaching professional development as a “continuous, lifelong process (p. 56)” that begins with teacher preparation. However, a number of researchers address the current issue that many teacher preparation programs provide disconnected experiences that influence what prospective teachers learn about teaching and learning. Feiman-Nemser (2001) criticized typical preservice teacher preparation programs as “weak interventions compared to the influence of teachers’ own schooling and their on-the-job experience” (p. 1014). Goodlad (1990) noted that many teacher preparation lack connectedness with other university programs and K-12 education. Kahle and Kronebusch (2003) called science teacher education “fractured” and reported that “often undergraduate programs do not adequately connect content knowledge to pedagogy in meaningful ways” (p. 590). However, Anderson and Mitchener (1994) have noted in their review of science teacher education research that “there is a ... small amount of research on preservice education [and what exists] is rather

limited in scope and usefulness” (p. 28). In studying the factors that contribute to science teacher preparation, researchers have investigated the impacts of methods courses and field experiences on teachers’ knowledge and practice.

Methods Courses

Debates exist as to the influence of science methods courses on preservice teachers’ knowledge and practice. A number of studies indicate that positive experiences in teacher education may improve prospective teachers’ understanding of science teaching. Adams and Krockover (1997a) investigated four beginning science teachers’ knowledge about teaching and learning during their first 3 years teaching. They reported that aspects of the science methods courses eventually translated into practice. For example, one of the teachers, named Bill, exhibited traditional and didactic practices his first 2 years teaching. However, during his third year he implemented more conceptual learning teaching practices. He credited his shift from teacher-centered to student-centered instructional practices to his experiences learning about constructivist teaching in the methods courses. Zembal-Saul, Blumenfeld, and Krajcik (2000) found that using multiple cycles of planning, teaching, and reflection, during a science methods course, helped preservice elementary students improve how they organized science instruction around science concepts. Van Zee (1998) studied how prospective elementary students learned how to conduct research in science methods courses. She found that participants’ experiences with an extended research project helped them integrate science content knowledge with their knowledge of learners and learning and inquiry-approaches to teaching science. Abell and Bryan (1997) described four contexts for reflection that help prospective elementary teachers examine and refine their beliefs about teaching and

learning during a methods course. These areas include: (1) students reflecting on media cases of conceptual change science teaching, (2) their own teaching in field experiences, (3) experts' opinions from course readings, and (4) themselves as science learners as they participated in science learning activities.

However, studies also indicate that science methods courses have little impact on preservice teachers' practices of reform-oriented science teaching when they enter the field (Zeichner & Gore, 1990). For example, Hewson and colleagues investigated the development of teacher knowledge of conceptual change approaches and learners across an entire teacher preparation program. They found that although teachers in their study learned about conceptual change approaches in methods courses, they were unable to use them in practice (Lemberger et al., 1999; Marion et al., 1999). Windschitl (2002) investigated secondary preservice teachers' conceptions of inquiry. He found that for these individuals, previous meaningful research experiences, not experience with using inquiry during their teacher internship, predicted their inquiry teaching practice. Demir (2006) investigated beginning secondary teachers' views of inquiry. He found differences between the teachers' views of inquiry and the faculty members views who taught their science methods courses. Demir reported that the program staff described the 5 essential features of inquiry across the continuum of inquiry (NRC, 2000). However, prospective secondary teachers perceived inquiry as being student-directed and unstructured, meaning that students were not provided with teacher guidance. Crawford (2007) studied five prospective teachers' knowledge, beliefs and implementation of inquiry. She reported that although all of the prospective teachers learned about inquiry in science methods courses, they lack a clear idea of how to implement inquiry in their

teaching practice. Settlage (2000) found that the elementary science methods course increased students' confidence in their abilities to teach science, while not significantly increasing their knowledge of reform-oriented practices. Geddis (1993) reported that exposing preservice teachers to typical students' misconceptions and teaching strategies was insignificant for developing knowledge of conceptual change approaches. Preservice teachers needed the opportunity to engage in reflection and brainstorming ideas. These findings resonate with conclusions from Clift and Brady's (2005) review of the literature on teacher preparation that prospective teachers have difficulty enacting the strategies they learn in science methods courses in practice.

Four studies reported prospective teachers' perceptions of their science methods courses (Adams & Krockover, 1997b; Geddis & Roberts, 1998; Mellado, 1998; van Driel et al., 2002). van Driel et al., (2002) reported that prospective secondary chemistry teachers believed readings and discussions in the University-based workshop had only a modest influence on their knowledge. Geddis and Roberts (1998) investigated how a preservice teacher, Kevin, thought the theory portion of the coursework--constructivism--was least helpful in his development as a teacher, because he believed it added little practical value to teaching. Mellado (1998) reported that three of the four prospective secondary teachers he studied believed that teacher education had little to no influence on their practice. Beginning teachers in Adam's and Krockover's (1997b) study believed that pedagogical course work had limited usefulness.

Field Experiences

Field experiences may contribute to improved understanding of teaching because prospective teachers are working with students. Two studies by Eick and colleagues

investigated whether coteaching with an inquiry-oriented mentor/cooperating teacher improves teachers learning to teach in reform-minded ways. Eick, Williams, and Ware (2003) were interested in the knowledge preservice teachers gain from authentic coteaching experience. They reported: (1) coteaching makes preservice teachers feel more comfortable (assertiveness and confidence); (2) preservice teachers were able to reflect, learn and make adjustment during a coteaching experience; (3) preservice teachers learned on-the-spot during real-time; (4) preservice teachers focused on teaching, not planning; and (5) inquiry teaching is effective and possible. In another study of the impact of coteaching on preservice teachers' learning about teaching, Eick and Dias (2005) found that methods students were able to model their mentor teachers' style and use structured-inquiry. Over time, they began to see the value in actively engaging students in inquiry and learned how to manage an inquiry-oriented classroom; at the end of the semester they used what they learned in practice about students.

However, the linkage between mentor/cooperating teachers, methods instructors, and supervisory personnel seems to be critical in the development of teacher knowledge of reform-based instructional strategies. Some field experiences are limited in their success in providing a venue where prospective teachers can realistically "test" the ideas they learn in methods courses. Puk and Haines (1999) investigated students' experiences with inquiry-based teaching in their semester-long teaching practicum. They found that although preservice teachers learned about inquiry, designed inquiry, and taught an inquiry-lesson in their preservice program, students that observed their mentor teachers using inquiry were more likely to implement inquiry themselves. In their study, only 25% of prospective teachers observed their mentors using inquiry during their field

experience. Crawford's (2007) study reported that the mentors beliefs and preferred instructional strategies influenced prospective teachers' practices. For example, some of the mentor teachers' styles were perceived to be lecture-driven, very structured, and rigid. In these cases, interns were reluctant to take risks and try out inquiry-based instruction. In a paper addressing prospective teachers' experiences in field internship, Feiman-Nemser (2001) reported, "Cooperating teachers often feel the need to protect students from 'impractical' ideas promoted by education professors who are out of touch with classroom realities" (p. 1020). In these cases, the field experiences undermined the effects of the science methods courses.

One study followed beginning teachers after the completion of their teacher preparation program. Adams and Krockover (1997b) found that their participants did not believe they were prepared to teach as a result of their preservice programs. The four beginning teachers in their study did not feel their preservice programs prepare them to teach outside their subject area and design curriculum; they were concerned about time management, discipline/classroom management, and how to present content (instructional strategies and what subject matter to teach). They believed that their coursework was too specific to prepare them. During the beginning years of teaching, these individuals used conventional teaching styles that focused on procedures rather than student understanding. These findings resonate with Kagan's (1992) review of professional growth of preservice and beginning teachers reporting that beginning teachers, in general, are often overwhelmed by the number of responsibilities and have difficulty implementing what they learned in their teacher education programs.

The findings of research on science teacher preparation are mixed. The conflicting reports suggest that we know little about how teacher preparation influences the development of PCK. Many prospective teachers believe the field experience component is the most beneficial part of their teacher preparation. However, Abell's (2006) review of field experiences in elementary science teacher preparation reported "despite the wide spread use of field experiences in association with elementary teacher preparation, the empirical support for field experiences is weak" (p. 72). It seems that when the components of teacher preparation (i.e., methods courses, field experiences, supervisor personnel) are disconnected, the development of prospective teachers' knowledge is limited. Although methods instructors may model reform-based instructional practices (e.g., conceptual change approach), the constraints of many field internships limit the opportunities for prospective teachers to teach in reform-minded ways. The research also shows that when prospective teachers are linked with reform-oriented mentor teachers in their internship, they may have more opportunities to practice instructional strategies that they learned about in methods courses. However, follow-up studies are needed to determine whether teachers who learn and practice inquiry through coteaching in field experiences use inquiry as beginning teachers. Due to the unique contexts and design of teacher preparation programs, Clift and Brady (2005) call for more research situated within a well-developed theoretical framework to better understand the impact of experiences during teacher education on teacher knowledge.

Gaps in the Literature

Although PCK has been accepted as a theoretical construct for investigating teacher knowledge, there are few examples in the science education literature to illuminate how PCK for learners and instructional sequence develops in prospective secondary teachers. In their review of the literature on PCK, van Driel et al. (1998) suggested that PCK is a type of teacher knowledge called “craft” knowledge, derived from teachers’ personal backgrounds, that develops with experience. They stated that craft knowledge “represents teachers’ accumulated wisdom with respect to their teaching practice” (p. 674). Few researchers have examined the interaction between components of PCK over time to gain a more holistic view of the development of teacher knowledge. No studies include a thorough investigation of orientations, PCK for learners, and PCK for instructional sequences. Investigating teacher knowledge development and integration based on these three components is a promising lens to view the development of PCK. Veal and MaKinster (2001) suggested that PCK is multifaceted, does not develop in a linear fashion, and a hierarchal relationship exists among components. Qualitative studies like this one that combine interviews and observations to investigate science teaching orientations, PCK for learners, and PCK for instructional sequences may shed light into the development of PCK.

CHAPTER THREE: THE RESEARCH PROCESS

Research Questions and Tradition

The purpose of this study was to: (a) investigate how teacher knowledge of learners and sequence of science instruction develop in an Alternative Certification Program (ACP), (b) study the relationship between teachers' knowledge of learners and how they sequence science instruction, and (c) describe the factors that influence teacher knowledge. The overarching research question was: How does science teacher knowledge of learners and sequence of instruction develop in an ACP? In order to answer the overarching question, I developed the following sub-questions.

1. What knowledge of learners do teachers have at various points during an ACP (entry, end of summer, end of first semester, end of first year)?
2. How do ACP teachers sequence science instruction at various points of their program?
3. In what ways do ACP science teachers integrate their knowledge of learners and sequence of instruction?
4. What is the nature of ACP teachers' orientations to science teaching at various points of their program?
5. In what ways do the following factors contribute to the development of teachers' knowledge of learners and sequencing of instruction: background experiences, science teaching orientations and school context?

These research questions focus on teachers' knowledge and my interpretations of their knowledge as related to practice. A constructivist qualitative research tradition and case study methodology guided the design and implementation of this study.

Constructivism

The term constructivism refers to both a theory about learning and knowledge and what “knowing” means. Historically, constructivism originated as a learning theory in cognitive science that explained how individuals incorporate new knowledge (Ferguson, 2007). In educational research, a constructivist methodological paradigm allows researchers to investigate knowledge by serving as a theoretical framework for describing the nature of knowledge, reality, and truth.

A constructivist research perspective suggests that knowledge is co-constructed between research participants and researchers. Denzin and Lincoln (2005) describe the aim of constructivism as “understanding” and “reconstructing knowledge.” The nature of knowledge is such that it is “individually” or “collectively reconstructed” and “sometimes coalesces around the consensus” (p. 194-196). Thus, constructivist studies are best suited for research that aims to understand individuals’ beliefs and knowledge (Ferguson, 2007)

Constructivism assumes that knowledge is embedded in the context and is relative rather than absolute. Individuals construct knowledge about reality, not reality itself; therefore all realities are meaningful realities (Patton, 2002). In this regard Patton (2002) suggested that, “Constructivists study the multiple realities constructed by people and the implications of those constructions for their lives and interactions with others” (p. 96). Individuals, with different past experiences and contextual influences, will construct knowledge differently. Constructivists do not seek a singular and universal “truth.” Rather, constructivists work to describe knowledge and look for patterns. They assume that “truth” is relative to the individual and not bound by time or space. Ferguson (2007)

tells us that, “Most constructivists do not question the existence of reality, they only question our ability to *judge or know* reality” (p. 29-30, italics in the original).

Constructivism provides a basis for understanding how people incorporate new knowledge into existing knowledge and how they make sense of that knowledge (van Glaserfeld, 1992). For this study, I adopted a constructivist research tradition, recognizes that meaning is constructed by individuals and that multiple realities occur in real-world settings (Denzin & Lincoln, 2005; Patton, 2002). A constructivist tradition assumes certain unique philosophical principles-epistemological assumptions, ontological assumptions, and methodological assumptions. By using a constructivist tradition and a case study methodology, I assume a subjectivist epistemology (knower and respondent construct personal understanding), ontological relativity (multiple realities exist), and naturalistic methodological procedures (Denzin & Lincoln, 2005; Patton, 2002).

Epistemological Assumptions. To study the ways in which people construct knowledge the researcher must recognize that knowledge is unique to the individual. A constructivist tradition assumes that knowledge is individually constructed and filtered through past experiences and personal beliefs (Denzin & Lincoln, 2005). Individuals construct knowledge about reality, not reality itself. Regardless of whether this knowledge is true or false from the researcher’s perspective, it is true to the individual and their personal reality. I assume a subjectivist epistemology and view my role to know the perceived realities of an individual (Denzin & Lincoln, 2005). My participants and I co-construct personal understanding. The co-construction of knowledge was achieved through collecting data from multiple sources over time. In this study, I focused on teacher knowledge of learners and sequencing of science instruction by conducting

interviews with each participant. I also observed their teaching in order to better understand their realities. I clarified my interpretations by asking questions and observing participants' teaching practices.

Ontological Assumptions. Related to the epistemological assumptions of a constructivist paradigm are the ontological assumptions that different perspectives or multiple "realities" exist for what constitutes knowledge. Patton (2002) explained, "Constructivists study the multiple realities constructed by people and the implications of those constructions for the lives and interactions of others" (p.96). Two people do not construct exactly the same knowledge from similar experiences. Knowledge develops as an individual encounters more evidence. Individuals construct knowledge based on their personal experiences that are context-dependent. Thus, all realities are meaningful realities (Patton, 2002). The multiple realities in this study include both those of participants and the researcher.

Even though all of the participants enrolled in the same coursework in the ACP, their background experiences and internships vary greatly. Maintaining a constructivist perspective allows me to make sense of individual teachers' knowledge related to their individual beliefs and experiences (Denzin & Lincoln, 2005). Lincoln and Guba (1985) suggested that, "Phenomena can only be understood within the context in which they are studied; findings from one context can not be generalized to another; neither problems nor solutions can be generalized from one setting to another" (p. 44). I can only know ACP teachers' realities related to their background experiences and contexts. I cannot generalize their knowledge to other teachers in unique teaching contexts.

Context of Study

This study took place within an ACP called “Science and Mathematics Academy for the Recruitment and Retention of Teachers” (SMAR²T). SMAR²T is a two track program. In one track, ACP interns are placed in local secondary classrooms for a year-long, guided internship (APB) where they observe and student teach 20 hours a week in a mentor teacher's classroom. The second track, the independent internship (ALT), is for individuals who are full-time classroom teachers teaching with temporary certification

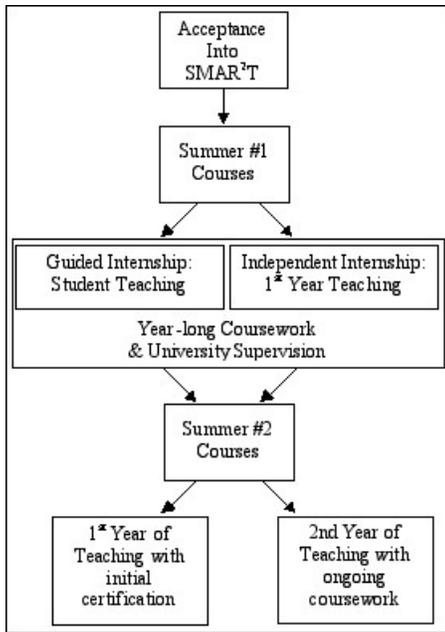


Figure 3. Alternative Certification program (ALT) and Accelerated Post Baccalaureate program (APB) tracks of ACP.

The APB program is designed for individuals with an undergraduate degree in science or a related area who desire a high quality teacher preparation program in an accelerated time frame. Interns attend two concentrated summer sessions on campus and spend one school year interning in a guided setting at a partner school (20 hours per

week), during which they take coursework and are part of a learning community with other interns, mentor teachers, and faculty members (see Table 3).

Table 3

Timeline of APB Program

Summer Year 1	Fall Year 1	Spring Year 1	Summer Year 2
Advanced Educational Foundations of Teacher Preparation (8 credits)	Teaching, Learning and Research in Secondary School Science II (3 credits)	Teaching, Learning and Research in Secondary School Science III (3 credits)	Integrating Mathematics and Science Instruction (2 credits)
Teaching, Learning and Research in Secondary School Science I (3 credits)	Reading in the Content Areas (2 credits)		Complete Portfolio and Action Research
	 1 School-year internship for fall and spring semesters (20 hours per week) (8 credits)		

The ALT program is designed for individuals with an undergraduate degree in science who are teaching full time in a school district with a Missouri Temporary Authorization Certificate. ALT teachers attend 2 concentrated summer sessions and spend 2 school years as full time teachers (see Table 4).

ACP candidates are screened through a comprehensive process to ensure that high quality individuals are accepted into the program. These measures include undergraduate grade point average (GPA), Graduate Record Examination (GRE) scores, letters of recommendation, and a written statement. To be admitted into the ACP, students must have: (1) a minimum 2.75 GPA overall GPA or higher, (2) a 2.5 GPA or higher in science content courses, and (3) a minimum combined GRE score of 1000. After admissions into the program, all students must pass the Praxis II for Biology with a score

of 150 in order to qualify for certification. Upon completion of the ACP program, teachers receive full state certification and a Masters degree in Education (M.Ed).

Table 4

Timeline of ALT Program

Summer Year 1	Fall Year 1	Spring Year 1	Summer Year 2	Fall Year 2	Spring Year 2
Advanced Educational Foundations of Teacher Preparation (8 credits)	Teaching, Learning and Research in Secondary School Science II (3 credits)	Teaching, Learning and Research in Secondary School Science III (3 credits)	Integrating Mathematics and Science Instruction (2 credits)	Reading in the Content Areas (2 Credits)	Complete Portfolio and Action Research
					
2 School-year internship (11 credits)					

Secondary Science Methods Courses

Both APB and ALT teachers take three Secondary Science Methods courses. While the courses have different class assignments and topics, they all address the nature of science, the nature of science learning, and the nature of science teaching. Within these three areas, the courses highlight knowledge of student-centered instructional sequences and knowledge of learners and learning. Table 5 shows the instructors goals related to knowledge of instructional sequences and learners and learning that are addressed in each course.

Table 5

Secondary Science Methods Course Goals

Course:	Goals:
Secondary Science Methods I (Summer 07)	<ul style="list-style-type: none"> • Future science teachers will develop a deeper understanding of the nature of science; the meaning of theory, principle, and law; the tentativeness of scientific knowledge; the role of "truth" in science; and the nature of inquiry. • Future science teachers will gain experience and develop a deeper understanding of students' conceptions and explanations about a variety of scientific phenomenon. • Future science teachers will reflect on how science teachers can model and support school science inquiry. • Future science teachers will become aware of instructional models that focus on conceptual change.
Secondary Science Methods II (Fall 07)	<ul style="list-style-type: none"> • Further deepen our understanding of how people learn through review/reflection on the first course experiences and additional readings in <i>How People Learn Science</i>. • Develop a working understanding of the design and rationale of the 5E Instructional Model. • Design science lessons using a variety of teaching strategies. In this class we will focus on discrepant events, inquiry labs, and interactive lectures. • Do the initial planning for a curriculum unit and collect teaching resources.
Secondary Science Methods III (Spring 08)	<ul style="list-style-type: none"> • Enhance your understanding of the nature of science and scientific inquiry through the development of model lessons. • Design and use pre-instructional, formative and summative assessments to inform teaching practice at each step of an instructional sequence. • Design an instructional sequence informed by current learning theory, the National Science Inquiry Standards, and the Missouri Grade Level Expectations.

ACP Scholarship

During the application process applicants may be eligible for a \$10,000 Noyce stipend based on academic merit and financial need. To qualify for a Noyce stipend student must meet or exceed academic qualifications which are similar to the ones for admission into the ACP. These qualifications include: (1) Undergraduate overall GPA of 2.75, (2) GPA in science content courses of 2.50, and (3) GRE combined verbal and

quantitative score of 1000. Priority for Noyce stipends are given to students who demonstrate financial need. Recipients of Noyce stipends must complete two years of science teaching in a high need school district within six years after graduation or completion of the program.

Re-SMAR2T

This study took place within the context of a larger National Science Foundation (NSF) funded project, “Researching Science and Mathematics Teacher Learning in Alternative Certification Models” (Re-SMAR²T). Re-SMAR²T is a 5- year project investigating how teacher knowledge develops in two tracks of an ACP located at a research extensive institution in the Midwest. The goals of Re-SMAR²T are to: 1) advance the knowledge base regarding teacher preparation in an alternative certification program; 2) advance the knowledge base regarding teacher learning in field-based settings; 3) understand the factors that facilitate and constrain teacher learning; and 4) train a new generation of researchers in teacher knowledge research.

Researchers in Re-SMAR²T aim to better understand the factors that facilitate and constrain teacher learning in these two tracks. The team is collecting longitudinal data from three cohorts of science teachers at 4-5 points during the ACP and into their first year of teaching. The teams conduct 8 interviews, 4 classroom observations, 2 written reflections, and a lesson planning task with each ACP teacher.

My Role in Re-SMAR2T

As a Graduate Research Assistant (GRA) working in the context of Re-SMAR²T, I participated in all aspects of research design, data collection, and initial analysis. I was involved with designing and revising the interview and field observation protocols. Over

2 years of data collection, I collected classroom data for 4 interns and 2 teachers, and conducted more than 20 interviews. By May of 2008 I will have completed the classroom observation cycle for 8 interns and conducted more than 40 interviews. During data analysis in year 1, I coded a significant portion of the data and made considerable contributions to the first conference manuscript from the project.

As part of the Re-SMAR²T project, I became interested in investigating some new questions that were beyond the scope of the original research project. In particular, I wanted to research how teacher knowledge of learners and their sequencing of instruction developed in the ACP under study.

Participants

The participants in this study were four interns who I identify with the pseudonyms Jason, Mary, Amy, and Lilly. All four interns were in their early twenties and have similar ethnic backgrounds (see Table 6).

Table 6

Participants' Personal Data

Pseudonym	Personal Data		
	Age	Gender	Ethnicity
Jason	24	Male	White (Non-Hispanic)
Mary	23	Female	White (Non-Hispanic)
Amy	26	Female	White (Non-Hispanic)
Lilly	23	Female	White (Non-Hispanic)

Although all four participants earned undergraduate degrees (BA or BS) in biology, there were differences in their undergraduate academic record, whether they received a Noyce stipend, and prior experiences. For example, although all 4 participants met the program requirements, there were differences in their cumulative GPA, content

GPA, GRE scores, whether they received a Noyce stipend, and Praxis II scores.

Additionally, only Lilly earned undergraduate minors (see Table 7).

Table 7

Participants' Academic Record

Pseudonym	Undergraduate Degree(s)	Undergraduate Grade Point Average (GPA)		Graduate Record Examination (GRE)		Praxis II Score	Noyce Stipend
		Cumulative	Science	GRQ (% ile)	GRV (% ile)		
Jason	BS Biology	3.20	3.051	0650 (57% ile)	0410 (33% ile)	165	No
Mary	BS Biology	3.618	3.503	0600 (46% ile)	0440 (42% ile)	163	Yes
Amy	BA Biology	3.135	3.093	0610 (48% ile)	0460 (48% ile)	150	Yes
Lilly	BA Biology Minors: French; Chemistry	3.727	3.688	0740 (78% ile)	0490 (56% ile)	168	No

Note. State pass score on the Praxis II in biology is 150.

Other differences among participants included self-reported prior experiences with children and experiences that reflect their organizational leadership. For example, Jason had served as a Boy Scout instructor and Young Life Leader; Mary had been a nanny and camp counselor; Amy was employed as a permanent substitute teacher for grades K-12, worked as an assistant soccer coach, and was a camp counselor; and Lilly was an after school tutor and a mentor with the Big Brothers Big Sisters program and Women of Worth (WOW).

Purposeful Sampling

I purposefully selected these four individuals from all of the interns in the ACP based on my background as a science teacher and research interests. First, I selected only interns in the APB track (see Figure 3). Second, because most of the APB interns are biology teachers, and because my background is biology teaching, I selected only interns

who teach general biology at the secondary level. It is important for the researcher to have a strong background in the content as PCK is a specialized knowledge base for teaching that draws upon an individual's knowledge of subject matter (Shulman, 1986). Third, APB teachers have the option of obtaining dual certification for both middle and secondary level. Because interns seeking dual certification interact with two different mentors, at two different schools, their experiences are assumed to be significantly different from teachers obtaining only secondary certification. I selected only secondary interns to minimize the effects of multiple mentors and two different schools on teachers' knowledge development. These four participants were selected because they are enrolled in the same track of the ACP and have similar academic backgrounds. Thus, understanding the factors that influence teacher knowledge of learners and sequence of science instruction (e.g., background experiences, orientations, and contextual factors) makes these four interns ideal cases to study.

Participant schools/districts

The contexts in which these four interns served their internship occurred in two different school districts in central Missouri. All high school names and the school district names are pseudonyms. Three of the interns, Mary, Amy, and Jason, taught at two high schools in the same school district. Mary and Amy taught at Rover High School and Jason taught at Harris High School. Both high schools are in the Cambridge School District. Lilly taught at Monroe High School in the Monroe School District.

According to demographic and census data, although both school districts served different size communities, they had comparable graduation rates, student per classroom ratios, and percentages of minority students with each other and the state (Department of

Elementary and Secondary Education [DESE], 2007; U.S. Census Bureau, 2006) (see Table 8).

Table 8

Comparison of Societal Factors between Participants' School Districts and with the State

District	Societal Factors (2000 Census)	
	Population Served	Average Household Income
Cambridge (Harris and Rover)	112,784	\$49,576
Monroe	15,554	\$42,805
State	5,842,713	\$40, 885

However, there were differences in the high schools in terms of the percentage of students that received Free/Reduced Lunch (FRL). Both Harris and Monroe have more students receiving FRL than Rover. Harris had twice as many students, and Monroe had nearly three times as many students receiving FRL as Rover. All three high schools are below the state average rate for students receiving FRL (see Table 9). All three high schools also had different ethnic diversity. Table 10 shows the ethnic diversity present in each school district.

Table 9

Comparison of Contextual Factors in Participants' School Districts and the State

Context Factors (2006-2007)				
School Demographic Information				
High School	Enrolled	Graduation Rate (%)	Free/Reduced Lunch (FRL) (%)	Student/Staff Ratio
Harris	2,038	82.4	24.0	16/1
Rover	1,717	88.7	11.4	18/1
Monroe	803	87.4	31.0	19/1
State	900,021	85.7	41.8	18/1

Table 10

Comparison of Ethnic diversity in Participants' School Districts and the State

Context Factors (2006-2007)					
School Demographic Information					
High School	White (%)	Black (%)	Hispanic (%)	Indian (%)	Asian (%)
Harris	69.00	22.90	3.00	0.40	4.70
Rover	81.10	11.10	2.60	0.30	5.00
Monroe	87.20	9.50	2.00	0.20	1.10
State	79.0	17.5	2.0	0.3	1.2

An analysis of graduates in the participants' high schools showed differences in the career paths students tend to take after high school graduation (see Table 11). Most notably is the difference between students that enter a four year college from Harris (71.50%) and Rover High Schools (76.10%) compared to the Monroe High School (37.70%).

Table 11

Graduate Analysis of Students in Participants' School Districts and with the State

Graduate Analysis ⁴							
High School	4yr. College/ University	2yr. College/ University	Post-Secondary (Non-college) Institution	Work Force	Military	Some Other Field	Status Unknown
Harris	71.50	11.40	4.10	5.30	1.50	2.00	4.10
Rover	76.10	12.50	3.10	3.50	2.00	0.90	2.00
Monroe	37.70	27.20	4.60	10.60	3.30	0.00	16.60
State	39.2	25.7	4.2	19.2	3.1	3.1	5.3

Note. Numbers represent percentages.

*Design of the Study**Case Study Approach*

I selected a case study approach to guide my collection and analysis of data. I used a case study approach in conjunction with a constructivist research tradition to study the unique background experiences and contextual factors as well as teachers' knowledge development. Traditionally, case study is used to investigate "how" and "why" questions. "How" and "why" questions seek to make sense of the operational links that individuals make over time, rather than at a single incidence (Yin, 1994). A case study is an inquiry of a bounded system over time, through the collection of multiple data sources (Denzin & Lincoln, 2005; Stake, 2005).

In case study research, the "case" is the main unit of analysis and constitutes a specific way of collecting, organizing and analyzing data (Stake, 2005). The focus of case study research is to describe the unique contextual settings of the cases and describe themes that emerge that differentiate or unite settings and/or participants. In case studies,

⁴ Retrieved from <http://dese.mo.gov/schooldata>

the researcher uses multiple data sources to construct a holistic and meaningful representation of participants' experiences (Stake, 2005).

A case study methodology can be used to study individuals, a group, cultures, or an organization (Stake, 2005). When choosing cases, researchers often use a purposeful sampling approach to identify cases they view to be "information-rich." Patton (2002) suggests, "Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term *purposeful* sampling" (46, italics in the original).

Each of the four interns represents a unique case that is influenced by their past experiences and factors associated with their teaching contexts. Yin (2004) would describe this study as a multiple case study because my goal was to better understand how each of individual interns constructs knowledge of learning and sequencing of science instruction. These cases illustrated the development of teacher knowledge by these four interns only, and it was their background experiences and knowledge that I wanted to understand.

To aid in the construction of holistic and meaningful representations, the sources used to collect data are semi-structured and open-ended (Patton, 2002). The primary data sources used in a case study are observations and interviews and secondary data sources are written documents and artifacts (Yin, 1994). Upon analysis of the primary and secondary data sources, the themes that emerged from these data sources served as the results of the study. In a case study approach, the themes are reported both within cases, called a within-case analysis, and across the cases, called a cross-case analysis (Denzin & Lincoln, 2005).

Methodological Assumptions. In case study research, knowledge and behaviors of the cases cannot be manipulated by the researcher. A case study methodology allows researchers to make sense of the nature of the complex and dynamic learning that occurs through teaching; the researcher attempts to understand the case by collecting data through multiple sources (Denzin & Lincoln, 2005). The methodologies used in a constructivist paradigm aid the researcher in understanding the research participant by allowing the researcher to reconstruct knowledge based on their interpretations of interviews and observations with high levels of trustworthiness (Ferguson, 2007). According to Patton (2002) a researcher's interpretation "depends on the cultural context in which it was originally created as well as the cultural context within which it is subsequently interpreted" (p. 113). Thus, every interpretation is dependant on another interpretation and established in light of my own understanding.

I can create a more holistic perspective by understanding these cases as a complex system that is created through the sum of many past and new experiences (Patton, 2002). Patton (2002) described well-constructed case analysis as being *holistic* and *context sensitive*. I provided in-depth descriptions of the methods I use to develop theory and construct claims and assertions about the research participants. Additionally, I support my interpretations through rich descriptions provided in the case narratives. Thus, according to the methodological assumptions of the case study approach, I can narrate and reconstruct teachers' knowledge from multiple data sources collected over time (Denzin & Lincoln, 2005).

Limitations of Case Study Research. As a researcher using a case study approach, I must acknowledge the limitations of the research strategy apart from more general limitations of doing this study. First, examining numerous cases impacts the researcher's ability to go into depth in each case. The researcher must decide how many cases and how much data are sufficient to answer the research questions within the proposed timeline of the study. Typically, researchers choose no more than four cases in order to give each case the depth of analysis needed to identify themes within and across cases (Creswell, 1998). The second limitation is that the researcher must select criteria and a rationale for purposeful sampling based on the research literature. Selection criteria and rationale are related to the research literature and researcher's questions and interests. Thus, criteria and rationales are researcher-dependent and another researcher investigating a similar topic may purposefully select different cases based on his/her unique set of criteria and rationale. My background experiences and knowledge served as the criteria for selecting these four interns.

Role of the Researcher

My interest in studying teacher knowledge of learners and sequencing of science instruction stems from my experiences as a teacher educator. However, my role as a researcher within Re-SMAR²T is complicated by the fact that I served as these ACP teachers' science methods instructor for one semester. My agenda to support beginning teachers in the enactment of inquiry-based science is an important component to my teaching. I acknowledge that my role as a teacher educator could be a source of potential bias. I was able to maintain my role as a researcher by clarifying the goals of the research project, my role during and after classroom observations, and my role as a

teacher educator. When conducting field observations, I acted as an observer and took field notes. I did not act as a participant observer in intern's classrooms (Patton, 2002). My role as an observer was made evident to the interns throughout this project; they did not expect me to provide them with formative or summative feedback of their teaching, nor did I offer any.

During data analysis, I used a separate journal to record my personal beliefs and views that were not directly related to the research questions. This allowed me to detach my beliefs and views from my interpretations of these four individuals' knowledge related to the research questions.

Institutional review board and data storage.

The Re-SMAR²T project gained approval by the university's Institutional Review Board (IRB) to conduct research. Written consent was collected from all principals from the participants' school districts (see Appendix A) and participants at the onset of the program (see Appendix B). I assisted in amending the IRB proposal to gain permission to review participants' application materials as a means to learn more about their background experiences and knowledge. Written consent was obtained from all of the participants to allow access to application materials in accordance with the IRB amendment (see Appendix C).

During the fall 2006 semester of the project, the mentor teachers were invited to an informational meeting about their roles as student intern mentors and about goals and purposes of Re-SMAR²T. Teachers present at the meeting gave written consent acknowledging that they would participate in the study. Teachers not in attendance at the

fall meeting were contacted and provided written consent at a later date (see Appendix D).

Parents of the students in the participants' classrooms were asked to provide consent allowing the researchers to video their child's classroom. Parents were made aware in the informed consent form that during observations the video would focus on the interns and interactions with students. Students who did not return the informed consent were positioned in the classrooms so that they were not video recorded. All attempts were made to focus the camera on the intern and those students who had provided consent (see Appendix E).

All consent forms, audiotapes, video cassettes, and DVDs from my data collection will be kept in a locked file cabinet for a minimum of three years following the final data collection conducted by the Re-SMAR²T team.

Data Collection

In a review of teacher knowledge research, Abell (2007) asserted, "Given the complexity of representing PCK, studies that use multiple methods over time to understand teacher knowledge seem to be the richest" (p. 1123). Taking this advice, I collected data at four different points during these interns' ACP: (1) upon entry into the program, (2) at the end of the first summer, (3) during the fall semester, and (4) during the spring semester. To gain additional information about factors that influence teacher knowledge, I collected data at different points (fall and spring semester) concerning the mentor teachers views and experiences with their interns.

Entry into the Program

I collected data that asked interns to develop a lesson plan for a science topic relevant to students and in an area in which these interns will likely teach. The lesson-planning task is based on Vander Valk and Broekman's work (1999). As part of the task, participants designed a lesson to address the following topic, "There is heritable variation within every species of organism." This topic was taken directly from the state science standards and has a range of applicability in biology. Additionally, the topic is taught in numerous K-16 science courses; I believe interns would have some experiences with the subject matter. Therefore, the content was well-suited for studying teacher PCK upon the entry into the ACP.

The participants designed two 50-minute plans for teaching the topic of heritable variation to eighth-grade students in a rural school. They were given one hour to design the lessons. The interns were not allowed to use any textbooks or internet resources. The only guidance provided was that they provide as much detail as possible to address the following: (a) what they want students to learn; (b) describe the beginning, middle, and end of each class; (c) describe the teacher and student roles; (d) list the materials they will need; and (e) prepare any handouts or overhead transparencies that they plan to use. The lesson plan was a secondary data source (see Appendix F).

Following the lesson planning task, I conducted one semi-structured interview (Patton, 2002; Seidman, 1998) with each intern. I structured this interview to minimize variations in the questions I asked of the participants (Patton, 2002). The interviews took approximately one hour and consisted of two parts. First the interns talked through their

plans and clarified the roles of the teacher and students during the lessons. Then interns were asked a series of questions about their subject matter knowledge, knowledge of students, knowledge of instructional strategies, knowledge of curriculum, and knowledge of assessment. These questions were designed to probe deeper about the specific components of the Magnusson et al. (1999) PCK model. The entry task interview served as a primary data source for this study (see Appendix G).

End of the First Summer

I conducted one semi-structured interview (Patton, 2002; Seidman, 1998) with each participant at the end of the first summer of the ACP. The purpose of this interview was for the intern to review and reflect on their initial lesson plan after their first summer of coursework in the ACP. I asked the participants to talk through their initial plan and to indicate whether they would make changes in their lesson plans. I asked clarifying questions addressing how and why interns would make these changes. The end of summer interview served as a primary data source (see Appendix H).

Fall and Spring Semester

I conducted one fall and one spring observation cycle with each participant. The fall and spring data collection cycle were the same and adhered to the following format: (a) pre-observation interview, and (b) field observations and stimulated recall interviews. Each of these is described below.

(a) Pre-observation Interview. The interview cycle began with a pre-observation interview centered on the participant's lesson plans for two days. The interview protocol was semi-structured (Patton, 2002; Seidman, 1998), and focused on what the intern intended to teach during two consecutive days. I asked clarifying questions about the

lessons in regard to how the lesson addressed the following: subject matter knowledge, knowledge of students, knowledge of instructional strategies, knowledge of curriculum, and knowledge of assessment. The pre-observation interview served as a primary data source (see Appendix H). Lesson plans were a secondary data source (see Appendix I).

(b) Observations and Stimulated Recalls. The second portion of the observation cycle involved field observations of the participant's classroom teaching in one class period over two consecutive lessons. All field observations were video recorded. Field observations ranged from 50 minutes to 1 hour and 40 minutes. Differences in the time that field observations were conducted were related to the schools' class scheduling. Both Harris and Monroe High School have 50 minute class periods. Rover High School utilizes block scheduling and each class meets for 100 minutes every other day. During the observations, researchers took field notes about interesting instances that occurred during the participant's teaching. Interesting instances were considered instances where the participant made instructional decisions that differed from his or her plan, answered students questions, or changed instruction. Following each field observation, I conducted one semi-structured interview with each participant (Patton, 2002; Seidman, 1998). I gave particular attention to instructional decisions made during the lesson relevant to the participant's PCK. Interview transcripts and classroom observations were primary data sources (see Appendix J).

Mentor Teacher Interview

I conducted two semi-structured interviews with each mentor teacher (Patton, 2002; Seidman, 1998). The first interview was conducted during the fall semester. The second interview took place during the spring semester. The interview protocol was

structured around the five components of the Magnusson et al. (1999) model of PCK and provided a window into understanding the mentor teachers' PCK and how the mentor teacher influenced his/her intern's knowledge. I asked clarifying questions so the mentors could provide details and examples about how they influenced their intern's knowledge in regard to subject matter, instructional strategies, curriculum, assessments, and students. The mentor teacher interview was a secondary data source (see Appendix K).

Although I collected data concerning all components of the Magnusson et al. (1999) PCK model, specific research questions within each interview protocol were related to my research questions. The data collection matrix illustrates how each of these data sources, including interview questions and tasks, informed the research questions in this study (see Table 12).

Table 12

Data Collection Matrix

Research Questions	Data Sources	Interview Questions/Tasks
(1) What knowledge of learners do teachers have at various points during an ACP (entry, end of summer, end of first semester, end of first year)?	Biology Lesson Planning Task	#1
	Lesson Planning Task Interview Protocol	# 2b, 7, 7a, 7b
	Pre-observation Interview Protocol	# 5, 5a, 5b, 5c, 5d, 6, 6a, 6b, 7a
	Stimulated Recall Interview Protocol	# 2b
	mentor Teacher Interview	# 2, 2a, 2b, 2c
(2) How do ACP teachers sequence science instruction at various points of their program?	Biology Lesson Planning Task	# 2
	Lesson Planning Task Interview Protocol	# 10, 10b, 10c, 11, 11a, 11b
	Pre-observation Interview Protocol	# 9, 9a, 9b, 9c, 10, 10a, 10b, 12, 12a, 12b, 12c, 12d
	Stimulated Recall Interview Protocol	# 2c
	mentor Teacher Interview	# 3, 3a, 3b, 3c
(5) In what ways do the following factors contribute to the development of teachers' knowledge of learners and sequencing of instruction: background experiences, science teaching orientations and school context?	Lesson Planning Task Interview Protocol	#3, 3a, 3b, 3c; 4, 4a, 4b, 4c, 10a, 12, 13, 13a
	End of Summer Interview	# 1, 2, 3, 4, 7, 8, 9, 11, 12, 13
	Pre-observation Interview Protocol	# 1d, 1e, 1f, 2, 2a, 2b, 2c, 3, 3a, 3b, 3c, 11, 11a, 11c
	Stimulated Recall Interview Protocol	# 5, 5a, 5b, 5c, 5d, 5e, 5f

Data Analysis

I used Magnusson et al. (1999) PCK model to develop codes for categories within knowledge of learners and instructional strategies. All coding was arrived through inductive and deductive processes. First, I read each interview transcript and decided which codes were necessary within the categories of knowledge of learners and sequencing of science instruction. Once I had created a set of codes, I created a coding

dictionary for orientations, knowledge of learners, and sequence of science instruction. The coding dictionary provided a definition of each code within these categories. After creating a set of codes, I read and analyzed a subset of interviews based on these codes using NVivo qualitative research analysis software. I added additional codes and definitions as they emerged from the data.

The process of constructing cases occurred in multiple steps. After the initial coding, I combined an individual interns' data from multiple data sources during various points. From these multiple data sources, I created a description, called a case profile that included verbatim data excerpts and told the story of each participant at various time periods during their program. Triangulation of multiple data sources allowed me to tease out my participants' experiential knowledge (Stake, 2004; Yin, 1994). Throughout the construction of case narratives I returned to the data sources to test claims and find additional supporting evidence. This within-case analysis allowed me to develop assertions about each individual's knowledge during their program and to explicate and clarify the professional knowledge of these four interns (Stake, 2005).

After creating each individual case narrative, I looked across the cases to identify common themes and differences and generate a set of tentative claims (Stake, 2005). In other words, the cross-case analysis allowed me to make comparisons among the interns in this study. While conducting the cross-case analysis, I returned to the data set to test claims and find additional supporting evidence. Yin (1994) proposed that the findings of multiple case studies are useful because they allow the research to explore themes and patterns across the cases. Thus, although knowledge is context dependent, findings from case studies can be compared to revise, formulate, and test theory (Yin, 1994).

Trustworthiness

As a qualitative researcher, it was my role to ensure credibility, dependability, transferability, and confirmability in order to guarantee the trustworthiness of the naturalistic methodological procedures used during data analysis (Lincoln & Guba, 1985). By remaining aware of these four criteria, I limited the influence of my personal beliefs and views. I increased the trustworthiness of my study by collecting multiple data sources over time (Lincoln & Guba, 1985; Yin, 1994), and triangulating the data sources (Stake, 2004). Apart from collecting and triangulating data from multiple sources over time, I implemented other measures mentioned below also increased the trustworthiness of this study.

Developing the coding dictionaries with the assistance of other researchers increased the credibility and dependability of the study (Patton, 2002). Stigler & Hiebert (1999) described coding dictionaries as, “definition(s) that will communicate to other coders what “counts as” developing a concept or asking an open-ended question” (22). To further increase the credibility and dependability of the study, two doctoral students served as peer debriefers (Patton, 2002). Peer debriefers helped analyze, review, and triangulate data sources. First, the two peer debriefers independently analyzed a subset of the data using the coding dictionaries. Then, they provided their interpretations of the data based on their own understanding. Finally, we compared interpretations by looking for similarities and differences. The peer debriefers were used as a means to reduce bias that is associated with an individual analyzing data (Patton, 2002).

To promote transferability, I provided detailed descriptions of the cases so that the reader could make connections between the participants of the study and the reader’s own

context. In this regard, Lincoln and Guba (1985) described transferability as “the degree of congruence between sending and receiving contexts. If context A and context B are ‘sufficiently’ congruent, then working hypotheses from the sending originated context may be applicable in the receiving context” (p. 584). The detailed description was provided to help readers determine how these findings were transferable to other circumstances and contexts.

In order to strengthen the confirmability of this study, I constantly reflected on the data and asked myself, “Are the data sufficient to merit the claims?” (Denzin & Lincoln, 2005, p. 528). During data analysis I recruited the assistance of my advisors to check claims and assertions and I asked my advisors to examine whether my methodology and analysis was careful and analytic (Lincoln & Guba, 1985). The excerpts I used to support claims were accurately transferred from the raw data. An outside reviewer looking at my study would be able to confirm that the claims were generalized from the coded data; check the codes against the coding dictionary; match the excerpts with the transcripts; and check the transcripts against the raw data. Finally, I confirmed any similar findings from this research to those cited in the literature.

CHAPTER FOUR: CASE STUDIES

The purpose of Chapter Four is to provide details and evidence for the assertions in Chapter Five. I present four case profiles that offer a window into the development of teachers' PCK. The profiles were constructed from interviews conducted at the beginning and end of the first summer of the ACP, and from interviews and observations during the fall and spring semester of the ACP. I selected these particular pieces of data to represent the knowledge of teaching and learning these individuals talked about in interviews and that I observed in their classroom practice. The four cases include: (1) Mary, (2) Amy, (3) Lilly, and (4) Jason.

1. Mary's Case

Experiences Prior to Program

Mary, age 23, did not set out to become a high school science teacher. Although Mary had never taught in a formal setting, she enjoyed "helping others, by explaining ideas and sharing knowledge." She viewed teaching as a fulfilling and worthwhile career based on her experiences as a tutor and as a nanny. Mary entered the ACP just after graduating from a large Midwestern institution with an undergraduate degree in biology.

Beginning of ACP

At the beginning of the ACP, Mary designed lessons to teach heritable variation to 8th grade students. After she designed her lessons, she was interviewed about her views and knowledge of teaching. Mary also watched a video of a reform-based class and reflected on the teaching and learning that occurred in the video segment. The interpretations below include data from the lesson Mary created, the interview, and the video reflection.

Orientations

Mary's images of teaching were based on her experiences as a student. She had always been taught science in a traditional, "delivery" mode. As a result of her past experiences, Mary believed that teaching science revolved around delivering terms and concepts to students. She expressed this view a number of times-- in talking about views of the teacher and student roles, her goals for teaching science, and in how she planned to teach. Mary expected that as a teacher she would be the leader in the classroom. Being a leader meant she was responsible for content, pace, and linking the big ideas together through teacher-centered strategies like lectures. Mary believed that teachers "can't wait for every student to grasp the concept, they should make sure they understand at least the basics" (Pre-observation Interview). During the Entry Task Interview, Mary talked at length about her role and made few comments about the students' responsibilities in her classroom. In accordance with her views that teachers are leaders, she believed students have a passive role.

Mary's central goal for teaching science was to present content so students could apply science to their lives. This included applying science ideas to students' current lives as well as in the future when they enter the workforce. Mary explained:

Even if they'll never do science again, I mean, which, you know, they will, they're in eighth grade, but even if they never do again that's something that's very important that they can apply to their daily life in the business world, in college, I mean, everything, in the working force.
(Pre-observation Interview)

Mary believed when she presented new content, she could show students how new science ideas are applicable in their own lives.

Instructional Sequence

Day 1. Mary planned to begin the lesson with a lecture on genetics, DNA, heritability, dominant versus recessive traits, natural selection, and Punnett squares. The purpose of the lecture was to provide students with new terminology and concepts. Mary planned to spend 20-25 minutes lecturing to students about new concepts and terms. This is what I have termed “inform” types of instruction and was the bulk of the lesson. “Inform” types of instruction are used by the teacher to transmit content to students. Following the lecture, Mary planned to let students practice new content by completing an in-class assignment where students did Punnett squares to practice how dominant and recessive traits are inherited. This occurred during what I have termed “practice” types of instruction. “Practice” types of instruction allow students to rehearse content presented during lectures and teacher-led discussions and apply new knowledge in other contexts. After students had an opportunity to practice new ideas, Mary planned to “continue on with lecture and go into more examples of Punnett squares (more advanced concepts)” (Lesson Plan, Day 1). The lesson concluded with a homework assignment where students practiced doing additional Punnett squares.

Day 2. Mary began Day Two by reviewing the previous day’s homework assignment during what I have termed “review” types of instruction. “Review” types of instruction are used to remind students of content covered during previous classes. Following the brief review, Mary had students practice the concepts of dominant and recessive traits through a large group activity. Mary described the activity: “They are required to find classmates that have different traits and tally the number of people who have different traits” (Lesson Plan, Day 1). Students finished the activity by making

conclusions about whether the traits in the classroom were dominant or recessive. The class ended with a teacher-led discussion about natural selection and survival of the fittest.

On both days, Mary planned to use an instructional sequence that centered on providing new content knowledge to students during “inform” types of instruction. Mary believed that teaching and learning begins when the teacher introduces terms and concepts and held students responsible for committing vocabulary to memory through practice. Table 13 summarizes Mary’s lesson plan for Day One and Two.

Table 13

Mary’s Lesson Plan, Day 1 & 2, Beginning of Summer

	Sequence	Activity	Description
Day 1	Inform	• Lecture	• Teacher lectures on genetics, DNA, and heritability, dominant versus recessive traits, natural selection, and Punnett squares.
	Practice	• Independent practice	• Students practice doing Punnett squares.
	Inform	• Lecture	• Teacher lectures and provides more detailed examples of Punnett squares.
	Practice	• Homework	• Students do Punnett squares as homework.
Day 2	Review	• Review homework	• Teacher reviews homework on heritability.
	Practice	• Students collect data	• Students count the number of different traits that are prevalent in the class and the number of people who have those traits.
	Inform	• Discussion	• Teacher leads a discussion on natural selection and survival of the fittest.

Knowledge of Learners

Even though Mary had not taught this content before, she believed that students would be familiar with the term “DNA,” from television shows and “they’ve probably heard about dominant and recessive from previous classes” (Pre-observation Interview). However, she thought she should not assume that students have prior science knowledge. She said, “I do not feel it’s appropriate for a teacher ever to just assume you have prior exposure” (Pre-observation Interview). Mary was adamant about not assuming students have prior knowledge and regardless of students’ experiences and knowledge, she could “go slow” and focus on concrete aspects of the content to help students learn.

Requirements for learning. Mary drew on her experiences as a student and believed learning is dependent upon relating new content to students’ personal experiences. During Mary’s lectures she would focus on “natural selection and how that applies and how the Punnett square is applied to our daily life” (Pre-observation Interview). Additionally she said, “At first it would be foreign for the students, but I’d be bringing what we talked about into their world” (Pre-observation Interview). Mary believed students would learn the material if she made personal connections for them.

Areas of student difficulties. Despite never teaching in a formal setting, Mary was concerned about teaching DNA and thought “students don’t grasp the unseen very well” (Pre-observation Interview). Even if Mary brought in a model of DNA that they could see and touch, they would have trouble learning new content. Mary explained:

There is nothing tangible for students to grasp [Referring to DNA]. I wanted to bring in a helical structure so they could see it, but it’s, I mean, it’s molecular, it’s teeny tiny, it’s very difficult. (Pre-observation Interview)

Mary planned to spend the least amount of time teaching about microscopic concepts like the structure of DNA and focus on the concrete aspects of the content that 8th grade students can understand. She mentioned, “I think that would be the hardest part and that’s why I wanted to give the least amount of time to that area” (Pre-observation Interview).

Contributing Factors to Mary’s Development of Knowledge of Teaching and Learning at the Beginning of the ACP

Mary attributed much of her knowledge about teaching heritable variation to her past experiences as a K-16 student. She drew on her experiences from high school when designing the lesson and activities. According to Mary,

The activity that I planned for my students ... was one that I did as a freshman ... I remember ... you run around, you find classmates that have certain traits ... who’s got the hitch hiker thumb? Who’s got, like, hair on their index finger? Things like that, who has got brown hair or blue eyes? (Pre-observation Interview)

Additionally, Mary used what she knew about how her own teachers sequenced instruction. She believed teachers plan a review at the beginning and give homework at the end of class as she explained, “Open by reviewing the homework, just to make sure that, you know, I’ve been in classes where, where teachers, you, they go over the easy stuff then they assign homework” (Pre-observation Interview). Mary also mentioned, “The majority of my classes it was a lecture for “x” amount of time, and usually it was at minimal for fifteen minute lecture” (Pre-observation Interview). In general, Mary used sequences and activities she had experienced in high school. Mary’s K-16 experiences were the source of her orientation to science teaching.

End of Summer

At the time the end of the summer interview was conducted, Mary had completed her first summer in the ACP. Mary had finished a course in Educational Psychology and the first Secondary Science Methods course. During the interview, Mary reflected on her initial lesson plan.

Orientations

Mary continued to view teaching as telling students science terms and concepts and learning as listening to teachers' explanations. Her views of the teacher's roles had not changed significantly. In describing her views of teacher and student roles, Mary believed she should be the "leader" in the class and focused on transmitting knowledge through lectures. She said, "I'm most comfortable with lectures because when they come back here you may lose control of them" (End of Summer Interview). Mary still thought her students had a passive role in learning and said, "The students' role is to learn and in some sense shut up, sit down, and write down information" (End of Summer Interview). Mary described her central goal as presenting science content. She planned to use students' life experiences as a bridge for introducing new content. Her goal was to "focus in on what do we know, let's go from there, and that can kind of get students more involved also" (End of Summer Interview).

Instructional Sequence

Mary planned on using the same instructional sequence to teach the lessons that she designed on the first day of her ACP. However, she would decrease the time she lectures, from 25 minutes to 15 minutes, so students could stay focused. According to Mary, "A twenty to thirty minute lecture, that's going to be brutal, not only on the

students, but on myself as well I would keep it in there, but I would try not to go over fifteen minutes” (End of Summer Interview). Mary would also still have students do worksheets to practice the ideas she gave them through lecture. Instead of having students work independently, she would have them do the worksheets in groups.

Mary would also keep her initial lesson she planned for the second day of instruction. She would keep the “review” activity to “make sure we’re [referring to the teacher and students] on the same page” (End of Summer Interview). Mary thought that the second day was better than the first because it was more student-centered. She explained, “I like day two more than day one, because it focuses more on the students. They’re doing a fifteen, twenty minute activity. They’re up and talking. They’re doing class discussion” (End of Summer Interview). The sequence Mary planned still focused on presenting information to students through teacher-centered strategies during “inform” types of instruction near the beginning of lessons.

Knowledge of Learners

Mary continued to believe that teachers cannot assume that students have prior science knowledge and should determine what students know at the beginning of a lesson. Once teachers know about students’ conceptions, they can design lessons.

According to Mary,

Students will bring a lot of stuff, you can’t assume that they know x, y, and z before they walk in, but they may know a, b, and c, which you didn’t even realize. So really focusing in on that before I even branch into stuff, say okay, well what do we know, let’s go from there. (End of Summer Interview)

Requirements for learning. Mary focused on lecturing being the key strategy that teachers do in science to help students learn new content. She commented, “You do have

to have lectures, some things are just unavoidable” (End of the Summer Interview).

However, Mary’s knowledge of the requirements for learning expanded as a result of the Secondary Science Methods course. Mary took on additional beliefs about learners’ needs that included: discovering science on their own; and group work.

When Mary talked about what she liked about her lessons, she focused on activities where students figured out concepts for themselves. She thought that investigating characteristics would help students discover ideas about dominant and recessive traits. She explained, “They’re learning on their own. It’s not me saying, this is supposed to be this, this is supposed to be, it’s like, hey, let’s go find out, let’s go do this, and then we’ll come back and talk about it” (End of Summer Interview).

Mary also believed that working together helps students learn new material because it “gets them talking” to help maintain their interest. According to Mary, “Whenever you have them in groups ... it helps facilitate this kind of environment, were we’re all learning and a place where you want to be, versus, I go and I sit by myself and I work by myself” (End of Summer Interview). She thought that working with partners increases student motivation because students feel part of a group.

Areas of student difficulties. Mary reflected on her own experiences when talking about the difficulties students would have with her lessons. She believed that it would be difficult for students to stay focused if she did not break up the time that she spent lecturing. Mary planned on having the students get out of their seats and move around the classroom to divide up the time she spent lecturing. She explained:

I would say get them up out of their seat, go over somewhere else and look at a DNA model, don’t just pass it around while they sit in their seat, like, get them up, get the blood flowing, because you start to get bored sitting there for too long. (End of Summer Interview)

Mary blamed student boredom with sitting and taking notes as being the cause for their inability to focus during lecture. Despite students having difficulty remaining focused, Mary believed lectures are vital for student learning.

Contributing Factors to the Development of Mary's Knowledge of Teaching and Learning at the End of the Summer

After 11 weeks in the ACP, Mary's knowledge of teaching and learning science developed from different experiences. Mary found value in working with other students during her Secondary Science Methods I course to learn new content. She said, "I'm not a real big fan of groups, I never have been until after this summer, and I was like, hey, this is really good." Additionally, Mary learned about inquiry in the Secondary Science Methods course. She described that the key feature of an inquiry approach is that it allows students to discover science on their own. Mary's knowledge of learners expanded as a result of the ACP courses and she believed she could use discovery and group work after she lectured to help students learn science. However, Mary placed more emphasis on what she knew about students learning needs than what she would do with that knowledge.

The ACP course work was very different than her own experiences as a student. Mary said that she was "raised on the teaching style, unfortunately, where the teacher just kind of takes over" (End of Summer Interview). She believed that the summer's coursework proposed that teachers should not lecture. The idea of not lecturing to teach science was hard for Mary to reconcile based on her own experiences in college science courses. She said, "Five years of college, it's all been lecture based" (End of Summer Interview).

Internship Context

The interview-observation cycle was conducted near the end of Rover High School's first semester. Mary was interning in a human anatomy class. Her mentor, Melanie, had taught anatomy for 6 years and was working on her Masters degree in Education. A general teaching philosophy used by mentor teachers in the science department at Rover High School was that interns begin by observing and mimicking their mentor. Mary talked at length about interning with Melanie and how she was learning to mimic and coteach. Mary explained, "She (referring to mentor) will teach on A Days then I will see how she presents the materials and I will relearn it. Then on B Days I'll present" (Pre-observation Interview). In general, Mary reported that she had "issues with transitions and how long it is appropriate before they need to move on So, [her mentor] help cue me in to they are ready to move on" (Stimulated Recall, Day 1). When Mary designed her own activities during the semester, she used the human anatomy objectives and common assessments.

Being placed in a human anatomy class was problematic for Mary who did not consider herself knowledgeable in the subject area. Although she had an animal physiology course in college, it was not specific to human anatomy and physiology. Mary believed she did not have the background knowledge necessary to teach human anatomy and even though she had the textbook and teacher resources for the course, she had difficulty learning the subject matter. Melanie taught Mary some human anatomy and physiology, but left the bulk of learning the subject matter to Mary who had her resources. Mary was hesitant to design activities and use strategies that deviated from what her mentor implemented due to her lack of subject matter knowledge.

Fall Semester

Mary was enrolled in Secondary Science Methods II and had been observing and teaching along side her mentor for approximately 17 weeks. In the Human Anatomy class there were 7 males and 8 female students. Most of the students were juniors or seniors. She considered the class to be highly motivated and had an interest in pursuing medical related careers. She described this class as having “really positive attitudes. They’re really excited to learn. They ask loads of questions beyond the scope of what we’re presenting” (Pre-observation Interview). However, Mary was concerned about her lessons due to her subject matter knowledge. She remarked, “Muscles contractions are kind of fuzzy for me” (Pre-observation Interview). Mary also talked about her plans as being atypical because students had missed school the previous day due to weather related issues. The interpretations below include data from the lesson Mary created, the interviews, and field notes.

Orientations

After four months of working with students and a mentor, the nature of the internship context strongly reinforced Mary’s science teaching orientation which focused on delivering vocabulary to students. This image was reiterated in her views of teacher and student roles and how she planned to teach. She learned that, in addition to giving students notes, teachers have other responsibilities. She explained:

I would have said the teacher's role is to give all the information and now it's clear that the teacher clears up misconceptions, is responsible for the information, for the learning, and testing them and assessing if they learned.
(Stimulated Recall, Day 1)

Mary believed that teachers should provide knowledge, resolve student misconceptions, and assess student knowledge. In accordance with these views, she thought students have

a passive role in the class and are responsible for following her lead. So, Mary's orientation that focused on teaching is telling and learning is listening was reinforced by her teaching context that mostly used teacher-centered, traditional-transmission modes of instruction.

Instructional Sequence

Day 1. On the first day, Mary began the lesson with having students write a quiz. Once all students had written a quiz, they traded and took a classmate's quiz. The purpose of the quizzes was to review previous content covered. Next, Mary had students take notes on muscle fiber contractions. The lecture took approximately 45 minutes of class time. The class concluded with a teacher-led review and homework. At the end of class, both Mary and her mentor teacher rent over a chart on neurotoxins.

Day 2. Class began with a review of the quizzes from the first day's lesson. Mary had "students grade the quizzes they took on Tuesday and give each other feedback." She followed this activity with a lecture over different types of muscle fibers, exercise, and fatigue. Similar to Day One, the lecture was the bulk of the lesson. After the lecture, students had the rest of class as "worktime" to practice the ideas covered in lecture by coloring and labeling different anatomical pictures of muscle fibers. Once students were done, they began studying for a quiz that addressed this material.

On both days, Mary planned to use an instructional sequence that focused on transmitting knowledge to students during "inform" types of instruction. She continued to believe that science teaching and learning begins when the teacher provides new vocabulary to students. Table 14 summarizes Mary's lesson plans for Day One and Two.

Table 14

Mary's Lesson Plan, Day 1 and 2, Fall Semester

	Sequence	Activity	Description
Day 1	Review	• Students write quizzes	• Students write and take each other's quizzes.
	Inform	• Lecture	• Teacher lectures on muscular contractions.
	Inform	• Teacher-led discussion	• Mentor teacher goes over a chart on neurotoxins.
Day 2	Review	• Review quizzes	• Students grade quizzes and provide feedback.
	Inform	• Lecture	• Students take notes on muscle fibers, exercise, and fatigue.
	Practice	• Group work	• Students color and label diagrams of muscle fibers.

Knowledge of Learners

Mary continued to believe that teachers should not assume that students have prior knowledge about human anatomy. When she was asked about what students might already know about bones, cells, and tissues she said,

That's variable. None of them are blank slates. They all have some pre-conceived idea of what's going on. Some of them are completely wrong and a lot of them come in with the information from Sophomore Bio. But we can't assume that everyone remembers. (Pre-observation Interview)

Even though Mary has "found that no student comes in as a blank slate," she assumed they do not have prior knowledge about human anatomy. Mary believed that in anatomy and physiology there are only a few ways to help students learn new content.

Requirements for learning. Mary continued to characterize how students learn human anatomy as primarily being dependent on lectures. Mary felt responsible for giving students the terminology and concepts and believed "in anatomy, lecture is the best way to get that across" (Stimulated Recall, Day 1). She focused on using lectures

because she believed students need direct instruction to learn Human Anatomy. She explained, “We’re not going any roundabout way of getting this across to them, we’re just saying ‘this is it, right here.’ Just very direct, none of it’s indirect or inferred. Write this down, this is what you need to know” (Pre-observation Interview).

Mary also learned from teaching human anatomy that when students have hands-on opportunities, they better learn the content because they are more motivated. She remarked, “When they get to do the hands-on and next semester we’ll be doing dissections, and the students are really looking forward to doing that. So, they really learn best with those activities” (Pre-observation Interview). Although Mary had talked about a number of different requirements for learning in the past, she focused almost exclusively on lectures.

Areas of student difficulties. From teaching Human Anatomy, Mary discussed student difficulties in greater detail. She knew that learners have trouble remaining focused during lectures. She said, “To learn about you know whenever you die this is rigor mortis and then go back to muscle contraction. I didn’t want to have to hold their attention for that long and then we go back to muscle contractions maybe” (Stimulated Recall, Day 1). In general, Mary blamed the students for being unfocused when she lectures.

Additionally, Mary recognized that students had difficulty learning specific topics. For example, she knew were confused by the biochemical processes that cause muscle contractions. She explained:

We're just going to say ATP to ADP, ATP to ADP, we're just going to kind of run over it and as long as they understand that they'll be ok. We're not going to get into the nitty-gritty about the Krebs cycle and all that. Those are the only two things I can see major problems with if they can't remember that or put those two concepts together. (Pre-observation Interview)

She planned to spend the least amount of time lecturing on biochemistry and focus more on gross anatomy.

Contributing Factors to the Development of Mary's Knowledge of Teaching and Learning during the Fall Semester

After 4 months in the ACP, Mary's experiences in the guided internship significantly influenced her knowledge of teaching where she observed and mimicked mostly "delivery" modes of instruction. She relied heavily on her mentors support to teach and used her mentor's unit and daily objectives, lecture notes, examples, activities, and worksheets. Additionally, Mary observed her mentor teacher lecture to students in a different class before she attempted to teach it. She said, "[Melanie] presented it in a way yesterday that was simple and straightforward and I'm hoping to do the same today, but it is a pretty big concept" (Pre-observation Interview). When asked whether lectures are her preferred mode of instruction, Mary remarked, "I guess for me there's a difference between preferred and comfortable, it is the most comfortable for me ... since it's what I was raised on." (Stimulated Recall, Day 1). For Mary, lecturing is a comfortable strategy to teach science and primarily used in her teaching context. Lecturing was also a way for her to control the content and not open herself up to questions that she could not answer. During the fall semester, Mary developed a growing awareness of student difficulties and found that lectures helped students overcome their trouble learning the content. Mary's

mentor teacher and the teaching context reinforced her image that science teaching is telling and learning is listening.

Mary's experiences in the ACP courses provided her with knowledge of student-centered teaching strategies and sequences. However, even though she has learned about other strategies and sequences in the Secondary Science Methods courses, Mary preferred to lecture. She said, "I love all we've got all these new teaching styles, but that's not how I learned. Lecture is the best way for me, so that's going to be a challenge to overcome that and see different ways to teach" (Stimulated Recall, Day 1).

Spring Semester

At the time the spring semester interviews and observations were conducted, Mary was enrolled in Secondary Science Methods III and had been interning in a Human Anatomy class for approximately 7 months. A total of 15 students were present that included 7 males and 8 female students. The students were learning about the circulatory system and heart. Even though Mary had read the student's textbook chapter on circulation, she talked about her level of confidence in her own subject matter knowledge. She was worried about teaching circulation because it is a "little confusing as far as deoxygenated versus oxygenated blood" (Pre-observation Interview). She planned to lessen confusion by focusing on structures rather than concepts. She said,

I'm fairly comfortable since we're just talking about the structure and the function. I think, the atrium brings in blood and ventricle pumps it out. It's kind of straightforward. Once we get into more of the physiology, my comfort level may drop some. (Pre-observation Interview)

In the past, Mary had experienced difficulty teaching because of a lack of sound subject matter knowledge and had been embarrassed by unexpected student questions that she

could not answer. The interpretations below include data from the lessons Mary created, the interviews, and field notes.

Orientations

Near the end of guided internship, Mary's science teaching orientation had not changed significantly. She strongly held onto the belief that teaching is telling and learning is listening. Additionally, Mary continued to think that it is the teachers' job to deliver content through direct means of instruction such as lectures. She commented, "I was just going to kind of go straight to the meat and start talking about the different parts of the heart...to make sure we are all on the same page" (Pre-observation Interview). In accordance with this view, Mary's comments about the students' roles in the classroom focused on students following the teacher's lead so that they finish their work. She stressed that she wanted students to "get through" the material, and "get their work done," so that she can "move on in her plan" (Pre-observation Interview). Mary's teaching context heavily supported a view that science teaching is telling and learning is listening.

Instructional Sequence

Day 1. Mary was finishing the unit on the respiratory system and moving on to her circulatory unit. She began the lesson by having students take a quiz over respiration. Next, Mary had students read an article that would lead into a discussion about the circulatory system and the unit objectives. The purpose of the reading and discussion were to focus students on the topic of the lesson. This occurred during what I have termed "focus" types of instruction. Mary concluded the lesson by having the students

work in pairs to use their textbooks to define 26 new vocabulary terms. Mary preferred that students find the definitions on their own rather than giving notes. She said,

Instead of getting up there and saying, ‘OK, this is a list of terms. Take notes.’ I’m going to say, ‘Here is a list of terms, go find out the function of these terms and where you are going to find them in the body.’ I’m going to break them up into partners. (Pre-observation Interview)

Students divided up the terms so they could finish the activity faster than doing it on their own.

Day 2. On the second day, Mary planned multiple opportunities for students to practice the new terms. First, students practice their understanding of blood circulation by filling out a diagram of the heart. Mary thought students would be able to “take their definitions and what they read in the book and applying it to the picture” (Pre-observation Interview). Next, students traced out the path that blood flows by walking through a large diagram of the heart placed on the floor. While students practiced these ideas, Mary corrected errors so that they all understood the content. She explained, “I will be monitoring them and questioning their placement of the chambers and valves.” After students had practiced the blood flow through the heart, Mary finished the lesson by having students begin their homework. Students’ homework was to write a children’s story of how the blood flows through the heart.

Similar to previous times, Mary used an instructional sequence that focused on transmitting new knowledge to students during “inform” types of instruction and provided time for students to rehearse the vocabulary during “practice.” Mary continued to believe that teaching and learning begins when the teacher introduces new terms and concepts. Table 15 summaries Mary’s lesson plans for Day One and Two.

Table 15

Mary's Lesson Plan, Day 1 and 2, Spring Semester

	Sequence	Activity	Description
Day 1	Review	<ul style="list-style-type: none"> • Quiz 	<ul style="list-style-type: none"> • Students take a quiz over the respiratory system
	Focus	<ul style="list-style-type: none"> • Read and discuss article 	<ul style="list-style-type: none"> • Students read and discuss about the role of the heart in the circulatory system.
	Inform	<ul style="list-style-type: none"> • Discussion 	<ul style="list-style-type: none"> • Teacher leads a discussion of the structure of the heart and blood flow through the heart
		<ul style="list-style-type: none"> • Group work 	<ul style="list-style-type: none"> • Students define 27 new vocabulary terms
Day 2	Practice	<ul style="list-style-type: none"> • Heart diagram 	<ul style="list-style-type: none"> • Students label the chambers and structures of the heart.
		<ul style="list-style-type: none"> • Large heart diagram 	<ul style="list-style-type: none"> • Students label the chambers and structures of the heart using a large heart diagram.
		<ul style="list-style-type: none"> • Homework 	<ul style="list-style-type: none"> • Students write a children's story of how the blood flows through the heart.

Knowledge of Learners

Mary continued to believe that teachers should not assume that students have prior knowledge about human anatomy because “you don’t know what their background history is with this content” (Pre-observation Interview). This view persisted in spite of Mary believing that students “have had some exposure to the heart” in 10th grade biology”, as well as having recently dissected a sheep heart during a field trip to a cadaver lab (Pre-observation Interview). Mary explained:

They actually did a field trip last week where they went to St. Louis to watch a cadaver dissection and they did sheep heart dissections. So they’ve already had some exposure to the heart So that’s something that I had to remind myself. I’m not walking into this where they’ve never seen a heart before. They’ve already seen one. They know the relative size at least for a sheep heart. (Pre-observation Interview)

When talking about students' experiences and ideas about the heart, she commented, "They don't know where it is, don't know what it looks like essentially even though they've already dissected one" (Pre-observation Interview). Mary believed teachers should not assume students have ideas about the content, even if students had firsthand experiences with the material.

Requirements for learning. Mary continued to believe that learners need lectures to learn science. She planned to tell students "this is how the blood flows. It goes through this valve, goes into this chamber, goes through this valve, etc. They will have a step-by-step of how the blood flows" (Pre-observation Interview). However, Mary learned from the guided internship that lecturing would not always be enough to help students learn new content. Mary's knowledge of the requirements of learning expanded to include providing students with multiple exposures to new material and collaborative experiences to support learning.

Mary observed that multiple "practice" types of activities facilitate student understanding of concepts. She thought that students would learn about the circulation by repeatedly tracing the blood flow through the heart and working with new terminology in the circulatory packet. Mary viewed practicing new content in multiple different activities as a way to "solidify [terms] in their heads" (Pre-observation Interview). Additionally, Mary believed that working with partners, as well as in large groups, helps students figure out how blood flows through the heart. She thought that students would teach each other when they traced blood flow by walking through the chambers of the heart. She commented, "Whenever we're actually constructing the heart where we're walking through, the entire class is going to be doing it where everyone is going to have

input, so the students are going to be kind of helping each other out” (Pre-observation Interview).

Areas of student difficulties. Mary talked about additional student difficulties in more detail as a result of her teaching experience. In general, Mary found that students have difficulties applying prior knowledge to new contexts. She said, “Anytime that you’re applying something that we talked about in class, they are really having difficulty grasping that” (Pre-observation Interview). For example, she knew that students had trouble making connections between their respiration and circulation units. She commented, “They were really having difficulty grasping the idea of oxygen diffusing across the alveoli to the blood or into the capillaries because of the high to low concentrations. That is something that I know they talked about, diffusion in biology” (Pre-observation Interview). Additionally, during her lessons on the heart, she observed that students had trouble understanding the path of blood flow through the heart and circulation through the body because “there is a misconception that blood just flows out and never comes back” (Pre-observation Interview).

Contributing Factors to the Development of Mary’s Knowledge of Teaching and Learning during the Spring Semester

After nearly 9 months in the ACP, Mary’s experiences in the guided internship significantly influenced the development of her knowledge of science teaching. She continued to observe and mimic using mostly a “delivery” mode of instruction. This was the first time this year that Mary designed lessons, activities, and assessments based on the department’s objectives. However, Mary had her mentor’s help and planned the unit with another intern who was student teaching in another Human Anatomy class at Rover

High School. For example, when Mary was asked about where she got the ideas to have students walk through a heart to trace the flow of blood, she said: “The other intern, Angie (Pseudonym), brought that in. She had found that activity online” (Pre-observation Interview). Even though Mary planned with Angie, she had different ideas about how to teach the content. Mary would rather focus on the structure and function of the heart, while Angie wanted to incorporate activities so students found meaning in learning about circulation. Mary explained:

Angie was the one that kind of came up with the idea of the article. I was going to completely abandon it, because it is on treating a sick heart. She really wanted to hit hard about the general importance of the heart and say, ‘look at the relevance.’ So I think she is kind of bringing it in as a relevance area to show kids that it is important. I was just going to kind of go straight to the meat and start talking about the different parts of the heart. (Pre-observation Interview)

Ultimately, Mary used the article because her mentor teacher thought students would benefit from reading about a personally relevant topic.

Summary: Mary’s Development of Knowledge of Teaching and Learning

The Development of Mary’s Orientation to Science Teaching

Mary’s science teaching orientation consisted of her beliefs about teaching and learning; views of the teacher and student roles; and goals (see Table 16). Mary came into the ACP with the belief that teaching is telling and learning is listening. This view was strongly reinforced in the guided internship where she observed and mimicked using mostly “delivery” modes of instruction. Although Mary gained additional goals, there is little evidence to suggest that Mary held other views of teaching and learning during the ACP. Over time, Mary’s orientation was resistant to change and remained stable.

Table 16

The Development of Mary's Orientation to Science Teaching

Dimensions	Entry	End of Summer	Fall Semester	Spring Semester
Views of teaching and learning	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening
Views of the teacher roles	• Leader	• Leader	• Leader	• Leader
Views of the students roles	• Followers	• Followers	• Followers	• Followers
Central goals	• For students to apply science to life	• For students to apply science to life • Build on students prior knowledge	• NM • NM	• NM • NM

Note. NM= Not mentioned

The Development of Mary's Knowledge of Instructional Sequences

Mary consistently sequenced instruction in ways that gave priority to transmitting information. Even though Mary gained knowledge of student-centered activities from the Secondary Science Methods courses, she did not put this knowledge into practice to design student-centered types of instruction. Table 17 summarizes Mary's instructional sequences to teach science.

Table 17

The Development of Mary's Sequence of Science Instruction

Entry		End of Summer		Fall		Spring	
Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Inform	Review	Inform	Review	Review	Review	Review	Practice
Practice	Practice	Practice	Practice	Inform	Inform	Focus	Practice
Inform	Inform	Inform	Inform	Inform	Practice	Inform	Practice
Practice		Practice					

The Development of Mary's Knowledge of Learners

Mary thought that students need lectures to learn science. Over time, Mary's knowledge of learners expanded to include a number of different ideas about the requirements for learning science and areas of student difficulties. During the End of the Summer interview, she talked about the importance of learners discovering new ideas on their own and through group work after she explained new vocabulary. Both of these ideas came from the ACP coursework. During the spring semester, Mary observed that, in order to help students overcome their difficulties learning new content, learners required: lectures; multiple exposures to new content; and collaborative experiences to support learning. This expansion of knowledge of the requirements of learners can be attributed to her work with a mentor teacher and to her growing awareness of student difficulties from firsthand teaching experiences. Table 18 shows Mary's development of knowledge for learners including: requirements for learning; and areas of student difficulties.

The Development of Mary’s Integration of Knowledge of Learners and Instructional Sequences

Mary developed knowledge of instructional sequences integrated with knowledge of learners, although her instructional sequences did not fully reflect her knowledge of learners. Her use of “focus,” “inform,” and “practice” types of instruction flowed directly from her memories of how her teachers taught. At the beginning of the ACP, Mary relied heavily on lectures during “inform” types of instruction to help students learn new content. Lectures during “inform” types of instruction were the common link between her knowledge of learners and instructional sequences.

Table 18

Mary’s Development of Knowledge of Learners

Knowledge of Learners	Entry	End of Summer	Fall Semester	Spring Semester
Requirements for Learning Science	<ul style="list-style-type: none"> • Students need lectures • Connections to life 	<ul style="list-style-type: none"> • Students need lectures • Connections to life • Discover new ideas own their own • Group work 	<ul style="list-style-type: none"> • Students need lectures • NM • NM • NM 	<ul style="list-style-type: none"> • Students need lectures • NM • NM • NM • Multiple exposures to new content • Collaborative experiences to support learning

Table 18 cont...

Areas of Difficulties Learning Science	<ul style="list-style-type: none"> • Visualizing the structure of DNA 	<ul style="list-style-type: none"> • NM • Remaining focused during lectures 	<ul style="list-style-type: none"> • NM • Remaining focused during lectures • Understanding the biochemical processes that cause muscle contractions 	<ul style="list-style-type: none"> • NM • NM • Overcoming misconceptions about blood flow • Applying prior knowledge to new contexts • Understanding the role respiration plays in circulation
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Note. NM= Not mentioned

During the spring semester, Mary realized that to help students overcome their learning difficulties, lectures would not be enough. Although she still planned to lecture to help students learn, Mary also believed students needed multiple exposures and group work to learn the content. Consistent with this view, she used a number of different “practice” type of activities so students could have multiple exposures to help them overcome their difficulties when learning new content. This illustrates a development in Mary’s knowledge of learners and instructional sequences from encompassing her memories of being a student to drawing on direct teaching experiences to sequence instruction to accommodate learners’ needs. However, her teaching continues to reflect a view of teaching as telling and learning as listening.

The Contributing Factors to Mary's Development of Knowledge of Teaching and Learning

Despite her experiences as a tutor, Mary attributed much of her knowledge of science teaching to her K-16 experiences at the beginning of the ACP. Mary's K-16 science experiences were the initial source of her science teaching orientation. Mary's science teaching orientation subsequently shaped her knowledge of learners and instructional sequences. After 11 weeks in the ACP, her experiences in the ACP courses (i.e., Secondary Science Methods and Educational Psychology courses) influenced her knowledge of learners. However, during this time, she mainly relied on her science teaching orientation to shape her knowledge of teaching and learning.

During both the fall and spring semesters, Mary's mentor teachers and the school context strongly reinforced her science teaching orientation. She encountered mostly "delivery" modes of instruction and used her mentor teacher's materials and the department's Human Anatomy curriculum. Although Mary was also enrolled in Secondary Science Methods courses during this time, she observed that the coursework was dissimilar to her K-16 experiences and her teaching context. Mary drew mostly on her K-16 experiences and the guided internship when talking about her knowledge of teaching and learning.

Over a nine month time span, Mary learned about student-centered instructional strategies in the Science Methods courses; however, her knowledge of instructional sequences remained teacher-centered. Even though she developed an awareness of student difficulties from working with students, she primarily thought students need lectures and "practice" types of activities to commit terms and concepts to memory. Her

science teaching orientation acted as a filter for making sense of her experiences in the ACP. She embraced strategies her mentor teacher used that matched her image of teaching and learning. She struggled to accept the strategies from the Science Methods courses that deviated from her experiences with her mentor teacher and her view that teaching is telling and learning is listening.

2. Amy's Case

Experiences Prior to Program

Amy, age 26, did not initially set out to become a science teacher. She graduated with an undergraduate degree in biology and planned to pursue a medical degree. However, after interning in a hospital, she decided against attending medical school because “the lifestyle of a doctor wasn’t the lifestyle [she] wanted to live.” In Amy’s application materials she described her reasons for changing career paths: “Being a teacher would allow me to give back to society in a positive and rewarding way, while still leaving time for my family and other things in life that I find important.”

Amy had numerous informal experiences working with youth as a snow board instructor, soccer coach, and camp counselor. She wrote at length in her application materials about how she worked closely with adolescents and developed different programs in these contexts to pique students’ interests. Amy also worked in a formal K-12 setting as a substitute teacher. However, she believed her job as a substitute teacher provided her with limited opportunities to plan and teach science content. When Amy described her job as a substitute she said the regular classroom teachers “would give us all the information that they wanted to give.” Additionally, most of her substitute teaching experiences were in elementary classrooms where she thought she “did a lot of babysitting.”

Beginning of the ACP

During the entry task, Amy designed lessons to teach heritable variation to 8th grade students. After Amy designed her lessons, she was interviewed about her views and knowledge of teaching. Amy also watched a video of a reform-based class and

reflected on the teaching and learning that occurred in the video segment. The interpretations below include data from the lesson Amy created, the interview, and the video reflection.

Orientations

Amy's teaching orientation consisted of her views of the teacher and student roles, her goals for student learning, and how she planned to teach. Based on Amy's experience as a mentor and a K-16 student, she thought that her role as a teacher was to be both a guide and leader. As a guide, Amy hoped students would ask questions about the origin of their traits so she could help them understand heredity. She said, "I was getting them to ask questions to get them to really think about, 'I don't just have brown hair because I was born with it. I have it because my family has it'" (Entry Task Interview). As a leader who controls the lesson, she planned to "find a nice medium pace that everybody could move along with fairly well and learn" (Entry Task Interview). Additionally, she could lead the class during discussions by collecting and summarizing students' big ideas. She mentioned, "While they're discussing I'll make notes on the overhead" (Entry Task Interview). She believed that students have a passive role and should follow her lead, meaning that students should participate in discussions and ask questions when they were confused.

Amy's central goals for teaching science included: for students to apply science to their lives, and to prepare students for future science courses. She explained, "I want my students to not only learn the subject material, but also take away valuable life learning lessons. I want them to learn to think analytically and critically not only in the

classroom, but also in their everyday lives” (Video Task). According to this goal, Amy would

Give them an opportunity to get their parents involved and to learn more about their own family as opposed to just learning about heredity and genetic ... (because) it’s always easier to learn when you relate it back to your own personal life and situation” (Entry Task Interview).

Amy also talked about the importance of preparing students for future courses. She wrote, “I would be satisfied if I was able to cover all of the material on the lesson plan for the day and had time for discussion at the end” (Video Reflection). Amy believed she needed to cover the content so students are prepared for high school science courses. Amy’s dominant conception was that science teaching is telling and learning is listening shaped her knowledge of teaching and learning.

Instructional Sequence

Day 1. Amy planned to begin with a discussion that involved students. She planned to ask students a number of questions about variation within a species and highlight that “traits” are variable within a species and have a genetic basis. After students understood the term “trait” she would “ask them to write as many traits as they can think of that may have heritable variation within a variety of species” (Entry Task Interview). Discussing variation within the class and within other species, allowed students to practice their ideas about traits. Amy concluded the first day’s lesson by showing how traits could be traced across generations using a family tree. For homework, Amy had students “pick one heritable trait and make a family tree starting with your grandparents or even your great-grandparents and list the trait next to their name.”

Day 2. During the second day, Amy planned to begin by having students share the family trees they constructed as homework. Then, Amy planned to transition to studying variation and heredity in different species of organism. She wanted students to “look at a few different species and discuss different heritable traits.” For example, she would begin with dogs, cats, and insects. Amy was unsure how to continue after the discussion and thought she might do a lab where students investigate heritability in fruit fly or have students read an article on heritability. Amy would conclude the day by summarizing heritable variation and traits.

On the first day, Amy planned to use an instructional sequence that focused on teacher-centered strategies to transmit knowledge to students in the “inform” types of instruction. Amy believed that science teaching and learning begins with discussions and lectures where the teacher introduces vocabulary. The other activities Amy planned were used to motivate students to learn the content she presented in discussions and to provide opportunities for students to practice new content in other contexts. Table 19 summarizes Amy’s lesson Plan for Day One and Two.

Table 19

Amy's Lesson Plan, Day 1 and 2, Beginning of Summer

	Sequence	Activity	Description
Day 1	Inform	• Discussion	• Teacher leads a discussion of variability within an organism and introduces the term “trait.”
	Practice	• Group work	• Students brainstorm variation within the class and within other species of organism.
	Inform	• Discussion	• Teacher discusses how family trees can be used to trace heritable traits across generations.
	Practice	• Homework	• Students do a family tree for one trait.
Day 2	Review	• Review homework	• Students share family trees.
	Practice	• Discussion	• Teacher and students use family trees and heritable traits within other species to discuss variation and heritability.

Knowledge of Learners

At the beginning of the ACP, Amy believed that students have life experiences but not prior science knowledge. She said, “I think that the variation, the heritable variation is probably going to be a new term to them, but they see it every single day, it surrounds them” (Entry Task Interview). Due to her uncertainty about students’ prior knowledge, Amy elected to focus on what students know about their characteristics, their peers’ traits, and traits found in their family, as a way to connect the content to students’ lives. She explained:

I don’t think that they’ll know exactly that their traits are heritable until ... we start looking at it Maybe they’ll be able to associate the different traits within their family that they inherited. There is variation between their families and there is variation between the students sitting next to them. And I’m sure that they’re going to have an idea of it, but I don’t think that they know where it came from. (Entry Task Interview)

In general, Amy stressed that she could help students learn genetics by relating new concepts to their life experiences.

Requirements for learning. Amy emphasized the importance of connecting new content to students' experiences through teacher-led discussions. She planned to discuss family trees because "it might make it easier [to see the] association of the different traits with the different family members" (Entry Task Interview). Additionally, she thought during discussions she could guide students' to make connections between their characteristics to think critically about inheritance. She commented, "I was hoping it would get them thinking more along the lines of, if there is this much variation just within my family, I wonder how much ... variations are in my family ... or the world around me" (Entry Task Interview).

Areas of student difficulty. Although Amy had not taught genetics in a formal setting, she thought that learners have difficulties visualizing how traits are passed across generations. Amy talked about these difficulties:

Visualizing how everything came together ... half of my parents' chromosomes and half of mine, so I think that would probably be hard if we started getting that indepth....And your grandparents, the same thing from them, so you even have a tiny bit of your grandparents' DNA. (Entry Task interview)

Amy believed inheritance was an abstract concept for students and difficult for them to visualize without physically seeing how traits and characteristics are passed across generations.

Contributing Factors to the Development of Amy's Knowledge of Teaching and Learning at the Beginning of the ACP

Amy's experiences as a secondary and post-secondary student influenced her knowledge and how she planned to teach heritable variation. She drew on her memories of being a student and how her teacher taught to design the activities she planned to use in the lesson. According to Amy,

I remember taking my 9th grade biology or regular science class in high school and I remember doing ... the actual fruit fly study. We had the little vials and we crossed them over and then count them every day and all that kind of stuff. (Entry Task Interview)

Amy learned from her informal experiences mentoring adolescents about the importance of teaching through discussions. Amy had success showing students how to snow board and play soccer by telling students how to do these activities during discussions. Amy's K-16 and mentoring experiences influenced her orientation to science teaching.

End of Summer

At the time the end of the summer interview was conducted, Amy had completed her first summer in the ACP. She had taken courses in Educational Psychology and Secondary Science Methods I. In the interview, she reflected on her initial lesson plan.

Orientations

After 11 weeks in the ACP, Amy's orientation had not changed significantly. She continued to view science teaching as telling and learning as listening. Amy reported it was her responsibility to start off leading the discussion to present terms and concepts, and then provide students with some freedom to work with new ideas by talking with their peers so they feel a sense of ownership for learning. Amy described her role as a leader and a guide during class,

I would kind of start off initially leading class discussion and then let the kids go on and I'd just walk around and listen and ask questions and kind of pipe in every once in a while. So, they're feeling like they have control of what they're talking about. (End of Summer Interview)

Although Amy gained some student-centered views of activities she could use from the Science Methods course, her knowledge of teaching remained teacher-centered. During the end of the summer interview, Amy focused on her responsibilities during the lesson and still believed students had a passive role and are responsible for following the teachers lead.

Amy continued to believe that the central goal of science teaching was to present science content so students could apply their science knowledge to their lives. In her lessons on heredity, she wanted students to think deeply about variation found in nature.

She stated:

It's not just within humans, but that there's a reason why, everything's different. There's a reason why in Missouri we don't have palm trees and in Florida they do. And just that ... that there is genetic variation or whatever within such a large species, that's the reason why. (End of Summer Interview)

Amy also still thought that a central goal of science teaching is to prepare students for future science classes. She said, "Just to give them kind of a solid framework to work with whenever they are taking a genetics course later in high school or in college. They can look back and go, oh, I remember" (End of Summer Interview). Thus, Amy believed one reason students learn science in 8th grade is to prepare for high school science courses.

Sequence of Instruction

Amy planned on using the same instructional sequence to teach the lessons that she designed on the first day of her ACP. However, she planned to modify the original activities to be more “student-centered” due to her experiences in the ACP coursework. Reflecting on her initial lesson plans, she thought her use of discussion and questions were too specific and elicited a limited number of correct responses. According to Amy,

I ask them very specific questions like what color hair do your parents and grandparents have, color eyes, and stuff. So maybe instead of asking such specific questions, ask them, what do you think are some heredity traits? Can you think of any? Look around in your classroom, and look around, you know, and just have them then tell me, oh well, hair color maybe, or eye color, or how tall you are, how short you are, or, you know, just these various things to, you know, so then they’re thinking maybe of all the different traits instead of limiting them. (End of Summer Interview)

Amy would ask students open-ended questions and have students participate more in the discussion to promote critical thinking. During the second day, Amy planned to do the same activities and was still unsure how to engage students at the end of the lesson. She contemplated having students go on a field trip to observe variation in plants instead of the fruit fly lab.

Amy still believed that science learning occurs through “inform” types of instruction where she could deliver knowledge to students through teacher-led discussions and lectures at the beginning of lessons. Although she gained more student-centered activities she could, her knowledge of instructional sequences remained teacher-centered.

Knowledge of Learners

At the end of the summer, Amy planned to evaluate students' knowledge about genetics before she started the unit. She thought she would find out what students know by having them create a concept map using the terms "gene, genome, DNA, RNA, single strand helix, and double strand helix" (End of Summer Interview). She learned about this strategy in the Secondary Science Methods.

Requirements for learning. Amy continued to believe that discussing the content in relation to students' life experiences is fundamental for learning science. However, she also learned from the Secondary Science Methods Course that teacher-led discussions would not always be enough to help students understand science. Amy developed additional ideas about the requirements of learning that included: making observations of phenomena; investigating scientific questions, collecting data; hands-on experiences; and coteaching. These additional ideas about learners and learning had limited appearances in her instructional practices.

Amy reflected on learning about the nature of science and inquiry during the Secondary Science Methods course and believed that observation and collecting data are part of science. She explained:

Get them out of the classroom and actually in an environment that, I think, is when science might be learned best It's pointless to learn about trees unless you're out actually looking at them and actually watching them or observing and seeing different things. (End of Summer Interview)

Related to these ideas, she thought students needed hands-on experiences because "humans are much better at hands-on and actually touching and relating that to things as opposed to just reading about them. So anytime they could get hands-on opportunities for learning, it's probably best" (End of Summer Interview). Amy also viewed inquiry-

based learning as a way to learn science because students are asked to answer questions about natural phenomena on their own or in groups. She compared the benefits of inquiry-based learning with a traditional, teacher-center approach. She explained:

It's really easy for you to tell me something and I'll just put it in the back of my mind, but if I'm actually going out and figuring out why a tree grows instead of you just telling me about photosynthesis, figuring it out, like, if we put a tree in a completely dark room and it doesn't grow as opposed to the one in the sunlight, that would help me to realize that sunlight is one of the main factors in photosynthesis. So just giving them a real life investigation that they can do will make them think about all aspects of it, instead of me just telling them things. (End of Summer Interview)

Amy thought that the benefit of students working together is that they learn new material by talking through their thoughts and teaching each other. She explained, "You really kind of learn it as you are thinking about 'how am I going to present the information to somebody else' (End of Summer Interview). During the end of the summer interview, Amy talked about a number of connected ideas about the requirements for learning; however, Amy still mostly believed that learning occurs when the teacher leads discussions that relate the content to students' experiences. At this point in time, she believed if she could connect content to students' experiences they would have no difficulties learning from her lessons.

Contributing Factors to the Development of Amy's Knowledge of Teaching and Learning at the End of the Summer

Amy learned from the Secondary Science Methods course about assessing prior knowledge. She believed that teachers are responsible for using what students know about the content to teach science. So, she planned to use students' concepts maps to assess prior knowledge of heredity and design instruction. Amy also experienced an

inquiry investigation to learn about the physics involved with parachutes. She made connections between this inquiry experience and accepted the view that students need to make observations of phenomena; investigate scientific questions, collect data, have hands-on experiences, and coteach each other to learn science. Amy believed that inquiry challenges students to learn on their own. According to Amy, “From all the mini-readings on inquiry, students or people in general learn best when they’re actually relating the information back to themselves and actually figuring it out on their own” (End of Summer Interview).

Internship Context

For the 2006-2007 school year, Amy interned with an experienced mentor, Emily, at Rover High School. Emily was a veteran teacher who holds “Nationally Board Certification,” is chair of the science department, supervised numerous teaching-interns, and taught a Science Methods course at a local university. As the chair of the department, Emily believed that teachers who taught the same subject matter should meet frequently to design a common curriculum that included: lessons, assessments, and unit objectives supported by state and national standards. Interns were encouraged to participate in weekly science faculty meetings and contribute ideas that could be used to teach the unit objectives. Amy took part in the weekly biology groups meeting and described them by saying “we try to do it exactly the same as the other honors biology. So the beginning of the week before each new unit, we all get together and kind of go over what we’re doing” (Pre-observation Interview).

Emily's philosophy on teacher preparation was that interns need to observe and mimic experienced mentors. While students mimic her teaching style, Emily cotaught with them so she could add her science knowledge and experiences during the lessons, teach student interns about instructional pace and timing, and ensure that her interns kept the same pace with other biology classes. As interns gained experience, Emily allowed them to use the unit objectives and common assessments to design some of their own instructional activities. After interns gained experience, Emily still used a coteaching approach, but did not have students observe and mimic her style. Amy described her experiences as a student intern, "I have not done a lot of the actual planning ... I probably teach at least half of every hour. Some days I teach the whole hour, but Emily and I generally coteach things together" (Pre-observation Interview). When Amy created her own notes and quizzes she talked about using her mentor's lectures as a guide: "I usually generally take her notes ... and make up my own notes based on that. It's not starting from scratch by any means" (Pre-observation Interview).

Fall Semester

At the time the fall semester interview-observation cycle was conducted, Amy also enrolled in Secondary Science Methods II and was teaching Honors Biology. The observations took place in Amy's third period block class. The third block class had 10 males and 7 female students. The students were beginning a unit on cloning and stem cells. The interpretations below include data from the pre-observation interview, lesson plans, field notes, stimulated recall interviews, and mentor teacher interview.

Orientations

During the fall semester, Amy observed and mimicked using mostly “delivery” modes of instruction. This strongly reinforced her view that science teaching is telling and learning is listening. She emphasized this view a number of times, in speaking about her views of the teacher and student roles, her goals, and how she was learning to teach. Amy thought that students needed teacher-centered, direct instruction to learn the content. She was working on being more direct and firm with students so she could get them through the lesson. She explained, “One of the main things we’ve been working on is, just being more drill sergeant-like, telling students pick up your piece of paper, write these three things down, do this” (Stimulated Recall, Day 2). Amy learned from her mentor that it was her responsibility to keep students focused so they receive all of the information she has planned for the lesson. When asked about the students’ job in her class, she said:

I think their role is to do what they’re told ... and to be cooperative with me and ... to realize that I’m not assigning this work because I don’t want you to have any free time. I’m giving you this work because I care about you and I want you to learn this. (Stimulated Recall, Day 2)

Amy believed students should be respectful and follow the teacher’s lead because they need direction.

Amy’s goals altered due to the topic she was teaching during the fall semester and she focused on presenting content so students were ready to make scientifically-based decisions. She thought that science class was a place for students to receive accurate information about different types of cloning such as therapeutic and reproductive cloning. According to Amy,

I want them to realize that that's not the only kind of cloning [referring to reproductive cloning] that, there are variants to that. Just to give them a broader understanding of something that they obviously have heard about, with the elections that were just a few months ago, so they've known something about it and have heard something about it

Additionally, Amy talked about students needing to be informed because the media's portrayal of cloning is not always scientifically accurate:

They don't really give all the facts So I want them to be able to kind of decide on their own and just understand all of the different types [referring to both reproductive and therapeutic cloning] and that it's more than just creating an exact replica of something. (Pre-observation Interview)

Amy's science teaching orientation continued to drive her thinking about teaching and learning.

Instructional Sequence

Day 1. Amy began the lesson by having students take a quiz to review content previously covered. Next, she used a PowerPoint lecture that she created in the Secondary Science Methods II course to involve students in the lecture by asking questions and have them look at pictures while they took notes. When Amy was finished giving notes, students worked in groups to read, summarize, and list the pros and cons of cloning presented in different articles. She talked about lecturing first so students had the necessary background knowledge to understand the articles: "They need that background knowledge so whenever they are reading the articles they know what the articles are talking about. So, that was my kind of reasoning behind it" (Pre-observation Interview). The class concluded with Amy summarizing the main points about cloning from her lecture and the articles.

Day 2. Amy began the second lesson by reviewing cloning and watching a video so students learned more about cloning. Next, Amy had students discuss cloning dinosaurs based on what they learned from the video and about embryo cloning from her lecture on Day One. During the discussion, Amy wrote big ideas that were scientifically accurate on the board to highlight previous terms and concepts.

On both days, Amy planned to use an instructional sequence that centered on providing new content knowledge to students during the PowerPoint lecture through “inform” types of instruction that occurred near the beginning of her lessons. Amy continued to believe that learning begins when the teacher introduces new terms and concepts through “inform” types of instruction. The other activities she planned served to focus students’ attention on the lesson, and provide them opportunities to practice terms and concepts. Table 20 summarizes Amy’s lesson plans for Day One and Two.

Table 20

Amy's lesson Plan Day One and Two, Fall semester

	Phase:	Activity	Description:
Day 1	Review	• Quiz	• Students take a quiz that focused students on being in science class.
	Inform	• Lecture	• Teacher uses a PowerPoint to lecture to students about cloning.
	Practice e	• Read articles	• Students read articles about cloning and answer questions.
		• Group discussion	• . Students discuss the pros and cons of cloning based on the articles from Day One
Inform	• Debrief	• Teacher summarizes main points from the articles and lecture.	
Day 2	Review	• Review lecture	• Teacher reviews main points from her lecture on cloning and the articles from Day One.
	Inform	• Video	• Students watch “The Real Jurassic Park.”
		• Discussion	• Teacher asks students questions about the film and highlights scientifically accurate conceptions of cloning on the front board.
	Practice	• Independent practice	• Students list the pros and cons of cloning based on the film and their discussions.
		• Group sharing	• Students share their ideas about the pros and cons of cloning as a large group.

Knowledge of Learners

Amy described students’ prior knowledge in more detail than in earlier interviews. She knew that students were exposed to popular media portrayals and ethical issues associated with cloning due to recent stem cell initiatives in local elections and talked about her students “watching the news...listening to the recent debates...and new amendments being passed” (Pre-observation Interview). Amy’s students also knew about examples of animals that were cloned such as Dolly. However, Amy thought that students did not know about therapeutic and reproductive cloning because “they have never really taken much biology” (Pre-observation Interview).

Requirements for learning. As a result of working with her mentor, Amy developed more extensive descriptions of students' learning needs. She built on her prior knowledge and now believed that learning mostly occurs through the combination of lectures and "peer teaching." Amy thought that learning starts when the teacher tells students information that connects the content to students' prior experiences. She commented:

Most of this biology stuff is kind of new to them so I feel like we have to start from the beginning, like this is what DNA is because they don't have any previous knowledge on that. But once we start giving them information, they pick it up really quickly and they're able to apply new knowledge to the old knowledge. (Pre-observation Interview)

Amy frequently had students "peer teach," which meant to her that they discuss the ideas she had told them during lectures to help them commit vocabulary to memory. She explained:

We give information and we talk about it and they talk to neighbors and I say discuss, it's not ever a lot of them just sitting and writing notes or that kind of stuff. So they do a lot of group work and talking about their work, it's really helpful. (Pre-observation Interview)

Amy learned from teaching other topics with her mentor that lectures and "peer teaching" are not always enough and she can lead students in hands-on, modeling experiences to help them understand difficult content. She explained:

When we did protein synthesis, we lined them up in the hallway, each one was a different space and each person was a different amino acid and we moved them in and out of the holes, like physically moved the kids, and I kind of felt sort of silly doing it, but I knew that this was the only way that they were going to understand, you put them to where they, with these kids, that's the way they learn. (Pre-observation Interview)

Amy maintained the role of the leader during the modeling experience by physically moving students during the demonstration and leading the discussions. During the fall

semester, Amy talked about a number of connected teacher-centered ideas about learners and learning that emerged from working with students and her mentor.

Areas of student difficulties. From teaching DNA, Amy described more areas of student difficulties. She observed that students have difficulties visualizing microscopic phenomena because they do not have firsthand experiences with cells and DNA.

Additionally, she recognized that students had trouble visualizing protein synthesis. She believed she could help students overcome their difficulties by using lectures, “peer teaching”, and modeling of complex biological processes.

Contributing Factors to the Development of Amy’s Knowledge of Teaching and Learning during the Fall Semester

Amy’s mentor and the nature of the guided internship reinforced the importance of teacher-centered instructional practices. When Amy was asked about her teaching style, she commented,

I think it’s Emily’s style, with my personality mixed in with it, but it’s her style. It is the only style that I’ve watched and mimicked I’ve spent my whole life in school, but I wasn’t watching what they were teaching and their style of teaching and stuff, so I’ve never really had to think of it in that sense. But every time I’m watching her teach and then just her ... telling me different things to change while I’m teaching....I’m just kind of mimicking what I’m learning. (Stimulated Recall, Day 2)

Additionally, the strategy of breaking up lectures with student “peer teaching” was inspired by her mentor teacher to help students learn the content. The guided internship strongly reinforced teacher-centered aspects of her science teaching orientation

The fall semester’s coursework also influenced Amy’s views of teaching and learning. In her Secondary Science Methods II course, she learned about interactive PowerPoints that use multiple forms of assessment and stream-in videos to involve

students in concept development. However, she interpreted the strategy to be a way for the teacher to focus on transmitting knowledge to students through lectures that use pictures. This strategy reinforced her view that science teaching is delivering knowledge and learning occurs during “inform” types of instruction.

Spring Semester

The spring data collection took place in early April. Amy was enrolled in Secondary Science Methods III and teaching in the guided internship. The interviews and observations took place in the same period as in the fall semester. The students were beginning their unit on cellular respiration and photosynthesis. The interpretations below include data from the pre-observation interview, lesson plans, field notes, and stimulated recall interviews.

Orientations

After teaching for nearly 9 months in the guided internship, Amy’s orientation remained unchanged. She retained the view that science teaching is telling and learning is listening. Amy continued to believe that teachers are both guides and leaders. She explained, “The role of the teacher was to provide guidance for the daily class activities but to make sure the students are staying on task. You are giving them the materials that they need in order to understand the objective” (Stimulated Recall, Day 2). Accordingly, the students’ role was to follow the teachers lead:

The student’s role is to ... do what we’re asking them to do and be a student The role of the student is to come to school and be prepared for whatever, and the teacher needs to be prepared to do. The student needs to be prepared to learn and turn in their homework assignments, those kinds of things and just to learn. (Stimulated Recall, Day 2)

According to these views, Amy believed the central goal of science teaching was to present science terms and concepts to students. Amy's science teaching orientation continued to shape her thinking about teaching and learning.

Instructional Sequence

Day 1. Amy began the lesson by going over the objectives for her photosynthesis and cellular respiration unit. She remarked, "We start off a new unit I give them their objectives and go over them so they know what they're going to be learning in this unit" (Pre-observation Interview). After Amy covered the objectives, she gave a photosynthesis and cellular respiration pretest to assess students' prior knowledge. Students worked in groups to complete the pretest and she did not go over the correct answers. The lessons continued with an investigation called the "funnel lab" where students collected data and answered a series of questions about the independent and dependent variables, the hypothesis, controls, data, sources of error, and the process of photosynthesis. Amy described the lab in detail:

They are going to use a straw and they're going to blow into the funnel connected to a test-tube filled with water and put the BTB [referring to Bromothyl Blue] in there they know they're blowing out CO₂ because the color is changing so we obviously do have CO₂ we're breathing out. (Pre-observation Interview)

I have termed the lab an "investigate" type of instruction because students follow the teachers lead to collected data about content they will cover in subsequent lessons.

During the lab, Amy and her mentor explicitly modeled how to do each step of the lab and told students what they should expect to observe. Thus, the lab provided limited opportunities for students to develop deep conceptual understanding. The hands-on lab

occurred in what I have termed the “investigate” type of instruction because the purpose was to provide students a chance to collect data.

Day 2. Amy began the second lesson by having students present their data from the “funnel lab” to their classmates on the front board. Once all data was on the board, Amy led a discussion about carbon dioxide’s role in cellular respiration and photosynthesis. The purpose of the discussion was for Amy to provide an explanation for what the students observed in the “funnel lab.” Amy was able to use students’ experiences collecting data in the “funnel lab” to verify her explanation. Next students did the “bubble lab” where they tested the rate of photosynthesis by exposing a plant submerged in sodium bicarbonate to different intensities of light. Similar to the first day, Amy and her mentor modeled the procedure, set-up, and gave a brief explanation of what students should observe.

On both days, Amy planned to use an instructional sequence that began by focusing the lesson in relation to the unit objectives. Next she provided a step-by-step procedure and explanation of what students should expect to find. When Amy led a discussion during “inform” types of instruction on Day Two, she was able to reinforce the science content with the data students collected. Amy continued to believe that science teaching and learning begins with lectures and teacher-led discussions. Table 21 summarizes Amy’s lesson plan for Day One and Two.

Table 21

Amy's Lesson Plan, Day 1 and 2, Spring Semester

	Sequence	Activity	Description:
Day 1	Focus	• Introduction	• Teacher goes over photosynthesis and cellular respiration unit objectives.
		• Pre-assessment	• Teacher implemented a photosynthesis and cellular respiration pretest to determine prior knowledge.
	Inform	• Laboratory procedure • Discussion	• Teacher models the step-by-step procedure for carrying out the “funnel lab.” • Teacher discusses the findings students should expect
	Investigate	• Laboratory	• Students carryout the “funnel lab.”
Day 2	Review	• Presentations	• Students present “funnel lab” data on the front board.
	Inform	• Discussion	• Teacher explains the role of carbon dioxide in cellular respiration and photosynthesis in light of the data students collected.
	Investigate	• Laboratory procedure • Laboratory	• Students follow teacher’s lead to carryout “bubble lab.”

Knowledge of Learners

Similar to previous times, Amy planned to implement a pretest to assess student’s prior knowledge and to design activities. She talked about the pretest:

It’s just a photosynthesis pretest to see what they remember from their ecology unit and what they're able to apply to the new unit were not going to really discusses it.We’re going to collected them so we have an idea what they know, what they don't know, and things they need to focus on more. (Pre-Observation Interview)

Amy also knew from teaching that students would remember some of the reactants and products in photosynthesis but did not understand the relationship between photosynthesis and cellular respiration. She explained:

I think they have an idea about the carbon and oxygen cycle and they understand that you know trees are going to have the glucose and some of the reactants and products, but I don't think they know how it all fits together yet [referring to photosynthesis and cellular respiration]. (Pre-observation Interview)

Requirements for learning. After teaching for nearly nine months, Amy's views of students' needs had not changed significantly. She continued to characterize learning as being dependent on lectures and teacher-led discussions, "peer teaching" experiences, and hands-on experiences to visualize complex biological processes. These were strategies her mentor teacher advocated to help students overcome their difficulties learning science. Amy thought that students did not make the connection between photosynthesis and cellular respiration because they had not taken notes on the topic. She remarked, "I just don't think that they've ever actually written out the equation before and really understood and studied how cellular respiration and photosynthesis work together" (Pre-observation Interview). Amy also continued to believe learners need to talk through the content and coteach each other. For Amy, the benefit of "peer teaching" is that students pay closer attention during lectures. She explained:

Students benefit from explaining the content to each other ...vs. just writing it down from the board....Students explain it correctly to each other because they don't want to explain it wrong to their peers ...they really listen so they can explain it right ...if they know they are going to share the right answers they work harder on it because they don't want to be wrong for their friends. (Stimulated Recall, Day 1)

Amy also continued to think that learners need to have hands-on experiences to visualize the process of photosynthesis. She talked about the importance of hands-on experiences during the "funnel lab:"

I think it is especially tough with photosynthesis because it's not process you can directly observed, but with these labs we're using indicators and different things to allow them to actually ... see the process of photosynthesis happening. So, I think that hands-on, being able to manipulate their variables, and "what if I just blow once into it, and just blow a little, ... will the same process happened if I blow a whole bunch in it?" So, I think it's good for them to be able to see and touch these things. (Pre-observation Interview)

As in previous times, Amy talked about students needing structure to do hands-on. This is why she planned to model the "funnel lab," step-by-step, and provide a brief explanations of what students should expect to see before they do the lab. After teaching for nearly two semesters, Amy believed that if she lectured, provided "peer teaching" opportunities, and led hands-on activities, then students would have no difficulties learning the content.

Contributing Factors to the Development of Amy's Knowledge of Teaching and Learning during the Spring Semester

Amy and her mentor had lengthy and extensive conversations about teaching and learning. These discussions heightened her awareness of the need for teacher-centered instruction and she worked on becoming more assertive and directive with students.

Amy commented:

[Initially] I was more concerned with helping and I guess just being nice in a sense. Instead of saying 'everybody please come back to the front,' she says (referring to mentor) 'you go here, you go here, and you sit down here, don't talk, and do this.' At first I thought it was very aggressive, and I was thinking 'ok, that's not me and I can't do that,' but now that I've seen how it worked I'm more directive with them and more like she said at the very beginning, 'you need to be more like a drill sergeant.' (Stimulated Recall, Day 2)

Amy believed she adopted her mentor teachers' style to teach science. She said, "My teaching style is very similar to my mentor teacher. She essentially has taught me how to

implement all the things that I've learned in school" (Stimulated Recall, Day 2).

Additionally, Amy believed that Emily's mentoring was vital for her professional growth as a teacher and without the mentoring she believed, "I wouldn't be able to do it at all I don't think. I wouldn't be comfortable as a first year teacher. (Simulated Recall, Day 2)

Amy reflected on how the ACP coursework influenced her knowledge of teaching. In the Secondary Science Methods courses she learned about inquiry. She made connections between the value of inquiry-based instruction and said, "I agree to a certain extent, that it should be inquiry based that the students do learn better doing that" (Stimulated Recall, Day 2). However, Amy believed inquiry had to be "hands-on" and required students to carry out an independent investigation. She explained:

There are some things that we can just say. For instance in our last unit, I can ask them an engaging question about food chains and food webs and we can read a story about it and have them make up their own food chains and food webs, but the concepts, they just get it. You don't really have to do what I think of at least as inquiry where they're doing experiments and they're doing something on their own first. (Stimulated Recall, Day 2)

Amy thought that the Secondary Science Methods courses only presented science teaching as being inquiry-based, when, there are other strategies that teachers implement. She said, "I feel like in school [referring to the Secondary Science Methods courses] they don't always give you that other way. It's always inquiry based" (Stimulated Recall, Day 2). Even though she learned new instructional strategies, like the 5E instructional model, and how this sequence relates to student learning, she reflected exclusively on the guided internship when speaking about how she has learned to teach. She explained in detail:

I think that the courses at the university you learn all of these things, you learn about classroom management, you learn about the different teaching philosophies in Educational Psychology and all of that kind of stuff. You learn about this 5E instructional model, and so I have it all there but I don't really use it ... So, I think the most beneficial thing for me was my

student teaching and working with my mentor teacher where I can say, when she gives me a whole unit to do, I can try to use all of that stuff that I've learned and implement it with her advisory and her saying 'oh, no we've tried this before. This is going to work.' (Stimulated Recall, Day 2)

Summary: the Nature of Amy's Development of Knowledge of Teaching and Learning

Development of Amy's Science Teaching Orientation

Amy orientation was complex and consisted of multiple dimensions. These dimensions included: views of teaching and learning; views of the teacher and student roles; central goals for teaching science (see Table 22). Amy came into the ACP believing science teaching is telling and learning is listening based on her observations of science teachers who mostly used "delivery" modes of instruction. This view was strongly reinforced in the guided internship where she observed, mimicked, and taught using mostly teacher-centered practices. Although Amy took on additional goals during the fall and spring semesters, there is little evidence that she held other orientations to science teaching during 9 month of the ACP. Over time, Amy's science teaching orientation was highly resistant to change and remained stable.

Table 22

Development of Amy's Orientation to Science Teaching

Dimensions	Entry	End of Summer	Fall Semester	Spring Semester
Views of teaching and learning	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening
Views of the teacher roles	• Guide/Leader	• Guide/Leader	• Leader	• Guide/Leader
Views of the students roles	• Follower	• Follower	• Follower	• Follower
Central goals	<ul style="list-style-type: none"> • For students to apply science to life • Prepare students for future courses 	<ul style="list-style-type: none"> • For students to apply science to life • Prepare students for future courses 	<ul style="list-style-type: none"> • NM • NM • Present science content so students are ready to make scientific decisions 	<ul style="list-style-type: none"> • NM • NM • Present science content

Note. NM= Not mentioned

Development of Amy's Knowledge of Instructional Sequences

Amy's knowledge of instructional sequences gave priority to transmitting information during "inform" types of instruction. Amy consistently believed that learning begins when the teacher introduces new terms and concepts. The other types of instruction Amy designed focused students' attention so they were ready for her lectures, provided opportunities to practice terms and concepts, and allowed students to have hands-on experiences collecting data. Table 23 summarizes Amy's sequence of instruction to teach science.

Table 23

Development of Amy’s Sequence of Science Instruction

Entry		End of Summer		Fall		Spring →	
Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Inform	Review	Inform	Review	Review	Review	Focus	Review
Practice	Practice	Practice	Practice	Inform	Inform	Inform	Inform
Inform		Inform		Practice	Practice	Investigate	Investigate
Practice		Practice		Inform			

Development of Amy’s Knowledge of Learners

Over time, Amy broadened her knowledge of the requirements of learners as a result of her experiences in the ACP courses, working with her mentor, and teaching students. For example, Amy’s knowledge of the requirements of learners expanded as a result of her experiences in the ACP course and she learned that students also need to: make observations of phenomena, have hands-on experiences, investigate scientific questions, collect data, and coteach. She learned during the fall semester that students need a combination of lectures and teacher-led discussions, “peer teaching” experiences, and teacher-led hands-on experiences to visualize concepts. Table 24 shows Amy’s development of knowledge of learners including: requirements of learners, and areas of student difficulties learning science.

Table 24

Amy's Development of Knowledge of Learners

Knowledge of Learners	Entry	End of Summer	Fall Semester	Spring Semester
Requirements for Learning Science	<ul style="list-style-type: none"> • Students need lectures and discussions • Connections to life 	<ul style="list-style-type: none"> • Students need lectures and discussions • Connections to life • Making observations of phenomena • Hands-on experiences • Investigating scientific questions • Collecting data • Coteaching experiences 	<ul style="list-style-type: none"> • Students need lectures and discussions • Connections to life • NM • Hand-on experiences • NM • NM • NM • “Peer teaching” experiences 	<ul style="list-style-type: none"> • Students need lectures and discussions • NM • Make observations of phenomena • Hands-on experiences • NM • Collecting data • NM • “Peer teaching” experiences
Areas of Difficulties Learning Science	<ul style="list-style-type: none"> • Visualizing how traits are passed across generations 	<ul style="list-style-type: none"> • NM 	<ul style="list-style-type: none"> • NM • Visualizing microscopic phenomena 	<ul style="list-style-type: none"> • NM • NM

Note. NM= Not mentioned

Development of Amy's Integration of Knowledge of Learners and Instructional Sequences

Over time, Amy developed knowledge of learners that was integrated with her knowledge of instructional sequences; however, her instructional sequences did not fully reflect her knowledge of learners. Amy primarily relied on teacher-led “discussions” during “inform” types of instruction to transmit knowledge to students. However, during the fall semester she thought students needed the combination of lectures, “peer teaching”

experiences, and teacher-led hands-on experiences. Thus, Amy often broke-up “inform” types of instruction to provide “peer teaching” experiences so students could re-state lecture notes in their own words. Additionally, she purposefully provided “practice” types so students could rehearse the material. Although the integration is relatively weak, the situation shows a shift away from a reliance on K-12 experiences to her current teaching experiences to help students overcome their difficulties learning science based on her first hand teaching experiences.

Contributing Factors to Amy’s Development of Knowledge of Teaching and Learning

At the beginning of the ACP, Amy planned to teach her classes similar to her K-12 teachers and how she mentored youth. This meant she focused on using teacher-led discussions that related new content to students’ life experiences. Her K-16 and mentoring experiences were the source of her science teaching orientation that characterized science teaching as telling and learning as listening. After the first Secondary Science Methods course, Amy’s knowledge of learners expanded; however her science teaching orientation remained unchanged. During the fall and spring semesters, Amy taught alongside a mentor who strongly advocated teacher-centered, “delivery” types of instruction. The guided internship strongly reinforced her science teaching orientation. During the fall and spring semesters, Amy drew almost exclusively on her experiences with a mentor and students in the guided internship when talking about her knowledge of teaching and learning. Amy observed that the instructional strategies proposed in the Secondary Science Methods courses did not align with her science teaching orientation and how she was learning to teach in the guided internship.

Only through the guided internship did Amy believe she developed knowledge of how to teach science.

Despite learning about student-centered instructional sequences in the Science Methods courses, Amy retained the view that teaching is telling and learning is listening. Amy developed an awareness of student difficulties from teaching, but primarily thought students need lectures and “peer teaching” to learn new content. Amy’s science teaching orientation acted as a filter for making sense of her experiences in the ACP. She embraced strategies her mentor teacher implemented. These strategies matched her views of teaching and learning. Meanwhile, Amy struggled to accept strategies presented in the Science methods courses that deviated from her science teaching orientation and mentor teacher’s instructional practices.

3. Lilly's Case

Experiences Prior to Program

Lilly, age 23, began her academic career in journalism, switching to biology after four semesters. In the fall of her freshman year, she took an influential class in general biology that led to her move into the science field. She stated, "The professor's enthusiasm for the subject helped me realize my own interest in biology, leading me to change my major." Not only did her professor influence her interests in biology, but she had an impact on her desire to become a science teacher. Lilly said, "The impact this professor had on my choice of major helped me recognize the great effect teachers can have on students and fostered my desire to teach biology." After Lilly completed an undergraduate degree in biology from a large research extensive institution she entered the ACP.

Beginning of the ACP

At the beginning of the ACP, Lilly designed two introductory lessons to teach heritable variation to 8th grade students. After she designed her lessons, I interviewed her about her views and knowledge of teaching. Lilly also watched a video of a reform-based class and reflected on the teaching and learning that occurred in the video segment. The interpretations below include data from the lesson Lilly created, the interview, and the video reflection.

Orientations

Lilly's images of teaching and learning were based on her memories of her teachers who mostly taught using a traditional, "transmission" modes of teaching. As a result, Lilly believed science teaching is telling and learning is listening. She expressed this a number of times, in her comments about the teacher student roles, her goals, and how she planned to teach. Lilly explained that her role in the science class is as a "leader" and students should take notes over vocabulary, practice terms and concepts, and ask questions when they are confused. Lilly focused on her responsibilities during instruction, and believed that students have a passive role in the classroom.

Lilly's views about the teacher and student roles were related to her central goal for teaching science that was to prepare and motivate students for future science courses.

She commented:

Before going into high school, where they're going to have a little bit more advanced biology, I think that understanding these basic topics ... gets them more interest in the topic, in the subject, so they would actually be interested in learning once they get on to the higher levels (Entry Task Interview).

Lilly talked a great deal about students needing to understand basic concepts in middle school in order to motivate and prepare them for high school science courses. Lilly's memories of how her teachers taught formed her science teaching orientation.

Instructional Sequence

Day 1. Lilly planned to begin by asking the students “what they know about codes” because she believed how codes were used in video games was an analogy for learning about alleles and traits. Lilly explained, “So while pushing up and forward may allow one to move to a secret room in a video game, having two certain alleles for a trait leads to brown hair.” The lesson continued with the presentation of new terminology and concepts for the day. Lilly planned to do an overview of “what an allele is,” and “what a gene is,” and how alleles and genes “code for a trait.” After Lilly covered new concepts, she planned to ask students to identify some of the traits (e.g., eye color, hair color and dominant hand), and have students think about whether they have any characteristics that differ from their parents. For homework, students would investigate their parent’s and grandparent’s traits.

Day 2. Lilly began the second lesson by having students share what they learned about their grandparents’ and parents’ traits. Lilly hoped students would find instances where she could emphasize how two brown-eyed parents could produce a blue-eyed child. Next, Lilly planned a demonstration to illustrate the difference between dominant and recessive traits. She described her demonstration in detail:

I would have 2 jars of dark purple paint, representing a dominant allele, and 2 jars of yellow paint, representing the recessive allele. In an empty jar, I would show that mixing purple with the purple (a dominant allele from each parent), leading to purple (the dominant trait). In another empty jar, equal parts of purple and yellow would be mixed (dominant from one parent and dominant from the other), which, although possibly a little bit lighter, would still give purple paint (the dominant trait), and in the third jar mix yellow with yellow (a recessive allele from each parent), leading to yellow (the recessive trait).

Lilly planned to do the demonstration at her desk while talking to students about how mixing colors of paint is like heritable variation. Next, she would distribute a worksheet so students could practice using the ideas of dominant and recessive traits to explain heredity. After students completed the worksheet, Lilly planned to lead a discussion to introduce heritable variation in other species.

On both days, Lilly planned an instructional sequence that focused on providing new knowledge to students during “inform” types of instruction. She talked about her ideal day of teaching beginning with lectures and/or discussions:

An ideal day of teaching would begin with doing a brief overview of the concept or idea we are discussing that day, giving the students the framework and definitions necessary to understand the concept ... Following the lecture and classroom discussion, an ideal day in the classroom would end with doing an experiment or demonstration. (Video Reflection)

The “inform” was placed near the beginning of her lessons because she thought teaching and learning begins when the teacher explains new terms and concepts. The other activities she planned focused students on the topic and reinforced knowledge she gave students. Table 25 summarizes Lilly’s lesson plans for Day One and Two.

Table 25

Lilly's Lesson Plan, Day 1 and 2, Beginning of Summer

	Sequence	Activity	Description:
Day 1	Focus	• Discussion	• Teacher asks students what they know about codes.
	Inform	• Discussion	• Teacher uses the analogy that video games and codes are similar to genetic traits and discusses the terms alleles, genes, and traits.
	Practice	• Independent and group practice	• Students brainstorm whether they have traits that differed from their parents.
Day 2	Focus	• Discussion	• Students and teachers discuss how two brown eyed parents can produce a blue eyed child.
	Inform	• Demonstration	• Teacher mixes different colors of paint to show how traits are inherited.
	Practice	• Worksheet	• Students practice the inheritance of dominant and recessive traits by doing a worksheet.
	Inform	• Discussion	• Teacher concludes lesson by discussing heredity in other species of organisms.

Knowledge of Learners

At the beginning of the ACP, Lilly tried to focus on what students would know about science in 8th grade; however, she thought “they’ve not even had much biology yet,” and she was uncertain whether “eighth grade students even understand really that all of your traits are based on both of your parents.”

Requirements for learning. In spite of a lack of students’ prior science knowledge, Lilly believed she could help students learn by relating new concepts to their life experiences during discussions. Lilly commented, “I feel like if you’re just talking to them they’re just not as interested and listening. Where as if you’re talking about them they’re more excited because they’re learning about themselves” (Entry Task Interview).

During discussions, Lilly would go over definitions and “bridge” new and old science ideas. She believed that her video game and paint analogies would engage students because they relate to students’ life experiences.

Areas of student difficulty. Although Lilly had never taught before, she believed that students’ have difficulties overcoming genetics misconceptions. Lilly was concerned that students’ prior conceptions would act as a barrier to learning new content. She said:

Because they don’t have a full concept of how alleles actually code for traits they may think, if you get brown hair from your mom shouldn’t you have a mix of brown and blonde hair? I can see that being a problem.
(Entry Task Interview)

Lily believed she could help students overcome their difficulties by lecturing and discussing content in relation to students’ life experiences.

Contributing Factors to Lilly’s Development of Knowledge for Teaching and Learning at the Beginning of the ACP

Many of Lilly’s ideas of how to teach can be traced back to her memories of how her teachers taught. Her experiences as a K-16 student influenced her knowledge and how she planned to teach the topic of heritable variation. Drawing on her prior experiences, she elected to use what her teachers had done. She said, “I kind of took that approach in doing the lesson plan because it’s what worked for me” (Entry Task Interview). Lilly mostly relied on her subject matter knowledge from undergraduate coursework as she developed her lesson plan. She commented,

I first learned about [heritable variation] in college. We never, that I can remember, went over it in high school, so that was during my undergrad career. I think it was my sophomore year when I took genetics and that was the first time I really knew ... about the topic, a little bit from Bio 1 but mainly then. Once I got into that more advanced class was when I felt I really learned about it. (Entry Task Interview)

Lilly's experiences as a K-16 student were the source of her science teaching orientation.

End of Summer

The end of the summer interview was conducted after 11 weeks of ACP coursework. Lilly had taken Secondary Science Methods I and Educational Psychology. The interview occurred prior to the beginning of Lilly's year-long, guided internship. The interpretations below are from Lilly's reflection on her initial lesson plan.

Orientations

While Lilly talked about a number of reasons for teaching science in middle school, she retained her image that teaching is telling and learning is listening. She continued to describe that the teacher's role is to be a leader who controls the content in the classroom. As a leader in the classroom, Lilly acknowledged that she must "maintain the fact that you are the one who's in charge." Lilly believed that students are responsible for following the teachers lead. Lilly also kept her central goal, which was to prepare students for future science-related courses. She talked about "getting as much knowledge to them as possible while still staying somewhat on track, so they'll be ready for the next year." Lilly saw middle school as an opportunity to provide students with prerequisite factual science knowledge.

Lilly developed additional views of the teacher's role to her science teaching orientation based on her experiences in the Secondary Science Methods courses. For example, she thought that it was her responsibility to act as a guide. Guides let students

have some freedom in choosing the content they want to study. Lilly said, “Guiding them, I mean you want to let the kids pick what they can do to an extent, giving them ideas kind of and setting certain parameters” (End of Summer Interview). Additionally, Lilly wanted to let students choose the content they wanted to study. She stated, “I think it’s a lot more fun if the kids get to pick what they do because they actually want to do it then, which is the whole goal.” Lilly’s science teaching orientation continued to direct her knowledge of teaching and learning.

Instructional Sequence

After the first summer of coursework, Lilly planned to use the same teacher-centered instructional sequence as in her original plan; however, she would have students do more with the definitions and terms to provide additional practice. Additionally, she would have students do “a scavenger hunt through their book ... to find different definitions just so that they’re kind of relating all of the actual definitions.” The sequence she planned still focused on the teacher providing information through lectures and discussions. This sequence held students accountable for knowing science vocabulary through practice.

Knowledge of Learners

Lilly continued to believe that students have few science experiences prior to middle school and primarily learn from teacher-led discussions. However, based on her experiences as a student, Lilly now reported that learners need repetition to commit terms to memory. She would have them “do more with definitions to ... hammer those in a little bit more because ... terminology can be more difficult than concepts especially in

science.” Repetition was important for science learning because Lilly believed students have trouble memorizing terminology.

Lilly gained additional views of the requirements for learning science based on her experiences in the Secondary Science Methods course. She thought that learners need inquiry experiences and equated inquiry with letting students choose what they want to study. She reported: “guiding them so they’re doing science inquiry, but letting them choose kind of the basic content” (End of Summer Interview). Although Lilly’s knowledge of learners expanded, she continued to think that students primarily learn science through lectures and repetition.

Contributing Factors to Lilly’s Development of Knowledge for Teaching and Learning at the End of the Summer

Lilly learned in the Secondary Science Methods course that providing students with the opportunity to make their own scientific decisions promotes critical thinking and engagement. According to Lilly, “We talked about that in this class ... you want to let the kids pick what they can do to an extent, giving them ideas, kind of setting certain parameters” (End of Summer Interview). Additionally, after the Secondary Science Methods Course, Lilly believed that teachers should be guides who provide students with some scientific decision making opportunities. Lilly gained additional views of the teacher’s role based on her experiences in the Secondary Science Methods course which allowed her to embrace more student-centered views of learners and learning. However, her central view that science teaching is telling and learning is listening, continued to dominate her thinking about teaching.

Internship Context

During the 2006-2007 school year, Lilly interned with an experienced mentor, named Linda, at Monroe High School. Linda had mentored numerous student teachers over the years and provided resources and curriculum materials including: lecture notes, assessments, and laboratories. When students interned with Linda, she had them begin by watching her teach. Then, interns mimicked her style in subsequent class periods. Once interns were comfortable teaching, they designed lessons using her resources to teach one class period. During this time, Linda expected to see daily lesson plans and provided interns with detailed and frequent feedback. Linda allowed interns to use her curriculum, but encouraged them to find new and different activities than the ones she provided. With time, she expected student-interns to prepare lessons for two different class periods.

First Semester

At the time the fall 2007 observation was performed, Lilly was enrolled in Secondary Science Methods II and had been in a secondary general biology classroom for approximately 13 weeks. I conducted a pre-observation interview with Lilly so she could clarify what she intended to teach during the two observations. The class I observed met for 50-minutes each and was composed of 14 males and 12 female students. Students were finishing their unit on osmosis and diffusion. The interpretations reported here are based on data from the pre-observation interview, lesson plans, field notes, stimulated recall interviews, and the mentor teacher interview.

Orientations

After teaching with a mentor for approximately 3 months, Lilly's orientation had not changed significantly. She continued to think that science teaching is mostly telling and learning is listening. Lilly viewed teachers as both a guide and a leader as she said, "I guess guiding them through the lesson, and they obviously don't have control, I do, giving them material but not just directing the whole time because they are involved as well" (Stimulated Recall, Day 1). Lilly believed her lessons varied from being teacher-guided to student-led. According to Lilly,

If it is more of going over new material, it's really guiding them through the new material and being sort of in command of what is going on. With a lesson like today, it's more students working on their own with the lab (Stimulated Recall, Day 1).

When talking about the students' "job" in the science class, Lilly thought that students should focus on the content and on "being a student," meaning that students work on science when in science class (Pre-observation Interview). This included that students participate in discussion, write down notes, and ask questions when they are confused.

Lilly explained in detail:

A student's job is to be working on whatever the activity is, if that means they're all caught up maybe helping their neighbor with what they are working on. A lot of times they want to get out other homework from other classes and work on it. I think that one of their jobs is to stay in the lesson and stay with it even if some students work so much faster than others and I know they get bored and we have to wait for everyone. (Stimulated Recall, Day 1)

Regardless of the pace at which students finished their tasks, she believed they should always be engaged in science when in science class. Lilly's central goal in science teaching was to present science content so students could apply science to their lives. She stated, "I want them to think what we are doing is interesting and make it feel

relevant to them” (Pre-observation Interview). Lilly’s initial science teaching orientation was strongly reinforced by her mentor in the guided internship. Her science teaching orientation continued to dominant her thinking about teaching and learning.

Instructional Sequence

Day 1. Lilly began the lesson by having the students take a short quiz to assess whether students could “connect the concepts discussed last week (hypertonic, hypotonic, isotonic, etc.) with a real-life application.” After students finish the quiz, Lilly drew “each of the answers on the board as well, just to ensure that everyone was on the same page.” The lesson continued with a diffusion and osmosis lab called the “Egg Lab-Part II” that was a follow-up to a previous lab. In “Egg Lab-Part II” students placed a deshelled egg in either a hypo, hyper, or isotonic solution of their own choice. Lilly had students make up their own procedure based on their prior experiences. While students work, Lilly said she would be “helping those who are having trouble with their observations, data, etc..., and helping students who need solutions mixed” (Pre-observation Interview). I have termed this an “elaborate” type of instruction because the purpose of the lab was to provide students with the opportunity to use their prior experiences and have a hands-on experience. After the lab, Lilly asked students to read an article on poisonous snails. The reading reviewed what students had learned about cell membranes and marker proteins in an earlier class.

Day 2. Lilly began the second lesson by focusing the lesson on the formal lab report that they would work on in class. Lilly planned on “walking through each part” of the formal lab report with students and have them “talk through what is going to be on the x-axis and y-axis” (Pre-observation Interview). The purpose of discussing line and

bar graphs was so Lilly could provide students with an explanation of how to graph their data from the lab. Lilly concluded Day Two by having students answer discussion questions and to write their conclusions for the formal lab report. Lilly planned to “guide them a bit through the process, giving them ideas of what background information they need to include, and how to draw conclusions from their graphs, etc” (Pre-observation Interview).

On the first day, Lilly planned to use an instructional sequence that centered on providing students with an “elaboration” where they were able to test and manipulate a variable during an investigation. The sequence allowed students to participate in defining and investigating different variables to make scientific claims based on evidence. However, the elaboration was based on students’ prior knowledge and experiences that included: a prior diffusion and osmosis lecture; and “Egg lab-Part I” where students placed a deshelled egg in hypertonic and hypotonic solutions. Lilly’s knowledge of instructional sequence centered on providing knowledge to students during “inform” types of instruction that occurs near the onset of a lesson. Table 26 summarizes Lilly’s lesson plan for Day One and Two.

Table 26

Lilly's Lesson Plan, Day 1 & 2, Fall Semester

	Sequence	Activity	Description
Prior to Lesson	Inform	• lecture	• Teacher lectures over diffusion and osmosis including the terms and concepts: hypertonic, hypotonic, and isotonic
	Investigate	• Laboratory	• Students follow a procedure to do a cookbook lab called the "Egg-lab-Part I." In the lab students placed eggs in syrup, vinegar, and water for 24 hours and then recorded change in mass.
Day 1	Focus	• Quiz	• Students take a quiz on hypertonic, hypotonic, isotonic solutions.
	Elaborate	• Laboratory	• Students design an experiment to explore how a new solution affects diffusion and osmosis in an egg.
	Review	• Homework	• Students read an article on snails that relates to what they previously learned about cell membranes and marker proteins.
Day 2	Focus	• Discussion	• Teacher discusses the lab write-up for Part II of the "Egg Lab-Part II."
	Inform	• Discussion	• Teacher shows students how to construct line and bar graphs.
	Practice	• Student worktime	• Students answer discussion questions and write conclusions for the "Egg Lab- Part II."

Knowledge of Learners

Lilly had learned that students had prior experiences with diffusion and osmosis from her previous lessons that covered the content. She used her knowledge of students' prior ideas about diffusion and osmosis to develop her lessons and help students learn new material.

Requirements for learning. While Lilly mentioned a number of requirements for learning science, she continued to believe learners need mostly teacher-centered instruction, like lectures to learn new content. This is evident in her sequence of instruction that relied on the lectures during “inform” types of instruction that occurred prior to the interview-observation cycle. Thus far, working with students and her mentor has reinforced the importance of multiple exposures to new content. Lilly observed:

I definitely learned it is important to go over a concept in multiple ways. These guys have shown me that because we did the notes for example we did a short PowerPoint on this topic. And they got it a little bit. Then we let them do a worksheet with it. They got it a little bit more. Then we did a project with it. It seems like each time we put the same concept into different arenas I guess they seem to understand it more and more.
(Pre-observation Interview)

Lilly’s other beliefs about the requirements of learning science were related to her knowledge of the importance of multiple exposures. Her knowledge of students’ learning requirements expanded to include: making scientific decisions; having evidence-based experiences; and having hands-on experiences.

Lilly planned the “Egg-lab-Part II” so could have ownership for their learning and test a variable of their own choice based on their knowledge and experiences with diffusion and osmosis. Lilly commented, “They seem to be taking more ownership with what is happening in the lab, because they feel like they’re writing their own procedure. I feel this is something they truly think they’re doing. It seems to help with their interest” (Pre-observation Interview). Additionally, Lilly observed that students better understand diffusion and osmosis by collecting data and measuring changes in egg mass. Lilly talked about how she thought her students would have done on a diffusion and osmosis quiz based on notes and worksheets alone:

Before the lab they did not have a good grasp of osmosis but I think working with the two numbers and realizing that if it went from 58 to 38 it shrunk, so that means water moved out, I don't know if they would have made each connection. (Pre-observation Interview)

Lilly talked about the important role “hands-on” played in collecting data. She explained, “They are really able to see water is moving in and they can feel there is water inside ... seeing it emphasized it in their head ... they can really believe what we are teaching them” (Stimulated Recall, Day 2).

Areas of student difficulties. Lilly's knowledge of student difficulties grew as a result of classroom teaching experience. She talked about more student difficulties in greater detail. For example, she reported that students were confused by the difference between hypotonic and hypertonic solutions: “They do have trouble keeping them [terms] straight ... there were a couple that had the words completely reversed. They had all the hypo as hyper and vice versa. I think that was getting them backwards in their head” (Stimulated Recall, Day 1). Additionally, she observed that students had difficulty transferring knowledge between her diffusion and osmosis lectures, labs, and quizzes. She said she was, “Worried about whether they were connecting this Egg Lab with what we did with the osmosis unit just last week, and connecting the whole hypertonic, hypotonic, isotonic ... and my PowerPoint lesson” (Pre-observation Interview). Although students had completed “Egg Lab- Part I”, she thought learners have trouble making connections between lectures and lab and drawing conclusions from evidence. She stated,

I think that the conclusion will be tough because it is looking at their hypothesis and then stating if their hypothesis was proven right or wrong and why. I think that will be tough for them because if it was proven wrong, I think they may have difficulty deciding why it was proven wrong. (Stimulated Recall, Day 2)

Lilly's knowledge of students difficulties expanded as a result of firsthand teaching experiences.

Contributing Factors to Lilly's Development of Knowledge for Teaching and Learning During the Fall Semester

Lilly expressed a number of times that her experiences in her guided internship had a strong impact on her knowledge of teaching and learning. Her mentor shared with her about addressing content through multiple activities and in different contexts.

According to her mentor,

Many of the students you have to teach and re-teach a concept. And not do it in the same way but come back at it a different way. I think she is learning some of those skills as she goes along in recognizing that you have to break things down. (Mentor Teacher Interview)

Like her mentor, Lilly believed that students learn science when they have multiple exposures to new material and the teacher addresses content through worksheets, lectures, and activities.

Lilly's experiences with her mentor and working with students in the guided internship reinforced her science teaching orientation that viewed teaching as mostly telling and learning as listening. Although she learned about student-centered instructional sequences in the Secondary Science Methods courses, she continued to believe that teacher's must use "inform" types of instruction, before students have hands-on, minds-on opportunities to learn science.

Spring Semester

At the time the spring interview-observation cycle was conducted, Lilly was enrolled in Secondary Science Methods III and near the end of her internship. The interview-observation cycle took place during the same class period as in the fall. Twenty five students were present and included 13 males and 12 female students. The students were in the middle of their unit on evolution. The first observation occurred during what Lilly described as a “typical day.” However, on the second day a number of different school-sponsored activities were taking place. During third period, the teachers decided whether to let their students attend a school wide demonstration. Lilly, decided she would carry out biology class as planned. The interpretations reported here are based on data from the pre-observation interview, lesson plans, field notes, and stimulated recall interviews.

Orientations

After nearly nine months in the ACP, Lilly’s science teaching orientation had not changed significantly. Her image that science teaching is telling and learning is listening dominated her thinking about teaching and learning. Lilly believed it was her responsibility to be both a leader and guide. She explained that it was her responsibility to “give them part of the idea, and to give them some strategies of how to do the worksheet” (Stimulated Recall, Day 1). In accordance with this view, Lilly believed students mostly have a passive role and should follow the teacher’s lead. She said, “They like having more direction ...they like having their roles” (Stimulated Recall, Day 1). Lilly also reiterated that the central goal of science teaching is presenting terms and concepts so students can apply new ideas to their everyday lives. She said:

I don't think that you need to teach them everything about a concept; just kind of tell them about the basics, and then they use those and apply them to activities, and that's how they learn more about what we're talking about. (Stimulated Recall, Day 1)

Lilly viewed presenting science vocabulary as “giving them the tools to be able to use them to learn more deeply” (Stimulated Recall, Day 1). Her orientation to science teaching still directed her thinking about teaching and learning.

Instructional Sequence

Day 1. Lilly began the lesson by having students take a quiz over homologous and analogous structures to help focus the lesson on evolution. She said:

I think having a quiz or some sort of activity to start out the class helps to get everyone in their seats, quieter, organized sitting before we try to do notes. It's hard if right away, we're sending them new notes, because they don't, and that's not anyone's favorite thing to do, and so it's harder to get them calmed down and sitting with the class if they were starting with notes. (Stimulated recall, Day 1)

Lilly followed the worksheet with a PowerPoint lecture on the biochemical evidence for evolution. She started with a brief review of genetics that drew on students' prior knowledge and asked the students: “What is a gene?” “What are amino acids?” “What are chromosomes?” Next, Lilly used a chart that compared the genetic similarities to highlight that DNA is strong evidence that humans and chimpanzees share a recent common ancestor. After she introduced these concepts, students compared amino acid sequences of humans, gorillas, and horses on a worksheet. Some students worked independently on the worksheet while others worked in pairs to divide up tasks and finish the worksheet.

Day 2. Lilly began the second lessons by having students watch a short video clip of birds displaying unique mating characteristics and behaviors. This activity focused

learning on the broader topic of evolution; however, it was not directly related to the lesson on biochemical evidence for evolution. Students used the remainder of class to compare amino acid sequences on the worksheet they started on Day One. While students worked, Lilly monitored their progress by checking to make sure they had the right answers and had not made errors in their analysis that would lead them to wrong conclusions. When students finished the worksheet, they began their homework which was to read and analyze a newspaper article about evolution.

On both days, Lilly planned to use an instructional sequence that focused on transmitting knowledge to students through “inform” types of instruction and allowing students to work with new ideas during “practice.” She continued to believe that teaching and learning begins when the teacher introduces new terms and concepts during the “inform.” Table 27 summarizes Lilly’s lesson plan for Day One and Two.

Table 27

Lilly’s Lesson Plan, Day 2, Spring Semester

	Sequence	Activity	Description
Day 1	Focus	• Quiz	• Students take a quiz on analogous and homologous structures.
	Inform	• Lecture	• Teacher uses a PowerPoint to lecture to students about the biochemical evidence for evolution.
	Practice	• Independent and group practice	• Students practice the concept of biochemical evidence for evolution by comparing amino acid sequences in different species of organisms.
Day 2	Focus	• Video	• Students watched a video on a bird’s mating rituals and discussed why characteristics evolve over time.
	Practice	• Independent practice	• Students finish comparing the amino acid sequences for different species of organisms and begin a reading on evolution.

Knowledge of Learners

Lilly's knowledge of the role of students' prior knowledge continued to develop during the spring semester. She used an evolution pre-assessment to determine students' prior knowledge before her unit on evolution and asked students: "What do you know so far about evolution?" and "What are your thoughts about evolution in general" (Pre-observation Interview). Lilly found that students "had a lot of really negative responses" and held misconception such as the term evolution means that "humans came from apes" (Pre-observation Interview). In general, she found that students' knowledge of evolution was limited and "they haven't ever learned about it at all." She used this information to design her lessons.

Requirements for learning. While Lilly's knowledge continued to expand during the spring semester, she still reported that students need mostly lectures and teacher-led discussions to learn science. She planned to relate her lecture on Amino Acid sequences to what students knew about DNA from a previous unit. She said: "We spent so much time on DNA and amino acids This helps tie those concepts together ... So I think this will really help the students get into the mindset of, 'so that's why DNA was so important' (Pre-observation Interview). Additionally, she talked about the importance of providing multiple exposures and repetition so students could commit vocabulary to memory:

I think that helps because any time you're trying to learn something, hearing about it over and over; reading about it; doing activities; working with it; you're naturally just gonna understand it better They just have to work with information a lot to be able to really grasp it. (Stimulated Recall, Day 1)

Lilly developed a growing awareness of how she could provide multiple exposures that were student-centered. These included: letting students make scientific decisions; have evidence-based experiences; and coteach.

Lilly learned from working with students that they develop a sense of ownership over the material when they are allowed to choose the content they study. When Lilly was asked about why it was important to let students choose the content versus the teacher just telling students she said, “I think it’s important because it is the students’ feeling of ownership of what they’re doing, because they have chosen what they’re doing, they’re feeling a bit more defensive of their work” (Stimulated Recall, Day 1). Lilly used laboratories and activities during her evolution unit so students could collect data and confirm what she has told them during lectures and discussion in another context. According to Lilly,

I wanted to do something where they worked with the idea, because I think again, just talking about it, I don’t think its very powerful, but I think them actually seeing it helps a lot I think that by doing some of these labs that we did, they have really grasped the idea. (Pre-observation Interview)

Lilly believed that peer collaborations have a positive influence on what students learn because students teach each other content by talking through their ideas. She explained:

Students seem to learn very well through collaborative learning, through doing group work. I found that when we did the second group activity ... when we did the post questions that I had them (initially) do in the beginning and in the middle, the exact same questions, it made a huge difference after we did this group work. (Pre-observation Interview)

While students enjoyed working together, Lilly thought the greater benefit was that they collaborated and taught one another.

Areas of student difficulties. Lilly described more student difficulties in extensive detail. In general, Lilly thought that students have difficulty remaining focused during her lectures because “attention spans are really short with this age” (Pre-observation Interview). Lilly helped students stay focused by delivering her lectures in smaller fragments, over multiple days. She explained:

The unit we are doing now is like twenty slides ... instead of doing ten and ten one day and the next day, we are doing like five slides and then some sort of activity. Or the next day we would do a worksheet and a couple slides and another activity and a couple more slides. So it seems to work better breaking up what we are doing. (Pre-observation Interview)

Lilly also observed that science content that deals with relating micro to macroscopic, complex biological processes, and large time spans are troublesome for students because they cannot visualize the content and relate to it on a personal level. She said:

It’s difficult sometimes, like with cells, obviously, that’s related to us. We are cells. But I had a little bit more trouble, I think, with the microscopic level, making that connection ... They can’t picture what these structures are. I mean, we showed them pictures, we even did stuff with slides, but even that isn’t very powerful for them to picture all these different organelles. (Stimulated Recall, Day 1)

Lilly noticed that students “tended to have a little more trouble as far as the steps of translation and what all is involved” (Pre-observation Interview) and had difficulties relating geologic time to the present day. She explained:

I think the main difficulties that they see what organisms look like on earth today and they have a little bit of trouble, I think, thinking about, what could an ancestor, five hundred million years ago of this organism look like. And it could be quite different looking and I think they have trouble kind of thinking about what it could possibly look like and how such changes could occur, that kind of idea. (Stimulated Recall, Day 2)

Lilly could help students overcome these difficulties by lecturing, leading discussions, and providing multiple exposures to new content.

Contributing Factors to Lilly's Development of Knowledge for Teaching and Learning during the Spring Semester

After nearly 9 months in the ACP, Lilly believed that she teaches in similar ways as her mentor. She said, "As far as teaching style, I think it's very similar. She does a lot of activities. Her notes are short like this, and there's talking involved during the notes, and so very similar teaching styles, which has been nice" (Stimulated recall, Day 1). She learned about the importance of providing students with multiple exposures and remarked, "It's real important to come at these topics or concepts multiple times, more than I think are necessary, and I feel like I'm just repeating myself sometimes. I think it's necessary" (Stimulated Recall, Day 1). Thus, her experiences in the guided internship strongly reinforced her science teaching orientation.

Lilly realized that there are differences between what she has learned in the Secondary Science Methods courses about inquiry and her experiences teaching at Monroe High School. She spoke about these differences in extensive detail. She learned that many students do like the responsibility of learning science on their own and leading inquiry investigations. Lilly explained,

It [inquiry] just gives the students a lot of freedom as far as what they're investigating; what kind of data or observations they should make; choosing, there's a lot of, like, choice involved, which is great, but I don't think a lot of students like that ... In my opinion, doing full open inquiry is impossible in high school, and maybe that's not fair for me to say. Maybe some people can. For me, though, it just doesn't work because it's way too much, putting way too much responsibility in the student's hands, and I don't think they even like it. (Stimulated Recall, Day 1)

The strategies she learned about in the Secondary Science Methods course contrasted with her experiences in the guided internship.

Summary: The Nature of Lilly's Development of Knowledge for Teaching and Learning
Development of Lilly's Science Teaching Orientation

Lilly's science teaching orientation included: her beliefs about teaching and learning; views of the teacher and student roles; images of the nature of the discipline, and central and peripheral goals (see Table 28). At the beginning of the ACP, Lilly drew on her memories of how her K-16 teachers taught when she talked about her knowledge of teaching and learning. Lilly had experienced mostly traditional, teacher-centered instruction and held a science teaching orientation aimed at presenting students science content. Lilly's experiences in the guided internship strongly supported her science teaching orientation. Although she developed additional goals and views of the teacher's role she retained her science teaching orientation.

Table 28

The Development of Lilly's Orientation to Science Teaching

Dimensions	Entry	End of Summer	Fall Semester	Spring Semester
Views of teaching and learning	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening	• Teaching is telling, learning is listening
Views of the teacher roles	• Leaders	• Leaders/Guides	• Leaders/Guides	• Leaders/Guides
Views of the students roles	• Followers	• Followers	• Followers	• Followers
Central goals	• Preparing and motivating students for future courses	• Preparing and motivating students for future courses	• NM • For students to apply science to life	• NM • For students to apply science to life
Peripheral Goals	• None mentioned	• Letting students choose the content they want to study	• NM	• NM

Note. NM= Not mentioned

The Development of Lilly's Knowledge of Instructional Sequences

Lilly's consistently gave priority to transmitting information to students during the "inform" types of instruction. Although Lilly learned about student-centered activities in the Secondary Science Methods courses, she relied on teacher-led discussions and lectures to provide students with science knowledge that occurred near the onset of her lessons. Table 29 summarizes Lilly's instructional sequences to teach science.

Table 29

The Development of Lilly’s Sequence of Science Instruction

Entry		End of Summer		Fall		Spring →	
Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Focus	Focus	Focus	Focus	Inform	Focus	Focus	Focus
Inform	Inform	Inform	Inform	Focus	Inform	Inform	Practice
Practice	Practice	Practice	Practice	Elaborate	Practice	Practice	
	Inform		Inform	Review			

The Development of Lilly’s Knowledge of Learners

At the beginning of the ACP, Lilly thought that students needed mostly lectures and teacher-led discussions to learn new content. During Lilly’s time in the ACP her knowledge of the requirements of learners and areas of student difficulties learning science expanded as a result of different experiences. For example, during the End of the Summer Interview, she talked about students needing to make their own scientific decisions to learn the content based on her experiences in the Secondary Science Methods course. During the fall and spring semesters, she learned from her mentor and students that lectures and teacher-led discussions would not be enough to help students learn new content. In addition to lectures, students needed multiple exposures to new material to commit content to memory. The expansion of her knowledge was due to working with a mentor and her growing awareness of student difficulties. Table 30 shows Lilly’s development of knowledge for learners including: requirements for learning, and areas of student difficulties.

The Development of Lilly's Integration of Knowledge of Learners and Instructional Sequences

Lilly developed knowledge of instructional sequences integrated with knowledge of learners, although her instructional sequences did not fully reflect her knowledge of learners. At the beginning of the ACP, Lilly's use of teacher-led discussions during "inform" types of instruction was the common link between her knowledge of learners and instructional sequences. Over time, Lilly's integration of these two components became more sophisticated. She realized that teacher-led discussions during the "inform" would not always be enough to help students overcome their difficulties. Lilly believed that the combination of lectures and multiple exposures to the content would help students learn science. As a result, Lilly purposefully planned multiple "practice" types of instruction in addition to "inform" types of instruction in her instructional sequences so students could learn science. The combination of lectures during the "inform" and multiple exposures during the "practice" and "focus" served as a common link between her knowledge of instructional sequences and learners.

Table 30

Lilly's Development of Knowledge of Learners

Knowledge of Learners	Entry	End of Summer	Fall Semester	Spring Semester
Requirements of learners	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life 	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life • Repetition • Making scientific decisions 	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life • NM • Making scientific decisions • Multiple exposures • Evidence-based experiences • Hands-on experiences 	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life • NM • Make scientific decisions • Multiple exposures • Evidence-based experiences • NM • Connections to previous course content
Areas of Student difficulties	<ul style="list-style-type: none"> • Genetics misconception 	<ul style="list-style-type: none"> • NM • Memorizing terminology 	<ul style="list-style-type: none"> • NM • NM • Terms hypotonic/hypertonic • Transferring knowledge between lectures, labs, and quizzes • Focusing during lectures • Using prior knowledge to make predictions • Making scientific claims based on evidence 	<ul style="list-style-type: none"> • NM • NM • NM • NM • Focusing during lectures • NM • NM • Micro-macroscopic phenomena • Steps in DNA replication/protein synthesis • Geologic time

Note. NM= Not mentioned

The Contributing Factors to Lilly's Development of Knowledge of Teaching and Learning

At the beginning of the ACP, Lilly drew exclusively on her memories of how her teachers mostly used “delivery” modes of instruction. These memories shaped her science teaching orientation which is characterized by the dominant conception that teaching is telling and learning is listening. Over time, she had experiences that influenced the development of her knowledge. She was enrolled in Secondary Science Methods courses and working with a mentor and students in her guided internship. Each of these experiences contributed to her developing knowledge of learners. However, these factors did not have equal influence on Lilly's development of knowledge of teaching and learning. Lilly latched onto her experiences in the guided internship which strongly supported her science teaching orientation. Over time, Lilly struggled to accept strategies from the Secondary Science Methods courses because they deviated from her science teaching orientation and her mentor's influence.

4. Jason's Case

Experiences Prior to Program

Jason, age 24, graduated with a biology degree from a large research extensive institution located in the Midwest. During this time he had experiences working with high school students as a Young Life leader. Young Life is a non-denominational, Christian ministry that seeks to build relationships among adolescents through scripture and prayer (Young Life Foundation, 2008). In this role he led discussions, acted as a tutor, and mentored students about personal factors in their lives. He talked at length about his background experiences in Young Life where he played a brotherly role. Jason wanted to help students mature into responsible citizens and believed he could engage adolescents in discussions about real-world problems. Additionally, he believed that it was through discussions in Young Life that many adolescents “discovered” themselves by gaining an understanding of how spirituality helps them make sense of their world. Justin emphasized that it was his experiences as a Young Life leader that made him pursue science teaching. Jason's entered the ACP directly after he completed his undergraduate degree.

Beginning of the ACP

At the beginning of the ACP, for the initial data collection task, Jason designed lessons to teach heritable variation to 8th grade students. After he designed his lessons, I interviewed him about his views and knowledge of teaching. Jason also watched a video of a reform-based class and reflected on the teaching and learning that occurred in the video segment. The interpretations below are from the lesson Jason created, the beginning of the ACP interview, and the video reflection.

Orientations

Jasons' views of teaching were based on his background experiences. Through Young Life, Jason had success leading discussions to help students "discover" knowledge on their own. As a K-16 student, Jason observed teachers mostly using "delivery" modes of instruction. As a result, Jason believed science teaching revolved around using teacher-led discussions to introduce concepts so eventually students could "discover" knowledge. He articulated this belief a number of times, in speaking about his views of the teacher and student roles, his views of the nature of science, his goals for science teaching, and how he planned to teach. Jason viewed teachers as "guides" and he "didn't just want to lecture to kids" (Entry Task Interview). He wanted to "be able to lead students in such a way that they are discovering things on their own" (Video Reflection). Although Jason enjoyed studying biology, he viewed science teaching as a springboard for discussing ideas that went beyond knowing vocabulary. He talked about science being an independent activity in many high school classrooms when in reality, it is a social endeavor. Jason viewed science as a way to socially create knowledge. He described his view of the nature of science in detail:

I think in high school you ... study for your test, do your own worksheet, and your own homework. But like once you get to college, and then even in the real world, science isn't like that at all. You collaborate, you use other people's information to go further and stuff. So I think that it would be good to explain like real science is when you get together and work together and use each other's ideas and stuff. So it would be building ... the bigger picture of what science is.... It is not just memorizing facts. It's kind of like using each other to figure stuff out and stuff. (Entry Task Interview)

Jason's central goal was to develop students' understanding of science so they could apply science ideas to their everyday lives. He wanted to show students that "science is not just something you go to the classroom to learn, it is something that can be applied" (Entry Task Interview). He thought that he could engage students in learning science because "science isn't just learning about like plants and animals, it is learning about stuff that has not been discovered yet" (Entry Task Interview).

Jason's other central goal for teaching science was to prepare students for future science courses. He explained that heritable variation is "a big chunk of like what everything is built on" and thought "there are a few pieces of like just basic science that are needed. I think it is just one of the cores" (Entry Task Interview). Jason's science teaching orientation embodied both a social and practical undertaking and his mission in science teaching was closely linked to his work in Young Life. His science teaching orientation dominated his thinking about teaching and learning science.

Instructional Sequence

Day 1. Jason began the lesson with discussion questions that focused the learning on variation. He said, "I just wanted to start with a few questions. Depending on how they answer I might ask other ones" (Entry Task Interview). Next, he would use familiar examples to discuss variation and planned on having students brainstorm how corn stalks might be different than another. He expected students to come up with examples such as height, corn production, herbivore, and vulnerability. At this point in the lesson, Jason would focus on a single trait --height of corn-- and discuss "why height could be an advantage or disadvantage in heritability" (Entry Task Interview). Jason used "discussions" to guide students' ideas and formally introduce the idea that individuals of

a species show variation. His “discussions” utilized the following sequence: (1) ask an open-ended question; (2) elicit student responses; and (3) introduce new terminology and concepts. Jason’s description of his “discussions” focused on student-teacher, rather than student-student interactions where the class as a whole constructed knowledge. After students had discussed their ideas, Jason planned to reinforce concepts with empirical evidence and show a graph illustrating that corn stalks differ in height and display a bell curve distribution.

Day 2. Jason began the second lesson with a brief review of the bell curve distribution to refocus the lesson on variation within a species. Next, he would introduce new terms and show students another example of variation that demonstrates a bell curve distribution-- sea turtle egg weight. Jason would move on to how selective pressures influence traits in a species. He planned to show an example of a bird whose tail length is sexually selected and he would “explain how female choosiness of males is a type of sexual selection.”

In constructing his teaching approach, Jason thought back to his experiences as a K-16 student and Young Life leader. He tried to move back and forth between students’ experiences and defining new concepts during “discussions.” This created a conflict for Jason. Although he believed students need to “discover” science on their own, he fell back on familiar, teacher-centered instructional sequences that primarily transmitted knowledge to students through “inform” types of instruction. Table 31 summarizes Jason’s lesson plan for Day One and Two.

Table 31

Jason’s Lesson Plan, Day 1 and 2, Beginning of Summer

	Sequence	Activity	Description
Day 1	Focus	• Discussion	• Teacher asks students questions to determine prior knowledge about variation.
	Inform	• Discussion	• Teacher introduces the idea of variation within a species and uses a graph of corn height distribution to reinforce variation.
Day 2	Review	• Review bell curve distribution	• Teacher reviews variation in plant height.
	Inform	• Discussion	• Teacher introduces that a bell curve distribution illustrates a “stabilizing trend.” Teacher shows students bell curve graph of sea turtle egg weight.
	Inform	• Discussion	• Teacher introduces that sexual selection in some species of bird can influence variation within a species.

Knowledge of Learners

At the beginning of the ACP Jason believed that students have life experiences but not prior science knowledge with heritable variation. Jason said, “I don’t think that they would know too much about ... heritability, just some basic middle school knowledge of just evolution in general” (Entry Task Interview).

Requirements for learning. Jason’s Young Life experiences forced him to think critically and deeply about learners’ needs. He emphasized the importance of learners “discovering” science on their own and applying science to their lives. Jason brought into the classroom his belief about using discussions in Young Life to help students learn science. He explained, “My facilitation of classroom discussion and questioning would lead my students to learn ideas on their own in hope that it would become real and that their discovery is what is leading their learning” (Video Reflection). Jason’s other beliefs

about the requirements for learning science were also based on his Young Life and K-16 experiences and included: evidence-based experiences to visualize the concept; making connections to previous science content; and collaborative experiences to build knowledge.

Jason talked about the importance of using real data to teach science. He hoped he could “find a study you know that would show actual data,” to teach about variation in corn plants and he thought “it is just better to see like maybe like a picture of the actual bird and to see the data behind it so I can see the actual trend” (Entry Task Interview). If Jason had more time, he could have students collect data firsthand. Jason commented, “I was thinking it would be good to talk about [height] because you could maybe do a class demonstration. You could use data in class” (Entry Task Interview).

Jason thought that once students knew about variation in corn, he could transition to studying variation in other organisms. On day 2, Jason believed he could help students learn about variation in the bird example by relating it to what students had learned about corn. He said, “Building on something they are pretty familiar with, like corn, then taking it to a bird like from the tropics that they have never seen before. You know just building on stuff they know and expanding it to other stuff” (Entry Task Interview). He believed that if he addresses students’ learning needs, then students would have no difficulties with the lessons he had planned.

Contributing Factors to the Development of Jason's Knowledge of Teaching and Learning at the Beginning of the ACP

At the beginning of the ACP, Jason's science teaching orientation was shaped by his Young Life and K-16 experiences. Jason drew on his informal teaching experiences when he used questioning to elicit students' ideas and engage them in activities. He talked about his experiences as a Young Life leader and how to ask students questions:

In my experiences with Young Life, I like to ask kids questions; it gets kids involved. I have definitely learned not to ask yes or no questions. Starting every day with questions gets them warmed up. You don't just jump in and start lecturing because kids ... are leaving English class and entering Science class kind of thing and I think it just gets more kids involved you know when you are just asking them. (Entry Task Interview)

Jason's experiences asking students questions in Young Life led him to believe that questioning and discussions would help focus students' attention and motivate them to learn. Additionally he had success using discussions in Young Life and students were able to "discover" valuable life lessons with his guidance.

Jason's experiences as an undergraduate student influenced his knowledge and how he planned to teach. In his Evolution course his professor talked about corn height, the height of people, and the bird example, as an introduction to variability. These classes resonated with Jason because the instructors used discussions to introduce new content and relate science to students' lives. He also found value in seeing data and empirical evidence in his undergraduate classes because it verified what he was learning.

End of the Summer

The end of the summer interview was conducted after 11 weeks of ACP coursework and just prior to the beginning of Jason's year-long, guided internship. During the summer, Jason took two courses: Secondary Science Methods I and Educational Psychology. The interpretations below are based on Jason's reflections on his initial lesson plan.

Orientations

Jason continued to believe he could expose students to important ideas through teacher-led "discussions" to help them "discover" science on their own. Jason said, "I would rather have them talk more than I would just get them involved and see what they think and then trying to get them to lead their own thinking" (End of Summer Interview). Jason also believed "it's the responsibility of the teachers to address (students') needs instead of just throwing information out there and expecting them to get it" (End of the Summer Interview). To address students' needs, he would need to guide students in becoming more self-directed learners. He explained, "If you lead them ... giving them more control step by step, it would be a lot better, less frustrating than just throwing them into it" (End of the Summer Interview). He believed his views of the students' role in the classroom changed since the beginning of the summer as a result of the ACP courses. He stated, "I think the whole teacher-center versus student-center thing is changing for me. Letting them lead more of the curriculum instead of the teacher just guiding it every day" (End of the Summer Interview). Jason's central goal was still to provide opportunities for students to be able to "lead their own thinking," and "figure it out on their own," because he thought science provided a way for students to "discover" knowledge (End of

the Summer Interview). At the end of the summer, Jason's orientation remained unchanged and continued to influence his ideas about teaching and learning.

Instructional Sequence

Day 1. Based on his experiences in the Secondary Science Methods course, Jason planned on modifying the original activities to be more student-centered. On the first day of instruction, Jason would have students brainstorm how corn plants vary as a focus activity. However, instead of having the whole class discuss corn heights, he would let them choose the traits they wanted to investigate. I have termed this an "elaborate" type of instruction because he planned to have students investigate a trait according to their own interests. After school, he intended on finding data to show students that the traits they choose were variable in corn plants. Thus, Jason still felt responsible for providing students with knowledge; however he wanted to fulfill their own interests.

Day 2. Jason would start the lesson by leading a "discussion" on the different ways that corn plants vary based on the research he provided to students. His "discussion" still focused on teacher-student, rather than student-student interactions to construct knowledge. He planned on moving on to sexual selection and variation with his bird example. Jason continued to focus on providing knowledge to students through discussions that occur during "inform" types of instruction near the onset of the lesson. He believed science learning is dependent on information provided during "discussions" by the teacher.

Knowledge of Learners

Jason's knowledge of learners was strongly reinforced by his experiences in the science methods where he learned about inquiry and the nature of science. He talked about the benefits of discussions versus lectures: "I could easily say that in three seconds, but I think they could definitely figure it out, just getting them to bring that out on their own" (End of the Summer Interview). Jason also continued to believe that students need evidence-based experiences to learn science. He planned to find data on different traits in corn plants so students could visualize variations based on empirical evidence during the discussions. During the end of the summer, Jason believed if he met students' needs then they would have no difficulties with his lessons.

Contributing Factors to Jason's Development of Knowledge of Teaching and Learning at the End of the Summer

Jason talked about only knowing a few instructional strategies, like lectures, before he entered the summer coursework. In the Secondary Science Methods I course, he learned about inquiry and the nature of science. For example, he learned how to make labs more student-centered and how there is more than one way to do science. He described these experiences.

The latest class I took was about inquiry in the science classroom. A big part of it was taking generally cookbook science experiments and expanding them and making them more inquiry-based on different levels. And how you can adjust that to full student-led to just arranging it. We talked a lot about the nature of science in general and how there is not a specific scientific method. (End of the Summer Interview)

The Science Methods course provided opportunities for reflection. Many of Jason's K-12 science experiences were teacher-centered and traditional in nature. He commented:

I really loved the idea of letting the students taking control of more of their own learning. It was really cool to see that and the whole idea of making science more realistic, because I know in my biology experience in high school it was more of just the study of biological facts, not really studying biology. It's cool to see you can make it more realistic and stuff, and that was pretty exciting. (End of the Summer Interview)

Jason believed that if he were to provide more student-centered learning experiences, he would need to have a better knowledge of the subject matter. He commented, "It made me realize that if I really want to implement more of the student-centered thing, I am going to need to know my content area a lot more than just superficial talk" (End of the Summer Interview). Unlike teacher-centered lectures, where the teacher maintains control, discussions were open forums and students' questions lead the conversation. He talked about the differences between lectures and discussions,

If you just lecture every day, you can just know what you lecture on and just talk about what you really know; but if you are leading an open forum, that is a challenge and you need to know the material good enough that if kids ask random questions you can address them ... I think that will require a lot more knowledge. (End of the Summer Interview)

The Secondary Science Methods course also influenced his knowledge of teaching; however, he struggled to sequence science instruction that allowed students to "discover" knowledge on their own. Jason was able to make the lesson more student-centered based on his experiences in the ACP coursework. Yet, he relied on familiar, teacher-centered strategies that focused on transmitting knowledge.

Internship Context

For the 2006-2007 school year, Jason interned with an experienced mentor, Nancy, at Harris High School. Nancy had hosted student teachers in the past and provided them curriculum materials including: unit objectives, common assessments, and packets that contained all of the students' worksheets for a unit. The biology teachers at

Harris High school used the same materials and met frequently to design curriculum.

Jason described how he used the common curriculum and how Nancy mentored him,

She gives me all of her stuff and she tells me ... you need to cover these [referring to objectives] you know, and she basically lets me do my own thingAnd we talk a lot so she knows what is going on The way I did this unit, is I kind of mapped the whole thing out, pretty rough ... then she gave me feedback. (Pre-observation Interview)

Unlike other ACP interns, Jason took over the entire course load because Nancy was on maternity leave for three months during the beginning of the spring semester. The other teachers in Harris's biology department would help support him and provide resources and materials.

Fall Semester

At the time of the fall 2006 interview-observation cycle, Jason was enrolled in Secondary Science Methods II and had been in the secondary general biology classroom for approximately 12 weeks. Students were finishing their unit on cellular structures and functions. I conducted a pre-observation interview with Jason so he could clarify what he intended on doing the next two days. Then I observed two consecutive lessons. At the end of each observation, I conducted a stimulated recall interview with Jason so he could reflect on and clarify his thinking about his teaching. The interpretations below are from the pre-observation interview, lesson plans, field notes, stimulated recall interviews, and mentor teacher interview.

Orientations

Jason's orientation had not changed significantly and he continued to view teaching as a process of "discovering" knowledge through teacher-led "discussions." He believed he could facilitate students' understanding of science content by guiding them. He described his preferred teaching style by saying, "I don't want my style to be just presenting information ... I would like my style to be more cooperation, just kind of like back and forth. Seeing, if we need to go back and learn more" (Stimulated Recall, Day 1). Jason explained how he favored "active" teaching practices that encouraged student participation. He commented, "I want these kids to get up front and teach instead of me just lecturing them" (Stimulated Recall, Day1). Additionally Jason thought students should lead their own learning by asking questions. He explained, "I think their role would be to ask the questions to learn and to understand the stuff, by doing stuff, or asking questions" (Pre-observation Interview). Jason believed it was important for him to provide a student-centered environment where students have an active role and collaborate to "discover" knowledge.

Jason retained his central goals that students should be able to apply science to their everyday lives to "discover" science on their own. Jason described what he wanted students to learn in 10th grade biology:

I would love to see kids be able to look for evidence, just not in science even, but in their life and they're making and I'm using science words to describe this stuff Making their choice in life ... by making good decisions based on facts and evidence. And I would like them to be able to take a scenario or a challenge in their life and be able to have the tools to investigate, like 'I wonder why this is?' I think science might give a lot of that. (Stimulated Recall, Day 1)

Related to this view, Jason explained why it was important for students to learn about prokaryotic cells in his unit:

Being informed and knowing, basics about like bacteria is important. So you are not clueless to what your doctor tells you. If a doctor tells you that you need to finish your prescription, you might or might not. But if you understand why that is important, there are more chances you will actually do it. (Pre-observation Interview)

Jason added a goal for teaching science as a result of his teaching context. For Jason, a peripheral goal was to present science vocabulary. This meant that he had to spend more time providing students with new terminology and concepts than he would typically prefer. Jason talked about wanting student to learn the “main functions of each organelle,” and to “understand the difference between a plant and animal cell,” because they were part of Harris High School’s biology objectives. His mentor insisted that he implement activities during the lesson so students would learn science terms. He talked about the importance of students knowing science vocabulary:

I think they have a lot of information written down, but they don’t have any of it internalized at all so I wanted them to start transferring that, first to get that jumble to something real specific and concrete, and then for them to start basically understanding it and remembering it. (Stimulated Recall, Day 1)

Although Jason gained a peripheral goal, his science teaching orientation had not changed significantly. His science teaching orientation continued to influence his thinking about teaching and learning.

Instructional Sequence

Day 1. Jason began by having students write down lesson objectives and their homework. Once he had students’ attention, groups gave presentations over different cell organelles. While groups presented, students wrote down the function of cell organelles

from the presentations. After each group presented, Jason highlighted the important functions of the organelles to ensure that students had accurate information in their notes. Next, Jason implemented multiple strategies so that students could practice identifying the structure and function of cell organelles. The class ended with group and independent practice where students used flash cards to memorize cell parts and functions.

Day 2. Jason started the lesson with a review video to show students images of cell parts and functions. While the students watched the video, Jason identified important features of organelles. He described his reasoning for narrating the video: “I really wanted to hit like the main things and talk about the cell membrane, and the Golgi, the nucleus. I just trying to hit main things like make sure they see things, things that they suppose to know stuff” (Simulated Recall, Day 2). After the video, students practiced new terms and concepts by playing a review game and discussing how a cell is like a factory.

On both days the instructional sequence focused on presenting factual information during “inform” types of instruction that occurred near the beginning of his lessons. Jason continued to believe learning begins when the teacher identifies new terms and concepts. Table 32 summarizes Jason’s lesson plans for Day One and Two.

Table 32

Jason's Lesson Plan, Day 1 and 2, Fall Semester

	Sequence	Activity	Description
Day 1	Focus	• Introduction	• Students write lesson objectives and their homework in their planners.
	Inform	• Presentations	• Students presented a model of their organelle. While students presented, their peers wrote down the functions of the organelles. • Teacher highlights important terms and concepts.
	Practice	• Group and independent practice	• Students practice cellular structures by identifying whether different cells were plant or animal given the presence of structures such as chloroplasts, central vacuoles, and cell walls.
Day 2	Review	• Video	• Video of different 3-D images of cell parts and their functions.
		• Students make note cards	• Students reviewed the structures and functions of different organelles.
	Practice	• Group practice	• Whole class discusses how a cell is similar to a factory.

Knowledge of Learners

Jason learned from the guided internship that students had prior experiences learning about cells. Jason believed that although students had learned about cells in an earlier grade, they did not remember the content because they were not engaged in the strategies that some teachers used. He talked about students' science knowledge and experiences in great detail:

I think teachers just present it and think kids are going to take it and move on. And they move on It is almost like they never really learned it. It backfires now because they have heard it before, they are like, I have heard this before, but they don't know anything about it so it is tough.
(Pre-observation Interview)

Additionally Jason believed “a lot of kids struggle with biology because they don’t see it as applicable to their life” (Stimulated Recall, Day 1). Jason used his knowledge of students’ prior science experiences to design his lessons.

Requirements for learning. While Jason continued to believe in a number of different requirements for learning science, he emphasized the importance of “discovering” science through discussions with student participation: “I would say that they learn the best through exploring and finding things on their own” (Pre-observation Interview). He still thought that using discussions that relate content to students’ lives best helps students learn. Jason also still thought that collaboration helps students build ideas. He explained:

I think the science especially, like science it is just so not like ‘on your own,’ it is collaborative. So just getting these kids in the mind set of like using each other as tools and bounce off idea of each other. (Stimulated Recall, Day 2)

Jason learned from working with his mentor and students that these strategies are not always enough and students need multiple exposures to content to commit terms and concepts to memory. In his unit on cells, he provided multiple opportunities for students to practice new material. These included: justifying why organelles are important for cell function; identifying plant and animal cells based on organelles; using flash cards to memorize organelles and their function; playing an organelle review game; and describing how a cell is like a factory.

Areas of student difficulties. Jason developed a growing awareness of student difficulties from teaching and observed that students had trouble going back and forth between cartoon and real images of organelles. He explained:

I show them these little cartoony things [referring to images of organelles] and they probably have in their mind that that's what a cell really looks like, but it doesn't at all. That's what they've been taught their whole life because it is easier to see things, but to actually see a real cell is probably very different for them. (Stimulated Recall, Day 1)

Jason believed that using discussions and “practice” type activities would help students overcome their difficulties learning science.

Contributing Factors to Jason's Development of Knowledge of Teaching and Learning during the Fall Semester

Jason's experiences made him rethink his goals and he believed he must present science vocabulary addressed in Harris's objectives because “that is what the state, the nation has told them that they need to learn so they have to [learn]” (Pre-observation Interview). He believed that using Harris's objectives meant he must focus on terms. He explained:

The way Harris does it, they take the GLEs [State Science Standards] and all of those things and they summarize them down to their points. So, for this unit, there was like six points I had to cover. So, my first thing is to just cover the things that Harris says you have to cover. So that is what I start with. (Pre-observation Interview)

Additionally, Jason began with activities that focused the lesson following his mentor's example. He said, “That's a Nancy thing to always give them their homework right off the bat first” (Pre-observation Interview). His mentor suggested using flashcards and his colleagues provided him with the video.

During the Mentor teacher interview, Nancy talked at length about how initially Jason wanted to sequence instruction so he could develop and construct ideas with students during discussions. She taught him that students needed more direct instruction and delivery of information through lectures and textbook readings. Nancy said,

At first it seemed to me that he wanted to have this sort of method of learning where we talked about ideas and developed them together as a group. And I think he is beginning to see the value of sometimes cutting to the chase and delivering information. Which sounds spoon fed, but you can still incorporate a phase of discovery and tossing ideas around with a more structured lecture or reading assignment or something like that. (Mentor Teacher Interview)

Nancy noticed some differences between Jason's and her teaching practices. Nancy said,

He is focusing very much on the inquiry model and he spends a lot of time talking through things and ideas. I think that implies, but I'm not certain of what he thinks, that people learn by thinking, talking, processing, and verbalizing- rather than a real visual model. I'm a real visual person. So it's kind of interesting and probably good for our students to see both methods. (Mentor Teacher Interview, Day 1)

Jason also talked about the similarities and difference between Nancy's and his teaching style. He thought that Nancy preferred teacher-centered strategies like lectures. He said,

I think she is typically more of a lecturer, even though her lectures are pretty short I'd say hers are a lot more teacher-centered, and I would hope I am trying to figure out how to make mine more student-centered. (Stimulated Recall, Day 2)

Jason thought that Nancy left the responsibility of learning up to the students. He believed he was responsible for motivating students to learn science. Jason explained:

We both want these kids to learn. But I think her way of doing that is presenting that and allowing them, it's kind of like their choice to learn I have the same goal, and I want these kids to learn, but I want it to be more of an interaction. I don't want it to be, 'okay I've done my duty, now it's on their end.' I think that's the biggest contrast. (Stimulated Recall, Day 1)

Even though Jason implemented many of his mentor teacher's strategies, he used other resources that he learned about in the Secondary Science Methods courses to design lessons. For example, he used the National Science Teachers Association (NSTA) website for ideas on how to engage students in learning about the structure of cells. He

stated, “I was looking on the NSTA website and I saw the idea of making big cells” (Pre-observation Interview). Additionally, Jason talked about his experiences in the Secondary Science Methods course where he observed science teaching through a 5E instructional model and inquiry. He stated,

I think one of the coolest things about the A-STEP program is that you have a lot of good teachers, and you all teach us certain things, but just seeing how you guys teach a class, I learn more about that than anything. (Pre-observation Interview)

Jason also continued to draw on his K-12 experiences when designing lessons. He said, “That is where I originally got the idea to present stuff because I remember, like myself presenting organelles when I was in high school” (Pre-observation Interview).

Spring Semester

During the spring interview-observation cycle, Jason was enrolled in Secondary Science Methods III and had been teaching full time for nearly 3 months since his mentor teacher left for maternity leave. He still received mentoring during this time. His mentor, Nancy, met with him weekly and he worked with colleagues and used the Harris biology curriculum to plan lessons. The interview-observation cycle took place in the same class as in the fall semester; however, some new students were in the class. Jason described the new dynamics of his class: “I think all of the new students we got were at the lower end of doing homework and stuff and class participation ... the students that just transferred in, their background is not as strong in science” (Pre-observation Interview). The class was composed of 8 males and 4 female students. The students were in the beginning of their DNA unit and learning about the structure, function, and replication of DNA. The interpretations below are from the pre-observation interview, lesson plans, field notes, and stimulated recall interviews.

Orientations

Jason's orientation to science teaching had not changed significantly and he continued to believe teaching is a process of "discovering" knowledge through teacher-led "discussions." Jason explained that his role was to "create that scaffolding that students need to learn on their own. I think I have to give them the tools so they can discover and build some background knowledge for them, but hopefully my role is a supporter and guider" (Stimulated Recall, Day 2). According to this view, Jason thought students were responsible for being creative and following through during investigations. He talked about the students' role in his class:

The students' role in my class would be just an active, I would say to be actively engaged and leading their own learning in a way instead of me just telling them something and having to memorize it You can't just sit there and expect me to give you the answers. (Stimulated Recall, Day 2)

He thought students were responsible for "supporting their own evidence and capable of investigating things on their own" (Stimulated Recall, Day 2).

Jason's central goal was for students to be able to use the "tools" of science to answer their own questions. He explained:

My objective for them just to be able to take it to the next level not just take what someone says to them is the answer. Give them the opportunity to predict, observe, and explain and just to give them the opportunity to see that this is real scientific method and give them the tools so they can do this in the future. (Pre-observation Interview)

Jason also retained his goal of preparing students for future topics and courses. He commented,

I think it is [DNA] important because it's pretty fundamental to understanding life. It's definitely a characteristic of life. Without some kind of understanding of DNA you can't really go off that and show that mutations were. To teach evolution, to teach it's hard, to teach heredity with genetics. (Pre-observation Interview)

After working with students for nearly 9 months in the guided internship and having numerous other experiences, Jason retained his initial orientation to science teaching. His science teaching orientation continued to shape his knowledge of teaching and learning.

Instructional Sequence

Day 1. Jason began the lesson introducing the topic of the lesson. Then, students spent 25 minutes following a step-by-step procedure to remove DNA from strawberries. The purpose of students following a step-by-step procedure was to provide a common, hands-on experience for students to extract DNA. This strategy allowed Jason to connect a laboratory experience with prior “discussions” about the structure and function of DNA. Following Jason’s explanation, the whole class discussed about manipulating variables to do an independent research experiment. Students brainstormed different items that could be used in place of strawberries including: fruits, vegetables, and meats that could be. After Jason compiled a list on the front board, students picked a variable they wanted to test on Day Two of the lab.

Day 2. To begin the second day, Jason had students summarize the previous laboratory experience. Then, students extracted DNA from other fruits, vegetables, and meats. The purpose of the “elaborate” lab was for students to explore a material and carry out an experiment on their own. After each group carried out an independent investigation, students presented their findings to the whole class. During the presentations, students reported their procedures, a scientific claim, and supporting

evidence. Students were able to make claims about DNA, including: (1) whether different fruits, vegetables, and meats had DNA; and (2) the amount of DNA in comparisons to their previous experience with the strawberry DNA extraction. The lab provided little opportunity for students to expand their conceptual understanding of the structure and function of DNA. Jason concluded the class with what I have termed an “evaluate” type of instruction. The purpose of “evaluate” types of instruction are for teachers to assess students’ understanding of science content according to the claims students make that are based on the data they have collected. The presentations of claims and evidence served as Jason’s evaluation of student understanding.

Jason used his interpretation of a 5E instructional model from the Secondary Science Methods courses to design these two lessons. The first day served the purpose of engaging students and providing a common experience during what I have termed an “investigate” type of instruction. Once students developed some procedural skills and related new experiences to prior knowledge, he allowed them to brainstorm variables that could be used in place of strawberries in the “elaborate-Part I” phase. After students carried out an independent investigation, he had them construct a scientific claim based on evidence in the “evaluate” phase. Although students made scientific claims based on evidence, his choice of DNA investigations limited students’ opportunities to form deep conceptual understanding of DNA. Students could not make conceptually deep scientific claims about the structure or function of DNA during what would typically occur during the explore phase of the 5E instructional model and students could only report whether other fruits and vegetables had DNA.

Jason consistently used “discussions” that focused on student-teacher interactions, and he did not promote students talking with each other to construct knowledge. He believed teachers need to have “discussions” during “inform” types of instruction directly before 5E instructional model. Table 33 summarizes Jason’s lesson plan for Day One and Two.

Table 33

Jason’s Lesson Plan, Day 1 and 2, Spring Semester

	Sequence	Activity	Description
Prior to Lessons	Inform	• Discussion	• Teacher introduces the structure and function of DNA
Day 1	Focus	• Introduction	• Teacher tells students that they would be extracting DNA from strawberries.
	Investigate	• Laboratory	• Students worked in groups to follow a procedure and remove DNA from a strawberry.
	Inform	• Discussion	• Teacher introduces that strawberries have DNA.
	Elaborate-Part I	• Discussion	• Students discussed different items that have DNA and could be investigated.
Day 2	Review	• Introduction	• Students review procedure and findings from Day 1 lab.
	Elaborate-Part II	• Laboratory	• Students investigated a new variable based on their previous experience.
	Evaluate	• Discussion	• Each group of students presented a scientific claim and supporting evidence from their investigation.

Knowledge of Learners

As a result of teaching, Jason described students’ prior knowledge in more detail. He was surprised that students did not have many prior experiences learning about DNA. Some students knew that DNA is a genetic code for traits; however, their knowledge about how DNA codes for characteristics was limited. Jason used a preassessment and

found that “most of them had never heard of the subunits ... none of them could give me an answer like how could this magic stuff inside of you hold information” (Pre-observation Interview). Jason used the preassessment to decide what to teach students in his unit on DNA.

Requirements for learning. While Jason held a number of beliefs about the requirements for learning science, he emphasized the importance of students “discovering” new ideas on their own through evidence-based experiences. He explained:

Basically why I am doing day two is because it's a lot more on the real science ... I'm definitely trying to let them have more control over their setting. I would just like to give them more opportunity to make some predictions, make some explanations, rather than them just having the data presented to them without having to figure anything out, just having them actually use their brains. (Pre-observation Interview)

Jason believed “students have a much better understanding when they have to make claims based on evidence ... they learn more about the scientific method and discovery” (Stimulated Recall, Day 2). From teaching and taking Science Methods courses, Jason was able to build on his knowledge of “discovery” learning and evidence-based experiences to develop a more sophisticated understanding of how students learn science. He emphasized the importance of students making scientific claims based on evidence.

Jason also continued to believe that students need teacher-led discussions about how the content relates to their experiences. To help students learn, he made connections between the double helix shown in the movie “Jurassic Park” and the “white substance” they extracted from the strawberries. Thus, although the double helix and “white substance” looked very different from each other, students understood that they both were DNA.

Areas of student difficulties. After teaching his unit on DNA, Jason observed that students had difficulty visualizing DNA replication and protein synthesis. He explained:

A lot of kids struggle with trying to picture the shapes in their head like a double helix or what that looks like. The fact that these things are so small that they can't really see them, especially when we talk about DNA replication and protein synthesis. (Pre-observation Interview)

Jason thought that students have trouble with content that they could not physically see and manipulate. He believed that if he could meet students' needs, then they would have few difficulties with the content.

Contributing Factors to Jason's Development of Knowledge of Teaching and Learning during the Spring Semester

Jason met regularly with colleagues to design lessons. His colleagues implemented the DNA extraction lab with strawberries; however, they did not plan to do the student-designed investigation Jason planned for Day Two. Jason planned Day Two because he wanted to engage students so they remembered concepts before leaving for a week-long vacation. Jason talked about the differences between his teaching style and that of his colleagues at Harris. He said, "A lot of them do not use inquiry because they see it as a waste of time, because they see a lab that takes three days that they can get done in one period" (Stimulated Recall, Day 1). Additionally, Jason described differences between his teaching style and his mentor. He explained, "I like to do a lot more open, student-centered things, and have kids write on the board where she is a put-an-overhead-up-and-copy-it-down type of person" (Stimulated Recall, Day 2).

Jason used his knowledge from the Secondary Science Methods II course to design his unit on DNA. He talked about a curriculum planning project called the PCK project: "The key thing about the PCK project was collecting all this stuff [referring to

teaching resources] and organizing and seeing what student misconceptions I could find and see if these labs and activities I found could attack these misconceptions” (Pre-observation Interview). Additionally, he learned from his summer methods course the importance of providing students with a common experience “as a starting point to explore from” (Stimulated Recall, Day 1). Although he had limited opportunities to design inquiry labs and implement them, he used strategies from the Secondary Science Methods courses to make his instruction more student-centered and inquiry-oriented.

Jason talked about how his experiences in all three Secondary Science Methods courses influenced his decision to have students make claims based on evidence. As a student, he learned about making scientific claims based on evidence when he created his teaching philosophy. He had been using the strategy consistently all year with his students and believed making claims based on evidence was a “crucial nature of science thing ... If the claim does not have evidence with it then it isn’t really scientific” (Stimulated Recall, Day 2).

Jason also drew on his subject matter knowledge from college coursework to teach the content. He remembered learning about DNA and stated, “I think we hit it, did a little Evolution, but I think the heaviest was definitely Genetics and Cell Biology and General Biology” (Pre-observation Interview). Additionally, Jason continued to talk about how his background experiences as a Young Life mentor influenced his teaching. He said, “My previous experiences with Young Life... those are the big reasons why I became a teacher” (Pre-observation Interview). He wanted to teach students about integrity, respect for oneself, and being unselfish, alongside the biology curriculum (Pre-

observation Interview). He used labs in science class to help teach these character traits, believing that interaction during labs created a community (Stimulated Recall, Day 1).

*Summary: the Nature of Jason's Development of Knowledge of Teaching and Learning
Development of Jason's Orientation to Science Teaching*

Jason's science teaching orientation was complex and included: views of teaching and learning, views of the teacher and roles, and central and peripheral goals (See Table 34). Jason held competing views of teaching and learning. Ideally, he wanted students to discover science on their own through "discussions" based on his Young Life experiences. However, he consistently saw his teaching as a two-way process of communicating through teacher-led discussions. He believed he was responsible for presenting content through teacher-led discussions in order for students to learn science. His view that teaching and learning occurs through teacher-led discussions based on his K-16 experiences highlights his belief that he must transmit knowledge. Samuelowicz & Bain (1992) referred to competing conceptions "ideal" and "working." They conceptualized "working" conceptions as representing a compromise to conditions. Thus, the challenge of teaching made holding two conceptions a necessity. Although Jason took on additional goals, his orientation remained resistant to change and played a central role in his planning, enacting, and reflecting on teaching and learning.

Table 34

Development of Jason's Orientation to Science Teaching

Dimensions	Entry	End of Summer	Fall Semester	Spring Semester
Views of teaching and learning	<ul style="list-style-type: none"> • Process of discovering knowledge so students can apply science to life • Teaching science is providing content through teacher-led discussions and learning is participating in discussions 	<ul style="list-style-type: none"> • Process of discovering knowledge so students can apply science to life • Teaching science is providing content through teacher-led discussions and learning is participating in discussions 	<ul style="list-style-type: none"> • Process of discovering knowledge so students can apply science to life • Teaching science is providing content through teacher-led discussions and learning is participating in discussions 	<ul style="list-style-type: none"> • Process of discovering knowledge so students can apply science to life • Teaching science is providing content through teacher-led discussions and learning is participating in discussions
Views of the teacher roles	<ul style="list-style-type: none"> • Guide 			
Views of the students roles	<ul style="list-style-type: none"> • Discoverers 			
Central goals	<ul style="list-style-type: none"> • For students to apply science to life • For students to discover science knowledge on their own • Prepare students for future classes 	<ul style="list-style-type: none"> • For students to apply science to life • For students to discover science knowledge on their own • NM 	<ul style="list-style-type: none"> • For students to apply science to life • For students to discover science knowledge on their own • NM 	<ul style="list-style-type: none"> • NM • NM • Preparing students for future courses
Peripheral goals			<ul style="list-style-type: none"> • To present vocabulary 	<ul style="list-style-type: none"> • NM

Note. NM= Not mentioned

Development of Jason’s Knowledge of Instructional Sequences

Jason consistently sequenced science instruction in ways that gave priority to transmitting information during “inform” types of instruction. He used “discussion” with student participation so he could move back and forth between students’ experiences and presenting new concepts. The sequence he implemented was consistently teacher-centered. Although Jason learned about the 5E instructional model in the Secondary Science Methods courses, he thought it was necessary to precede his 5E instructional model with a discussion during “inform” types of instruction so students had prerequisite knowledge. Table 35 summarizes Jason’s sequence of instruction to teach science.

Table 35

Development of Jason’s Sequence of Science Instruction

Entry		End of Summer		Fall		Spring	
Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Focus	Review	Focus	Inform	Focus	Review	Inform	Review
Inform	Inform	Elaborate	Inform	Inform	Practice	Focus	Elaborate-
	Inform			Practice		Investigate	Part II
						Inform	Evaluate
						Elaborate-	
						Part I	

Development of Jason’s Knowledge of Learners

Jason attributed much of his knowledge of learners to his experience mentoring youth through Young Life. Jason thought that to learn the science content, students needed to participate in “discussions” in which the teacher connects science concepts to students’ lives. To supplement his discussions, he planned to have students look at empirical evidence. These conceptions were strongly reinforced by his experiences in the first summer’s coursework.

During the fall semester, Jason's knowledge of the requirements of learners expanded as a result of working with his mentor and students. He learned from teaching that students have difficulties remembering cell organelles functions and teacher-led discussions would not be enough for them to commit new vocabulary to memory. At this point in time, he believed that students needed multiple exposures to new content. As a result, he provided multiple "practice" types of activities that included: justifying why organelles are important; identifying plant and animal cells based on their organelles; creating flash cards of organelles function; playing review games of organelles and their functions; and describing how a cell is like a factory.

The Secondary Science Methods III course had a significant impact on the development of his knowledge of learners during the spring semester. Jason realized that both teacher-led discussions and multiple exposures were not always enough to help students overcome their difficulties learning science. He believed that students also required independent investigations where they made scientific claims based on evidence. Table 36 shows Jason's development of knowledge of learners including: requirements of learners, and areas of student difficulties learning science.

Development of Jason's Integration of Knowledge of Learners and Instructional Sequences

Jason integrated his knowledge of learners with his knowledge of instructional sequences; however, his instructional sequences did not fully reflect his knowledge of learners. At the beginning of the ACP, Jason acquired much of his knowledge of teaching and learning through his observations as a student in his high school and college classes. Additionally, his experiences mentoring youth through Young Life shaped his

knowledge of using “discussions” to help students comprehend new concepts. In Jason’s lessons, he planned to use discussions to relate content to students’ lives during “inform” types of instruction because he thought it would help students discover science on their own.

From working with his mentor and students, Jason realized that students would not learn cell organelle’s structure and function by only having teacher-led discussions. He learned students needed multiple opportunities to rehearse vocabulary. Thus, he planned a number of different “practice” types of instruction so students could apply vocabulary in different contexts. Jason’s integration of knowledge was directly related to his experiences with students and his mentor.

Over time, Jason observed that learning requires a combination of “discussions,” independent investigation, and students generating scientific claims based on evidence. In his lessons, he sequenced instruction so that he could discuss science content with students during “inform” types of instruction, then provide students with hands-on activities collecting data based on their own interests during “elaborate” types of instruction, and make a scientific claim based on evidence during “evaluate” types of instruction. After nearly nine months in the ACP, Jason integrated his knowledge of learners and instructional sequence to design instruction so students could learn by discovering, on their own, some patterns in how the world works. The integration was related to working with students and the Secondary Science methods courses.

Table 36

Jason's Development of Knowledge of Learners

Knowledge of Learners	Entry	End of Summer	Fall Semester	Spring Semester
Requirements for Learning Science	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas own their own • Evidence-based experiences • Connections to previous content • Collaborative experiences • Connections to life 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas own their own • Evidence-based experiences • NM • NM • NM 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas own their own • NM • Connections to previous content • Collaborative experiences • NM • Multiple exposures 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • NM • NM • NM • NM • NM • Discover new ideas through evidence-based experiences • Making claims based on evidence
Areas of Difficulties Learning Science	<ul style="list-style-type: none"> • None mentioned 	<ul style="list-style-type: none"> • None mentioned 	<ul style="list-style-type: none"> • Visualizing cellular structures 	<ul style="list-style-type: none"> • NM • Visualizing DNA replication and protein synthesis

Note. NM= Not mentioned

Contributing Factors to Jason's Development of Knowledge of Teaching and Learning

At the beginning of the ACP, Jason credited his knowledge of teaching and learning to his K-16 experiences observing his science teachers and mentoring adolescents through Young Life. These experiences formed his science teaching orientation that acted as a filter for making sense of his experiences in the ACP. Over the nine months of the ACP, Jason did not latch onto one specific source when deciding how to teach. Rather, he talked about how the culmination of his experiences influenced his knowledge of teaching and learning. For example, although Jason believed his mentor held dissimilar and sometimes incompatible views of teaching and learning, he learned from the guided internship about the importance of multiple exposures with content to help students overcome their difficulties. Jason's experiences in the Secondary Science Methods courses provided him with an understanding of the skills involved in making lessons more student-centered. Jason tried to implement a 5E instructional model for teaching DNA during the spring semester. However, his interpretation of the 5E instructional model meant that he needed to use "inform" types of instruction before his lessons so students could understand new content. Over time, Jason drew on multiple experiences to resolve tensions in his competing views of teaching and learning.

CHAPTER FIVE: CROSS-CASE ANALYSIS

In this chapter, I present assertions based on the full data set from the four cases presented in Chapter Four. The assertions describe major themes common among the participants' development of PCK and are organized around the sub-research questions that guided this study.

Sub-Research Questions and Assertions

1. What knowledge of learners do teachers have at various points during an ACP (entry, end of summer, end of first semester, end of first year)? (Assertion 1)
2. How do ACP teachers sequence science instruction at various points of their program? (Assertion 2)
3. In what ways do ACP science teachers integrate their knowledge of learners and sequence of instruction? (Assertion 3)
4. What is the nature of ACP teachers' orientations to science teaching at various points of their program? (Assertion 4)
5. In what ways do the following factors contribute to the development of teachers' knowledge of learners and sequencing of instruction: background experiences, science teaching orientations, and school context? (Assertion 4)

In discussing each of the four assertions, I refer back to the case profiles and use relevant data from the interviews and classroom observations in order to understand participants' development of knowledge.

Assertion 1: Over time, prospective teachers broadened their knowledge of requirements for learning science without forming a cohesive view of science learning.

At the beginning of the ACP, Mary, Amy, Lilly, and Jason were unsure of students' knowledge of genetics; however, they all believed they could help students learn science by relating new content to students' life experiences through lectures and teacher-led discussions. For Amy, Mary, and Lilly, these were strategies they observed their high school and/or college professors use to help students learn science. For example, Mary thought students might be familiar with the term "DNA" and planned to teach heredity by using teacher-led discussions to relate to students' experiences with television shows. Amy thought that students had been exposed to heredity in previous science courses, and planned to help students learn by showing them how to construct a family tree. Lilly also believed that students did not have much experience learning biology. She planned to help students learn heredity by: (1) using an analogy that video game codes are like alleles and traits, and (2) showing how mixing different colors of paint is similar to the inheritance of dominant and recessive alleles. Jason came into the ACP with an understanding that learning is dependent on a number of factors from his experiences as a K-16 student and through Young Life. However, he believed he could help students learn science by using "discussions" with student participation. He planned on using "discussions" to go back and forth between asking questions, eliciting student ideas, and introducing new terminology and concepts. Each of these participants thought they could help students learn science by relating to students' experiences either through lectures or discussions.

After 11 weeks in the ACP, Mary, Amy, and Lilly realized that relating the content to students' life experiences would not be enough to help students learn science. Their ideas expanded as a result of their experiences in the ACP courses. For example, Mary still believed that learners need lectures, but learned from the Secondary Science Methods and Educational Psychology courses that they also needed to "discover" content on their own and engage in group work. Similarly, even though Amy primarily thought students needed lectures and teacher-led discussions to learn science, she learned from the Secondary Science Methods course that students also need to make observations of phenomena, investigate scientific questions by collecting data, and have collaborative opportunities to teach each other. Lilly believed that, regardless of students' prior knowledge, she could help them learn by lecturing and allowing them to make scientific decisions so they could learn on their own. Jason found that the ideas proposed about learners in the Secondary Science Methods Course strongly reinforced his initial conceptions about students "discovering" science on their own and making evidence-based explanations about science phenomena.

Over time, Mary, Amy, Lilly, and Jason developed a growing awareness of student difficulties and broadened their knowledge of the requirements for learning. Each prospective teacher added to his/her knowledge of learners while retaining prior conceptions of students' needs. Mary, for example, believed lectures are fundamental for learning, but that teachers frequently need to provide multiple exposures and group work to help students commit new terms to memory. When Mary developed her unit on the heart, first she discussed structures and functions, and then she provided multiple opportunities for students to practice tracing blood flow through the heart. Likewise,

prior to developing her cloning unit, Amy knew that students had trouble comprehending all of the information presented in her lectures. She also knew that students learn better when they have the opportunity to “peer teach,” and talk through the ideas presented in lecture with their peers. By considering the benefit of “peer teaching,” she was able to breakup her lectures into segments to allow students to formulate and practice new ideas in their own words. Like Mary and Amy, Lilly primarily used lectures to teach the content. However, she knew from working with students and her mentor teacher that students also need multiple exposures to material to commit terms and concepts to memory. In Lilly’s spring semester lessons on the biochemical evidence for evolution lesson, she used a PowerPoint to lecture, and then provided students multiple opportunities to compare and contrast different organisms’ amino acid sequences. Although Jason’s knowledge of the requirements for learning did not seem to grow as much in quantity as the other participants, he also developed additional ideas about learners. For example, Jason learned from his mentor teacher that students need multiple opportunities to practice new terms in order to commit them to memory. During the spring semester, Jason believed that providing students with an independent investigation was a way for them to “discover” some science content on their own. Jason was able to combine his ideas about “discovery learning” and evidence-based experiences to create a more sophisticated idea about how students can learn content on their own. For these teachers, understanding students’ difficulties helped them broaden their knowledge of learners. However, they did not make meaningful links between their knowledge of learners and learning and more student-centered views. The teachers demonstrated naïve views of the requirements of learning and talked about students’ learning needs as

separate, unrelated items. Table 37 and 38 indicates what prospective teachers' focused on across time.

Table 37

Development of Mary and Amy's Knowledge of the Requirements for Learning Science

Participant	Entry	End of Summer	Fall Semester	Spring Semester
Mary	<ul style="list-style-type: none"> • Lectures • Connections to life 	<ul style="list-style-type: none"> • Lectures • Connections to life • Discover new ideas on their own • Group work 	<ul style="list-style-type: none"> • Lectures • NM • NM • NM • Hands-on 	<ul style="list-style-type: none"> • Lectures • NM • NM • NM • NM • Multiple exposures to new content • Collaborative experiences
Amy	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life 	<ul style="list-style-type: none"> • Teacher-led discussions • Connections to life • Making observations of phenomena • Hands-on experiences • Investigating scientific questions and collecting data • Coteaching experiences 	<ul style="list-style-type: none"> • Teacher-led discussions/lectures • Connections to life • NM • Hands-on experiences • NM • NM • "Peer teaching" experiences 	<ul style="list-style-type: none"> • Teacher-led discussions/lectures • NM • NM • Hands-on experiences • NM • NM • "Peer teaching" experiences

Note. NM= Not mentioned.

Table 38

Development of Lilly and Jason's Knowledge of the Requirements for Learning Science

Participant	Entry	End of Summer	Fall Semester	Spring Semester →
Lilly	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Repetition • Make scientific decisions 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • NM • Making scientific decisions • Multiple exposures • Evidence-based experiences • Hands-on experiences 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • NM • Making scientific decisions • Multiple exposures • Evidence-based experiences • NM • Connections to previous course content
Jason	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas on their own • Evidence-based experiences • Connections to previous content • Collaborative experiences to build knowledge 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas on their own • Evidence-based experiences • NM • NM 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • Discover new ideas on their own • NM • Connections to previous content • Collaborative experiences to build knowledge • Multiple exposures 	<ul style="list-style-type: none"> • Students need teacher-led discussions • Connections to life • NM • NM • NM • NM • Discover new ideas through evidence-based experiences.

Note. NM= Not mentioned

Assertion 2: Prospective teachers consistently sequenced instruction in ways that gave priority to transmitting information to students.

At the beginning of the ACP, Mary, Amy, Lilly, and Jason planned to use an instructional sequence aimed at providing new knowledge to students during “inform” types of instruction. These four participants believed that science learning begins when the teacher transmits knowledge to students. The other activities they planned were dependent on the knowledge provided during “inform” types of instruction and included: (1) “review” types of instruction to remind students of content previously covered; (2) “focus” types of instruction to provide an opportunity for the teacher to motivate and focus students; and (3) “practice” types of instruction to have students use and rehearse ideas from “inform” types of instruction through interactions with peers, texts, the teacher, and worksheets. During the End of the Summer interviews, the participants continued to focus on presenting information to students during “inform” types of instruction because they believed that learning starts when the teacher lectures or “discusses” new content. They continued to plan “review,” “focus,” and “practice” types of instruction.

All four participants’ knowledge of instructional strategies developed during the fall and spring semesters. This is evident in the lesson plan summaries in the individual case profiles. However, all four participants continued to believe that teaching and learning begin when the teacher tells students new content through “inform” types of instruction. For example, although Mary learned about other instructional strategies in the Secondary Science Methods courses, she stated that, in Anatomy class, lectures were the best way to provide students with science vocabulary.

During the spring semester, Amy implemented a photosynthesis laboratory so students could collect data in an “investigate” type of instruction. However, Amy relied on teacher-led discussions and told students what they should expect in the investigation after modeling, step-by-step, the lab procedure. On the second day, she used students’ data to lead a discussion about the role of carbon dioxide in photosynthesis. Even though students had hands-on experiences exploring the role of carbon dioxide in photosynthesis, Amy relied on lectures and discussions during “inform” types of instruction to teach photosynthesis.

In Lilly’s diffusion and osmosis unit in the fall semester, she had students manipulate variables in an independent investigation which was part of her “elaborate” type of instruction. However, the placement of the “elaborate” was based on students’ prior knowledge and experiences that included: (1) lectures and teacher-led discussions on diffusion and osmosis, and (2) an “investigation” where students collected data to verify what Lilly had told students in her previous lectures. Although students were able to investigate questions and make scientific claims based on evidence in another context, the experience provided limited opportunities for students to construct scientific explanations. Lilly believed that students needed knowledge provided during “inform” types of instruction to be successful in the “elaboration.”

After teaching full time, without a mentor teacher, Jason used his interpretation of the 5E instructional model from the ACP coursework to design his lesson on DNA. However, prior to the interview-observation cycle, Jason used lectures and teacher-led discussions to provide students with knowledge of the structure and function of DNA. Jason believed the order of the phases of the 5E instructional model was unimportant and

students needed knowledge about DNA before they could have hands-on, minds-on experiences to formulate their own explanations. Additionally, although students made scientific claims based on evidence during his “elaborate” phase of the 5E instructional model, his choice of DNA independent investigations provided students with limited opportunities to form deep conceptual understanding of the content. Students were not asked to formulate explanations of the structure or function of DNA. The only scientific claim students could generate from the experience was whether different fruits and vegetables have DNA.

These prospective teachers consistently placed “inform” types of instruction near the beginning of lessons so they could transmit new terms and concepts to students. They consistently believed that science learning begins when the teacher introduces new terms and concepts. Although Mary, Amy, Lilly, and Jason increased their knowledge of instructional strategies, they did not sequence instruction so students could first formulate an explanation of science phenomena in their own words. Table 39 summarizes the participants’ instructional sequences over time, and table 40 describes the different types of instructions used by the participants.

Table 39

Summary of Mary, Amy, Lilly and Jason's Knowledge of Instructional Sequences

Participant	Entry		End of Summer		Fall		Spring	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Mary	Inform	Focus	Inform	Focus	Focus	Focus	Focus	Practice
	Practice	Practice	Practice	Practice	Inform	Inform	Inform	Practice
	Inform	Inform	Inform	Inform	Inform	Practice		Practice
	Practice		Practice					
Amy	Inform	Focus	Inform	Focus	Focus	Focus	Focus	Focus
	Practice	Practice	Practice	Practice	Inform	Inform	Inform	Inform
	Inform		Inform		Practice	Practice	Investigate	Investigate
	Practice		Practice		Inform			
Lilly	Focus	Focus	Focus	Focus	Inform	Focus	Focus	Focus
	Inform	Inform	Inform	Inform	Focus	Inform	Inform	Practice
	Practice	Practice	Practice	Practice	Elaborate	Practice	Practice	
		Inform	Inform	Inform	Extend			
Jason	Focus	Focus	Focus	Inform	Focus	Inform	Inform	Focus
	Inform	Inform	Elaborate	Inform	Inform	Practice	Focus	Elaborate-
		Inform			Practice		Explore	Part II
							Inform	Evaluate
						Elaborate-Part I		

Table 40

Description of Types of Instruction used by the Participants

Type of Instruction	Purpose
Inform	<ul style="list-style-type: none"> • Transmit content to students.
Practice	<ul style="list-style-type: none"> • Rehearse content presented during lectures and teacher-led discussions and apply new knowledge in other contexts.
Review	<ul style="list-style-type: none"> • Remind students of content covered during previous classes.
Focus	<ul style="list-style-type: none"> • Introduce topics that will be covered during class.
Investigate	<ul style="list-style-type: none"> • Collect data about content covered in subsequent lessons.
Elaborate	<ul style="list-style-type: none"> • Use prior experiences and knowledge to manipulate a variable during lab.
Evaluate	<ul style="list-style-type: none"> • Assess student understanding of science content based on experiences collecting data and knowledge from class.

Assertion 3: Prospective teachers developed knowledge of instructional sequences integrated with knowledge of learners, although their instructional sequences did not fully reflect their knowledge of learners.

Over time, the knowledge of instructional sequences held by Mary, Amy, Lilly, and Jason was reflective of their beliefs about how students learn science. However, at no point in time did their instructional sequences fully reflect their knowledge of learners. The prospective teachers started their careers with some knowledge of learners and instructional sequences. At the beginning of the ACP, their knowledge of instructional sequences was reflective of how they were taught and/or their experiences mentoring youth. For example, Mary, Amy, and Lilly drew on their prior experiences as students where they primarily learned from lectures. Jason drew on his experiences mentoring

youth, and his K-16 memories of how his teachers taught, to formulate his ideas about the benefits of using “discussions” to talk about the content in relation to students’ experiences.

As Mary, Amy, Lilly, and Jason gained experiences working with their mentors and teaching students, they integrated specific elements of their knowledge of learners and sequence of science instruction. The case profiles show that, over time, these four teachers’ knowledge of learning and instructional sequence grew to encompass a deeper understanding of the relationship between the two. Although Mary still planned to lecture during the fall semester, she also believed students needed multiple exposures and group work to learn the content. Consistent with this view, after her lectures she used a number of different “practice” types of activities so students could have multiple exposures to help students overcome their difficulties learning new content. Similarly, Amy believed students need a combination of lectures, “peer teaching” experiences, and teacher-led hands-on experiences. When teaching, Amy often used “inform” types of instruction that included both lectures and “peer teaching.” Additionally, Amy purposefully provided “practice” types of activities so students could rehearse the material. Similar to Mary and Amy, Lilly believed the combination of lectures and multiple exposures to the content would help students learn science. Lilly planned multiple “practice” types of activities after “inform” to help students learn science content. From working with his mentor and students, Jason also realized that students would not learn cell organelle structure and function by only having “discussions.” During the fall semester, he believed students needed multiple opportunities to rehearse

terms and concepts. As a result, he planned a number of different “practice” types of activities so students could apply the terms and concepts in different contexts.

In each of these cases, teacher integration of knowledge of learners and instructional sequences was directly related to their experiences with their mentor and with students. This illustrates a shift in their source of knowledge away from their K-12 learning experiences to sequencing science instruction to meet students’ needs. For these individuals, the integration of knowledge of instructional sequences and learners meant that they purposefully added “practice” types of activities to help students learn terms and concepts.

Assertion 4: Prospective teachers’ science teaching orientations were stable over time, acted as filters for making sense of experiences, and limited the development of knowledge of learners and instructional sequences.

All four teachers held science teaching orientations that were shaped by their background experiences as students and youth mentors. Their orientations were complex, consisting of multiple dimensions that included: views about teaching and learning, views of the teacher and student roles, and central and peripheral goals for teaching science (see Case Summaries). Their views about teaching and learning were evident in their lesson plans and teaching practice. Although the participants gained additional goals and views of the teacher’s role, the central components of their science teaching orientations persisted throughout the ACP. Their science teaching orientations played a pivotal role in their planning, enacting, and reflecting on teaching and learning.

Mary, Amy, and Lilly entered the ACP with science teaching orientations influenced by their experiences as students. These three prospective teachers were highly

committed to the view that science teaching is transferring knowledge to students. Their incoming science teaching orientations influenced their interpretation of new ideas and experiences, and therefore, what they learned about learners and learning and instructional sequences. Each of these teachers interned with mentor teachers who predominantly used traditional, transmission types of instruction. Their mentors strongly reinforced their incoming science teaching orientation. During their 9 months in the ACP, they interpreted experiences based on their science teaching orientation. For example, Mary's view of teaching and learning expanded to include building on students' prior science knowledge as a result of the Secondary Science Methods course. Amy's goals expanded to include preparing students to make educated decisions due to the topic (i.e., cloning) she was teaching during the fall semester. Lilly believed her role was to be both a leader and a guide after the Secondary Science Methods course. Although their experiences resulted in adding goals and views of the teacher roles to their science teaching orientation, they maintained the dominant view that teaching is telling and learning is listening.

Mary's, Amy's, and Lilly's science teaching orientations acted as a barrier to developing more sophisticated knowledge of instructional sequences and knowledge of learners. These three prospective teachers gained knowledge that was congruent with dimensions of their science teaching orientation. Mary and Lilly learned from their mentor teachers and students that learners need multiple exposures to new content to memorize vocabulary. Amy learned that she needed to break-up lectures with "peer teaching" experiences so students can practice the content in their own words. These views of the requirements for learning meshed with their views that teachers are leaders

and/or guides and responsible for transmitting knowledge and students primarily have a passive role in science learning.

Although the Science Methods Course instructors hoped to influence teachers' PCK towards a careful integration of knowledge of learners and instructional sequences reflecting constructivist ideas, these participants demonstrated that their incoming science teaching orientations were highly resistant to change. These individuals consistently thought students had a passive role, indicating a lower conception of teaching as transmitting knowledge. Their incoming views of teaching and learning were strongly reinforced by their mentor teachers, who primarily implemented traditional, teacher-centered instructional approaches. Their mentor teachers were reluctant to let the interns implement student-centered strategies learned in the Science Methods courses. Amy, Mary, and Lilly never became dissatisfied with their view that teaching is telling and learning is listening based on their experiences in the Science Methods courses or from working with their mentor teachers. Additionally, they held on to limited views of teaching and learning to avoid the anxiety of the unknown, and never saw the advantages of the student-centered approaches they learned about in the Science Methods courses. As a result, these three teachers struggled to embrace reform-oriented views of teaching and learning because these views deviated from their science teaching orientations and their experiences working with their mentors.

Jason held an orientation to science teaching that was largely based on his experiences mentoring youth through Young Life and from his K-16 experiences. Jason was successful using discussions in Young Life to help students discover "life lessons." However, he experienced "delivery" modes of instruction as a K-16 student. Jason held

competing conceptions based on these background experiences. Ideally, he hoped he could guide students in discovering science on their own through discussions. However, his working knowledge of teaching science through discussions was characterized by the following sequence: (1) asking an open-end question, (2) eliciting student responses, and (3) introducing new terminology. Although students were able to participate with the teacher during the “discussion,” they did not collaborate to “discover” general science principles. This contrasted with his experiences in Young Life where he used “open-ended discussions” with students to have them live according to the authority of scripture.

Thus, Jason’s ideal views of teaching and learning were incompatible with his past science learning experiences. His diverse experiences with learners through Young Life made holding two views of teaching and learning a necessity. Jason tried to incorporate his beliefs about discovery through discussions with his views of teaching and learning science. However, there are great differences between using discussions to discover “life lessons,” and using “discussions” in science. Scientists do not discover general principles from particular terms, concepts, or instances. Rather, scientists invent theories that are then checked against observations, experiences, and empirical data. Jason’s views of teaching and learning by discovery were incompatible with the nature of science and with his beliefs about the necessity of teacher-led discussions in science. He held unrealistic expectations that he would be able to promote students in discovering general science principles from his teacher-led “discussions.”

Jason’s orientation acted as a filter for making sense of his experiences in the ACP; he drew on multiple experiences during the ACP to try and resolve tensions in his views of teaching and learning. Jason drew on his Young Life experiences because he

was dissatisfied with his K-16 experiences that were mostly traditional, and teacher-centered in nature. He was eager to find new ways to think about science teaching that mirrored his knowledge of learners from Young Life. As a result, he embraced the strategies presented in the Science Methods courses, because they provided intelligible ways to make teaching and learning more student-centered. Additionally, Jason drew on his experiences working with his mentor and the teaching context. During the fall semester, he developed a peripheral goal of students learning science vocabulary and learned that students need “practice” types of activities to memorize terms. Due to the teacher-centered nature of his mentor teacher’s instructional practices, Jason was unable to fully test his new ideas from the Science Methods courses. Ultimately, Jason did not replace his ideas about “discovery learning” with more accurate conceptions of how science knowledge is “invented” rather than “discovered.” As a result, his conflict of using “discussions” during “inform” types of instruction to promote “discovery” learning persisted throughout the ACP.

Jason entered the ACP with more student-centered views of teaching than the other three participants. Additionally, his views that students should have an “active” role in learning indicated that he held a more sophisticated conception of teaching and learning (Biggs, 1989). Jason’s conflict was a result of the interaction taking place between different views of teaching and learning. At the end of nine months in the ACP, Jason was in the process of restructuring his knowledge of teaching and learning. Jason developed knowledge of learners that closely aligned with his science teaching orientation. However, his knowledge of instructional strategies remained unchanged as he consistently gave priority to using “discussions” during “inform” types of instruction.

Implementing the 5E instructional model and replacing views of “discovery learning” may require a more radical re-structuring of Jason’s science teaching orientation.

Ultimately, Jason was unable to completely abandon his beliefs about using traditional instructional strategies that focused on explaining content to students.

Figure 4 shows the interrelationship between the sources and experiences that influenced Mary’s, Amy’s, and Lilly’s science teaching orientations. Figure 5 shows the interrelationship between the sources and experiences that influence Jason’s science teaching orientation. Table 41 summarizes the relationship among components in Figures 4 and 5.

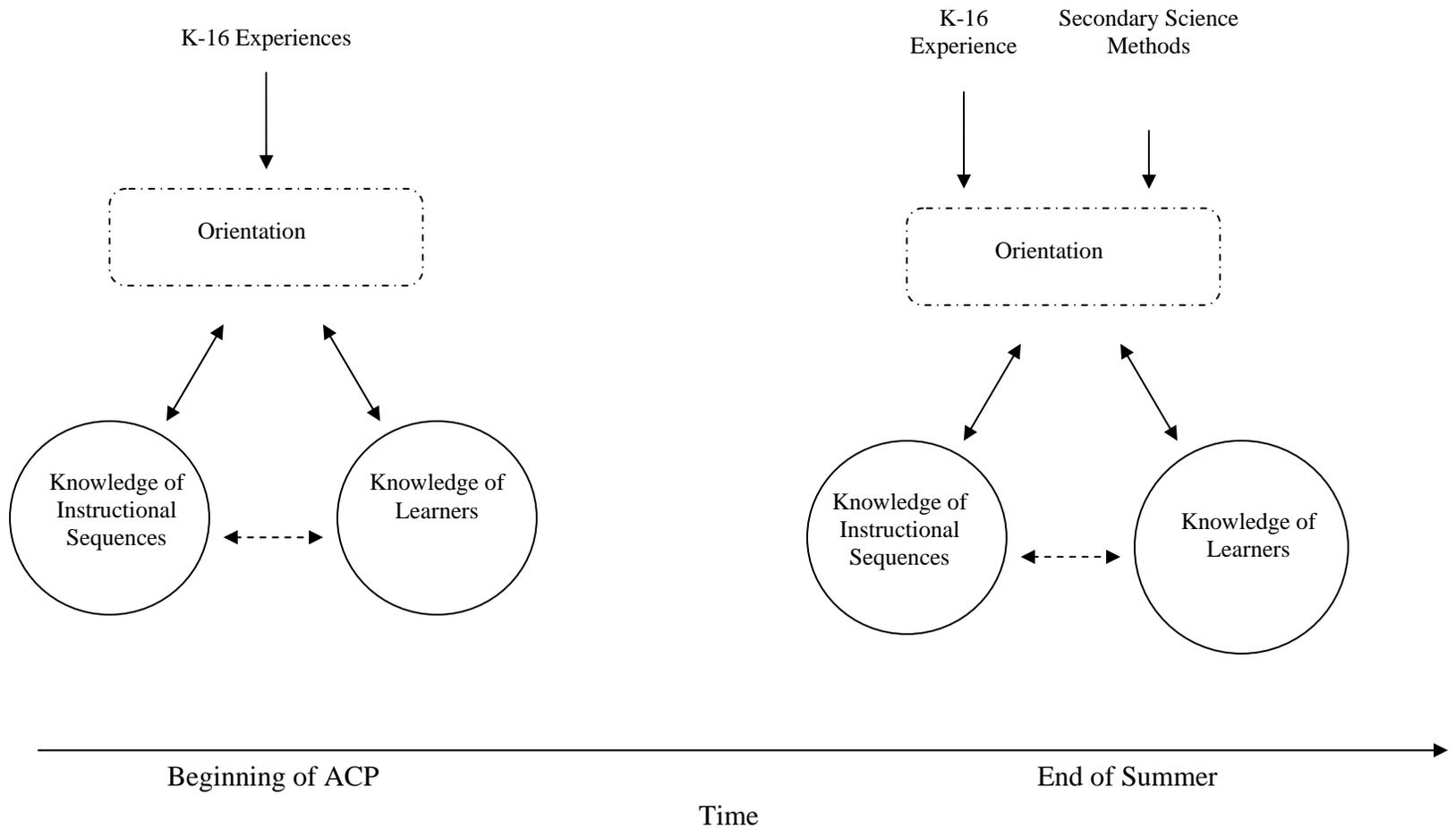


Figure 4. Development of Mary, Amy, and Lilly's knowledge of learners and instructional sequences.

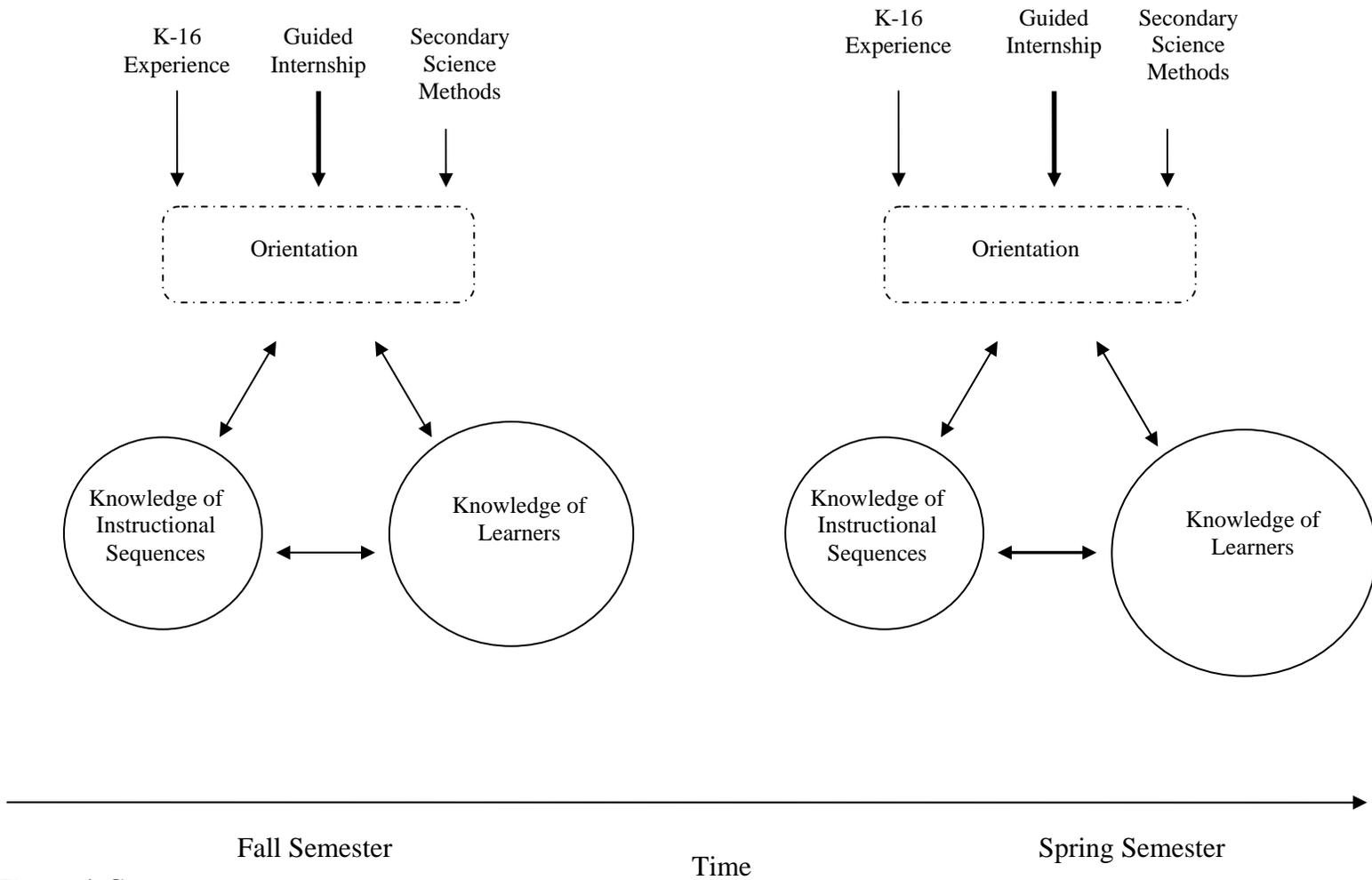


Figure 4. Cont...

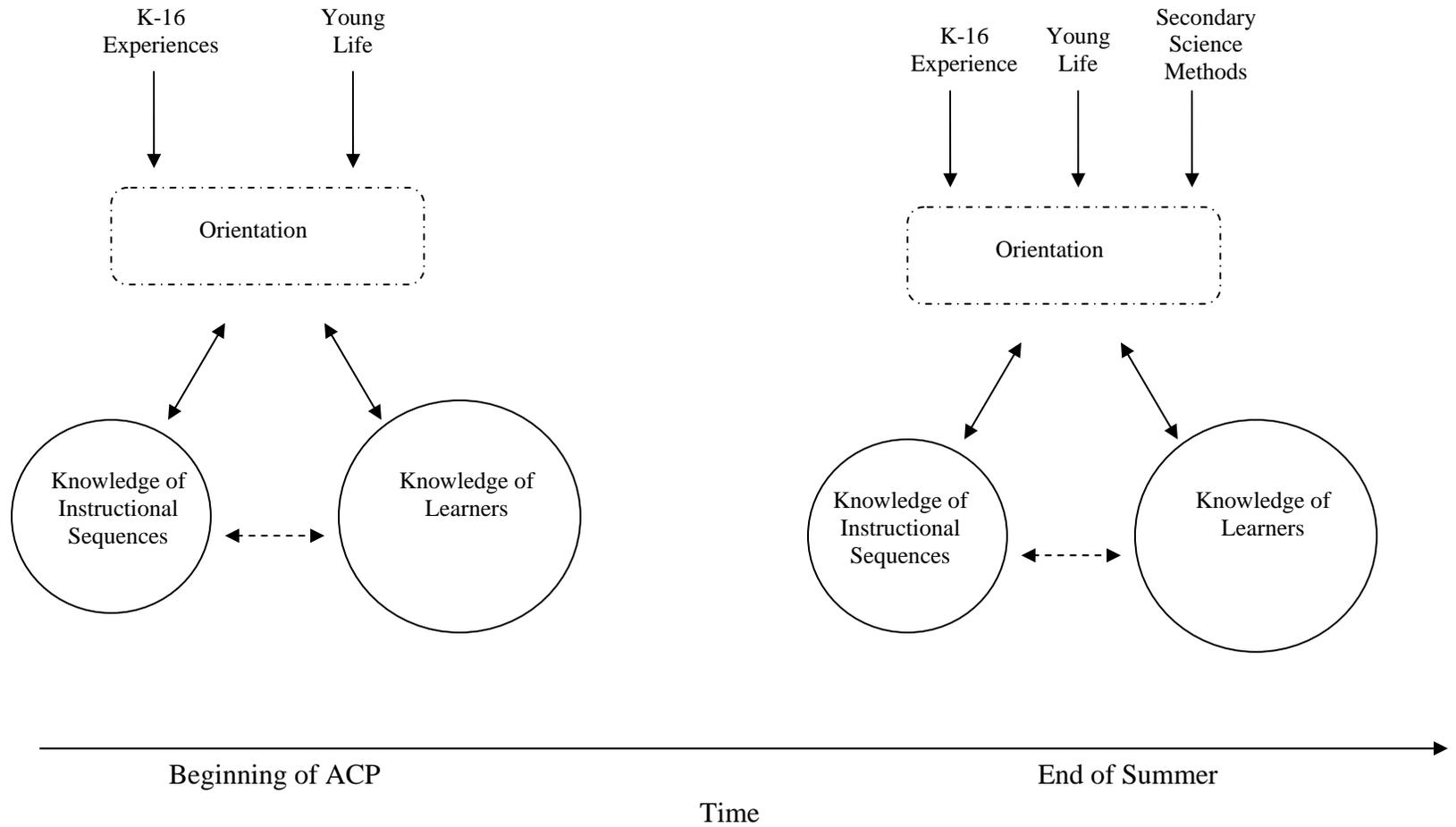


Figure 5. Development of Jason's knowledge of learners and instructional sequences.

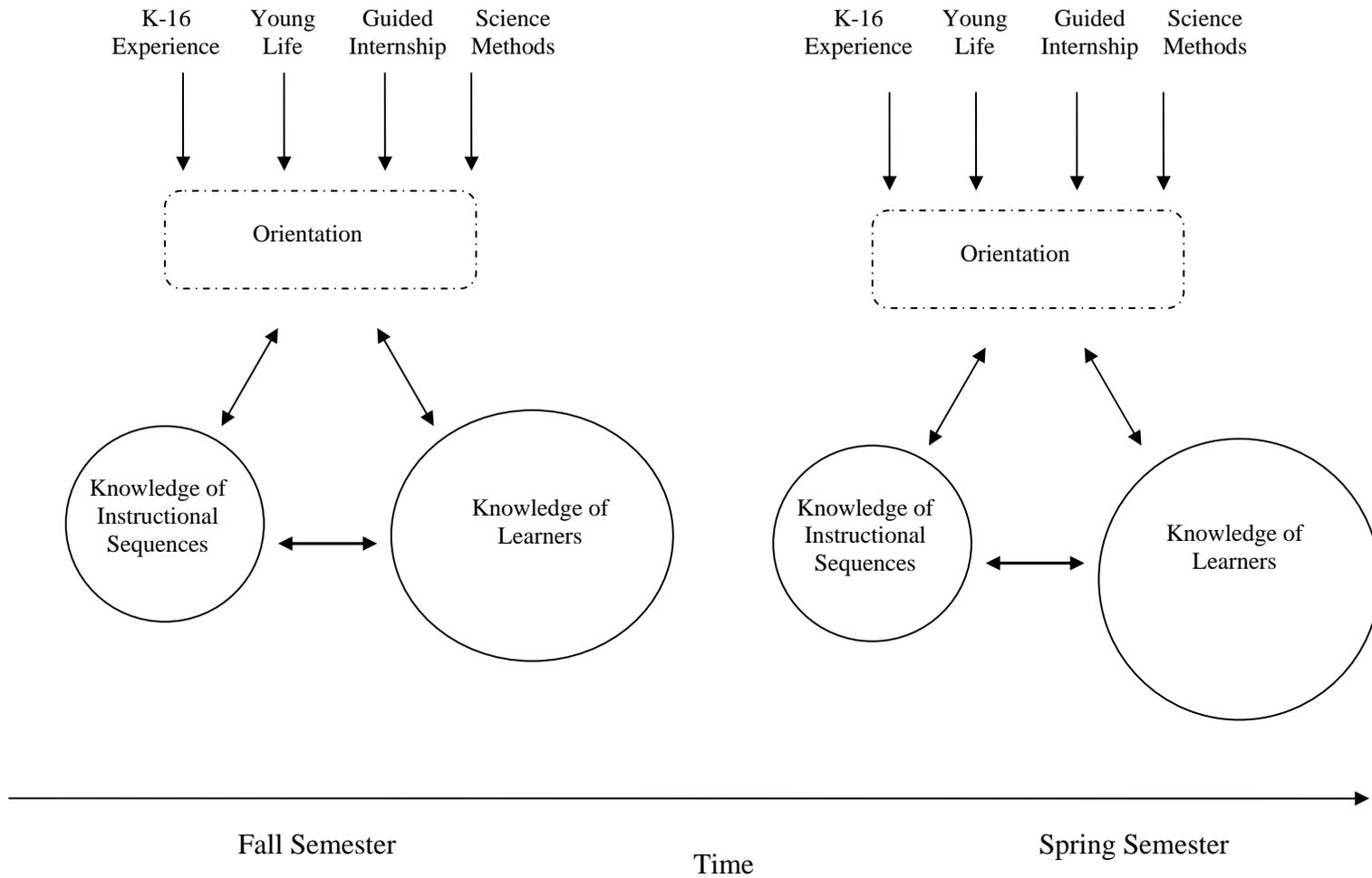


Figure 5. Cont

Table 41

The Relationship between components in Figures 4 and 5

Figure components	Description
Experiences	The lengths of the arrows connecting experiences to orientations indicate their relative influence on these teachers' orientation. The thickness of the line shows factors that strongly reinforced these science teachers' orientations.
Orientations	A dotted line surrounds orientations to illustrate that it acts as a filter that allows the incorporation of knowledge from different experiences. Over time, these teachers' retained their initial orientation despite gaining additional goals and views of the teachers' role to their science teaching orientation.
Knowledge of Learners	The increase in diameter illustrates the knowledge of learners broadened to include multiple views about the requirements of learners and areas of student difficulty.
Knowledge of Instructional Sequences	Over time, the knowledge of instructional sequences component remained unchanged.
Integration of Knowledge of Learners and Instructional Sequences	A two-way arrow connects knowledge of learners and instructional sequences to illustrate these participants' central beliefs about learners and learning informed their planning and enactment of instructional sequences. The line becomes solid over time, to illustrate that these components of PCK became more integrated.

CHAPTER SIX: CONCLUSIONS AND IMPLICATIONS

The purpose of this study was to investigate the development of prospective science teachers' knowledge of learners and sequence of science instruction during an ACP. Five research questions guided the analysis and construction of this chapter. These questions included: 1) what knowledge of learners do teachers have at various points during an ACP (entry, end of summer, end of first semester, end of first year); 2) how do ACP teachers sequence science instruction at various points of their program; 3) in what ways do ACP science teachers integrate their knowledge of learners and sequence of instruction; 4) what is the nature of ACP teachers' orientations to science teaching at various points in their program; and 5) in what ways do the following factors contribute to the development of teachers' knowledge of learners and sequencing of instruction: background experiences, science teaching orientations, and school context?

This chapter includes: a) a summary of the findings; b) a comparison of the findings in relation to the literature discussed in Chapter Two, and a discussion of how this study contributes to the bodies of literature on the development of secondary ACP teachers' knowledge of learners, knowledge of sequence of science instruction, and the nature of science teaching orientations; c) implications for teacher preparation and policy; d) recommendations for future science education research; and e) conclusions.

Summary of Findings

Sub-Research Question One: Knowledge of Learners

The first question investigated the four teachers' knowledge of learners at four different points during their ACP. Based on interviews and classroom observations, I can assert that Mary, Amy, Lilly, and Jason's knowledge of learners developed as a result of

their experiences in the ACP. At the onset of the ACP these teachers' knowledge of learners and learning was limited to their memories of being a student and/or experiences mentoring youth. Many of the participants thought they could help students learn science by relating the content to students' prior experiences through teacher-led discussions and lectures. These individuals focused on students' prior life experiences, assuming that students' prior science knowledge about specific topics was limited. As the participants gained teaching experience, they developed a growing awareness of students' difficulties, and learned that students need more than lectures and teacher-led discussions; however, they did not form meaningful links between their knowledge of learners and learning and more student-centered views. Additionally, they talked about the requirements of learning as separate, unrelated items. In this study, I have identified a number of different participant views of what students need in order to learn the content. Additionally, this study reported numerous concerns prospective secondary teachers have related to students' difficulties learning science content.

Sub-Research Question Two: Knowledge of Instructional Sequences

The second question investigated the four teachers' knowledge of instructional sequences to teach science at four different points in the ACP. From interviews and observations, I can assert that these teachers consistently sequenced instruction in ways that gave priority to "inform" types of instruction. They planned and implemented lectures and teacher-led discussions during "inform" types of instruction so they could transmit knowledge to students. This view persisted in spite of learning about student-centered sequences of instruction, like the 5E instructional model, in the Secondary

Science Methods courses. Over time, the four teachers struggled to sequence science instruction in student-centered ways.

Sub-Research Question Three: Integration of Knowledge of Learners and Instructional Sequences

The third question investigated how the four teachers integrated their knowledge of learners and instructional sequences to teach science. Based on interviews and observations, I can assert that over time teachers integrated their knowledge of learners and sequence of science instruction. For these individuals, the integration of knowledge of instructional sequences and learners meant that they purposefully added “practice” types of activities to help students learn terms and concepts.

Sub-Research Question Four: Nature of Prospective Teachers’ Science Teaching Orientations

The fourth question investigated the nature of ACP teachers’ science teaching orientations. ACP teachers’ science teaching orientations were complex, consisting of multiple dimensions that included: views of teaching and learning, views of the teacher and student roles, and central and peripheral goals. During this study, I found that ACP teachers gained additional goals and/or views of the teacher’s role. Although each teacher added goals and/or views of the teacher’s role, their transmission science teaching orientations were highly resistant to change. Teachers’ strongly held science teaching orientations shaped their knowledge of teaching and learning.

Sub-Research Question Five: Contributing Factors to Teachers' Knowledge

Development

The fifth question investigated the different factors that influenced the development of teachers' knowledge of learners and sequences of science instruction during the four data collection points. All four teachers entered the program with views of teaching and learning from their past experiences. During the study, prospective teachers' science teaching orientations acted as a filter for making sense of experiences in the ACP. Mary, Amy, and Lilly came into the program with teacher-centered views of teaching and learning. Their incoming orientations were strongly reinforced by their mentor teachers who primarily used traditional, teacher-centered instructional strategies. They drew almost exclusively on the knowledge and beliefs of their mentor teacher when reflecting on their knowledge of teaching and learning. Each of these three individuals struggled to embrace the student-centered, reform-oriented instructional strategies presented in the Secondary Science Methods courses.

Jason came into the ACP with student-centered goals for teaching and learning, while having primarily experienced teacher-centered instruction as a K-16 student. Jason's case represents his struggle to better align his "ideal" views of teaching and learning with views of teaching that were based on his observations as a K-16 student. To reconcile his competing views, he drew on multiple experiences during the ACP. For example, he talked at length about how the student-centered strategies he learned in the Science Methods courses influenced his knowledge of teaching and learning. Additionally, he learned from his mentor teacher and working with students that by adding "practice" types of activities to his instructional sequences he could help students

overcome difficulties learning content. Like the other three cases, Jason's science teaching orientation served as the driving force for his development of knowledge of teaching and learning.

Discussion

This study investigated how prospective secondary science teachers' orientations to science teaching, knowledge of learners, and knowledge of instructional sequences developed within an ACP consisting of Science Methods courses and a guided internship. Each of the teachers in this study developed science teacher orientations based on their extensive experiences as students and/or as youth mentors. Koballa et al. (2005), in a study of ACP teachers, reported a similar finding. Koballa et al. proposed that prior learning experiences formed individuals' conceptions of science teaching.

Mary's, Amy's, and Lilly's science teaching orientations were dominated by the view that teaching is telling and learning is listening. These three individuals experienced mainly traditional, teacher-centered instruction during their K-16 education that influenced their science teaching orientations. Mary, Amy, and Lilly were young, entering their first occupation, and drew primarily on their K-16 experiences as students. Contrary to studies of experienced teachers (Friedrichsen & Dana, 2005) and individuals entering teaching from other careers (Greenwood, 2003), Mary, Amy, and Lilly, did not have significant, long-term work experiences that influenced their science teaching orientations.

Jason also learned science in teacher-centered, traditional classrooms. Based on these experiences, he believed he needed to use teacher-led discussions to provide new knowledge to students. However, Jason also aspired to help students discover knowledge

on their own based on his experiences using “open discussions” with adolescents in Young Life. For Jason, his knowledge of learners and the challenges of teaching led to competing views of teaching and learning. This finding is similar to Koballa et al. (2005) who reported that ACP teachers can hold multiple conceptions of teaching science.

Apart from their background experiences, these prospective teachers experienced several different ways of thinking about teaching and learning during the ACP. These included learning about students and instructional sequences in the Secondary Science Methods courses, and observing and teaching with mentor teachers. The Science Methods courses provided a rich resource for understanding the relationship between learners and instructional sequences. The Methods courses were designed to help teachers integrate learning science content and pedagogy through the 5E instructional model, while reflecting on the theories supporting this instructional sequence.

After the first of three Secondary Science methods course, three of the participants expanded their knowledge of learners, while Jason found that some of his initial ideas were strongly reinforced. During the guided internship, the participants built on their prior ideas about learners’ needs as a result of working with students and their mentor teacher. Additionally, the participants became aware of student difficulties and changed their instruction to accommodate learners’ needs. The literature indicates that secondary prospective teachers often became aware of student difficulties through teaching and change their instruction accordingly (Van Driel et al., 2002). However, in each of the four cases, this accommodation translated into adding more opportunities for students to practice terms and content. Their overall sequence of instruction remained teacher-centered and they consistently believed that students need lectures and teacher-

led discussions during “inform” types of instruction to learn science. This finding is also congruent with the literature. A number of researchers have found that secondary prospective teachers do not consider their students in sophisticated ways or think about their students’ knowledge extensively (Geddis & Roberts, 1998) and believe teaching is telling (Geddis et al., 1993; Lemberger et al., 1999; Mellado, 1998; Russell & Martin, 2007). The data reflect the difference between novice and expert teachers’ understanding of what is required for teaching and learning science. The novice teachers in this study demonstrated that they were inexperienced and had a limited knowledge base. For example, they talked about learners needs as separate, unrelated items. Over time, they gained ideas about the requirements for learning science without forming connections among their existing views and new ideas (Donovan & Bransford, 2005). Conversely, expert science teachers might be expected to have a more integrated knowledge base where connections are continually being made within their knowledge of learners’ ideas and across other types of knowledge.

It is important to note that Jason attempted to teach science through inquiry and the 5E instructional model during the spring semester. However, he believed inquiry meant that students carried out independent investigations, and “inform” types of instruction must be used to provide students with knowledge before his 5E instructional model would work. The independent investigations he planned and his interpretation of the 5E instructional model provided limited opportunities for students to develop deep conceptual understanding of science phenomena. Jason seemed to lack a clear idea of how to enact the 5E instructional model in his classroom and held limited views of inquiry. In a study of prospective elementary teachers, Odom and Settlage (1996)

concluded that preservice teachers' lacked an understanding of the purposes and activities used in the phases of the learning cycle even after learning about and experiencing the learning cycle extensively in the methods courses.

Although Mary, Amy, Lilly, and Jason learned about their students and student-centered instructional sequences, they did not gain sophisticated knowledge of learners integrated with instructional sequences. A literature search revealed no studies on how prospective science teachers develop knowledge of learners integrated with knowledge of instructional sequences to teach science. This study sheds light on the nature of the integration of prospective secondary teachers' knowledge of learners and instructional sequences to teach science. One of the most important aspects of teaching is realizing that students come to class with preconceptions that affect their thinking about the content. Students' preconceptions can shape (or misshape) their understanding of phenomena. Additionally, a second essential component of teaching is providing opportunities for students to explore phenomena and form explanations in their own words before the teacher provides an explanation. The 5E instructional model sequences based on these general theories of learning. Thus, effective science teaching involves a simultaneous focus on sequencing science instruction and the learning process of students. To teach science through a 5E instructional model, a teacher must hold strong understandings of how students learn science through interaction with phenomena, ideas, and people. The prospective teachers demonstrated relatively unsophisticated knowledge of learners, which caused difficulties in their development of knowledge of instructional sequences.

The development of knowledge of learners and knowledge of instructional sequences was influenced by teachers' science teaching orientations. For Mary, Amy, and Lilly, considerable consistency existed among each individual's science teaching orientation, her mentor teacher's views on teaching and learning, and teacher-centered instructional practices. The mentors' beliefs and teacher-centered instructional strategies had a powerful influence on the participants' development of knowledge for teaching. In fact, there is evidence that there was tension in the interns' minds concerning the teacher-centered beliefs and practices of the mentor teachers, and the reform-oriented views proposed by the Secondary Science Methods courses. Feiman-Nemser (2001) reported that mentor teachers often protect their interns from ideas proposed in teacher preparation coursework that they perceive to be "impractical."

It seems that Mary, Amy, and Lilly actively looked for experiences in their internship that confirmed rather than disconfirmed their existing views of teaching and learning. These three teachers were reluctant to pursue alternative instructional sequences. Anderson et al. (2000), in a study of elementary teachers, reported a similar finding. They found that some elementary teachers in their study came into the program already moving along a particular trajectory; these individuals valued experiences that aligned with their conceptions of teaching and learning. Although Mary, Amy, and Lilly took on additional goals and/or views of the teacher's role, their incoming science teaching orientations remained stable over time. These findings are congruent with Koballa et al. (2005), who found that ACP teachers were reluctant to change their conceptions about science teaching and learning.

Jason's incoming view of teaching was also difficult to change because it was deeply rooted in his K-16 experiences. Additionally, Jason had limited knowledge and experiences with learning and teaching science according to his ideal view of teaching, which was for students to discover science knowledge on their own. Jason was unable to fully test his new ideas from the Science Methods courses due to the constraints of his mentor teacher who primarily implemented teacher-centered, traditional forms of instruction. He did not learn from his mentor or the Secondary Science Methods courses how to teach so students could meet his vision of discovering science on their own. Ultimately, Jason did not replace his ideas about "discovery learning" with current accepted conceptions of how science knowledge is "constructed" rather than "discovered." Although Jason added new goals for teaching science, he retained his view that teaching science is providing content through teacher-led discussions. His competing views of teaching and learning persisted throughout the ACP. Similar to Koballa et al.'s (2005) findings, it appears that prospective science teachers' incoming beliefs about teaching and learning are highly resistant to change.

Although Jason's science teaching orientation remained stable over time, his case adds to what we know about how novice teachers form "ideal" and "working" views of teaching and learning (Samuelowicz & Bain, 1992), as well as the complexity of science teaching orientations (Friedrichsen & Dana, 2005). Jason formed his ideal views of teaching and learning from his Young Life experiences, and his working views of teaching and learning from his K-16 experiences. During his internship, Jason struggled to align his ideal and working views of teaching and learning. Holding both ideal and working views simultaneously illustrates the complexity of Jason's science teaching

orientation. Similar to Friedrichsen's and Dana's (2005) findings, viewing science teaching orientations as a "single, homogenous entity" (e.g., Magnusson et al., 1999) was insufficient for describing Jason's science teaching orientation. Jason's science teaching orientation was composed of multiple dimensions; using a single label (e.g., didactic, discovery) would mask Jason's competing views of teaching and learning. Jason's science teaching orientation played a pivotal role in his development of PCK for teaching and learning. He drew on multiple experiences in the ACP to better align his competing views of teaching and learning. This interpretation is supported by Anderson et al. (2000) who found that a science methods course acted as a "force" for helping prospective elementary teachers align their views of learners and learning towards more reform-oriented views. This finding sheds light on the importance of investigating multiple dimensions (e.g., views of teaching and learning, views of teacher/student roles, central and peripheral goals) to better understand the influence of teachers' science teaching orientations on their development of knowledge and beliefs about teaching and learning.

In each of the cases, the congruency, or lack thereof, among field experiences, mentor teachers, and methods courses seems to be critical for the development of PCK. All four participants struggled to implement reform-based practices due to the traditional, teacher-centered nature of their internship mentors. Other researchers have also reported that the nature of the internship and beginning teaching context can override prospective and beginning teachers' abilities to implement reform-minded practices (Adams & Krockover, 1997b; Hewson et al., 1999; Marion et al., 1999, Puk & Haines, 1999). For example, in an investigation of 127 student/beginning teachers, Puk and Haines (1999)

found: (a) although student teachers (97%) reported that reform-oriented strategies were valuable for student learning, only 28% of the student teachers used these strategies in their practicum; (b) only 25% observed their associate and mentor teachers using these strategies; and (c) those who observed their mentor teachers using constructivist approaches were more likely to implement them. Hewson and colleagues found that, even though prospective teachers learned about conceptual change approaches in methods courses, they were unable to implement these approaches due to the traditional nature of their field experiences (Hewson et al., 1999; Marion et al., 1999). The culture and context of many field internships often inhibits prospective teachers' abilities to implement and embrace reform-minded practices. This study clarifies the role of science teaching orientations in how prospective science teachers' make sense of their teaching contexts. Science teaching orientations are primarily formed from K-16 experiences. The orientations that the prospective secondary science teachers brought to teacher preparation served as filters for making sense of knowledge and experiences. They also functioned as barriers to change by limiting the ideas prospective teachers were willing to entertain. Thus, science teaching orientations play a pivotal role in teacher preparation.

What can be Learned from this Study?

Teachers' conceptions of science teaching have been theorized to serve as "conceptual maps" for their instructional decisions (Grossman, 1990), and have been proposed to shape teachers' knowledge and beliefs about teaching and learning (Magnusson et al., 1999). The sources and impacts of prospective teachers' beliefs on their thinking about teaching and learning have been established in the literature (Borko & Putnam, 1992; Calderhead, 1986, Kagan, 1992). Previous studies have investigated

prospective teacher knowledge of reform-based approaches, like inquiry (Eick & Dias, 2005; Eick et al., 2003; Windschitl, 2002), and the development of teacher knowledge of the learning cycle (Marek et al., 2003; Odom & Settlage, 1996), and 5E instructional model (Duran et al., 2004). Additionally, researchers have recognized what prospective teachers learn about their students during a teacher preparation program (Davis et al., 2006; Geddis & Roberts, 1998; Geddis et al., 1993; Lemberger et al., 1999; van Driel et al., 2002; van Driel et al., 1998). However, the design and reporting methods used in these studies does not allow science educators to fully understand the complex nature of the development of PCK for learners and instructional sequences. The Magnussen et al. (1999) PCK model theorizes that science teaching orientations shape teachers' knowledge of learners and knowledge of instructional sequences. However, they provide little empirical evidence to support this claim. This study clarifies that science teaching orientations act as a filter for making sense of experiences in an ACP, and in turn the development of knowledge of teaching and learning. By examining the integration of science teaching orientations, knowledge of learners, and instructional sequences, the science education community gains a deeper understanding of how prospective teachers develop PCK.

The significance of science teaching orientations on the development of teacher knowledge is profound. Teacher candidates come to teacher education programs with well established orientations to science teaching that are primarily based on their K-16 experiences. Their incoming science teaching orientations significantly shape how they make sense of what they learn in methods courses and field experiences. While science teaching orientations could be a powerful support for future learning, they can also act as

a barrier to the development of knowledge of teaching and learning. If initial science teaching orientations are not elicited and engaged, then prospective science teachers may fail to develop knowledge of reform-oriented sequences of science instruction. To develop reform-minded knowledge of teaching and learning, prospective teachers must become dissatisfied with their existing science teaching orientations that are teacher-centered while simultaneously finding alternative orientations intelligible, plausible, and fruitful in science teaching. This study contributes to our understanding of how teacher knowledge develops during teacher preparation. Revealing and confronting science teaching orientations during the course of teacher preparation is critical to the development of teacher knowledge.

Implications

For Teacher Education

The findings of this study indicate that teacher educators must identify and attend to ACP teachers' science teaching orientations. As a result of background experiences, ACP teachers came to teacher preparation with strongly held science teaching orientations. These science teaching orientations were important indicators of classroom practice. Thus, teacher educators must identify science teaching orientations at the onset of a teacher preparation program. Teacher educators are responsible for explicitly addressing views of teaching and learning that are beneficial for their students and those views that are not conducive to effective science teaching and learning. Additionally, prospective teachers must examine their views of teaching and learning in light of reform-oriented science teaching.

The findings of this study suggest that change in science teaching orientations is a prerequisite for knowledge development of reform-oriented practices to occur. Russell and Martin (2007) suggest that teacher preparation might be better viewed as a process of conceptual change. This means that science methods courses and field experiences would help prospective teachers become dissatisfied with traditional, teacher-centered instructional practices while providing intelligible, alternative science teaching practices. Creating conditions for cognitive conflict, where the teacher educator challenges prospective science teachers to look for limitations in their views of teaching and learning, and provides thoughtful reflection on practice, could begin to spur reconceptualizations of how to teach according to how students learn science best.

Identifying and confronting inadequacies in prospective ACP teachers' subject matter knowledge is a promising strategy for addressing the shortfalls of prospective teachers' teacher-centered views of instruction. In my experience as a science educator, many prospective ACP teachers have learned science through traditional, teacher-centered instruction. Additionally, they lack deep conceptual understanding of K-12 science content that they will have to teach. Science educators can engage students in constructing explanations for why they hold inadequate understanding of K-12 science content despite holding undergraduate degrees in science related fields. Promoting discontent and dissatisfaction with prior science knowledge, and teacher-centered learning experiences, is a strategy to help prospective teachers generate new ways to think about teaching and learning. An interaction must take place between an individual's experiences learning science, the deficiencies in their understanding of science content, and the introduction of new reform-oriented conceptions of science

teaching and learning. Teacher educators must engage and challenge prospective teachers SMK, while simultaneously confronting teacher-centered science teaching orientations, in order for prospective teachers to develop more reform-minded views of teaching and learning.

Once science teaching orientations are elicited and confronted, teacher educators can help teachers broaden their knowledge of the role of learners' needs and difficulties to influence their design of instruction. The participants consistently sequenced science instruction in teacher-centered ways and relied on the "inform" types of instruction to transmit knowledge to students, in part due to the nature of their internship. Teacher educators can help teachers engage students in scientific questions, have students collect data, and provide opportunities for students to make scientific claims based on evidence before explaining new terms and concepts. As teacher educators, we need to help support prospective teachers in implementing student-centered instructional sequences, like the 5E instructional model.

All of the teachers in this study developed a more refined understanding of learners' needs by identifying student difficulties and working with mentors. Thus, the role of the mentor teacher should be given special attention. All four of the participants relied heavily on their mentor teachers' knowledge when deciding how to teach. Many of the participants viewed the guided internship as separate from what they learned in the ACP science methods courses. At times, the views of the mentor teachers were in direct opposition to the reform-oriented practices proposed in the ACP. Because many ACPs require a significant amount of experience teaching with a mentor and novice teachers lack PCK, prospective teachers are heavily influenced by their mentor teachers. As

teacher educators, greater attempts must be made to ensure that mentor teachers' practices align with the values of the ACP. For example, local teachers who are graduate students may be ideal mentor teachers because they are learning about reform-minded practices in their coursework. Over time, this may be a strategy to create a cohort of reform-minded mentor teachers. This could be a strategy to create a mentor-teacher social network where mentors can draw on each other and university faculty for support. Mentor teachers can share ideas for best practice, and university faculty can provide mentors with content and theory covered in science methods courses.

Additionally, I recommend that professional development programs support mentor teachers in eliciting and reflecting on their science teaching orientation and PCK for learners and instructional sequences. As mentor teachers reflect on their science teaching orientation and PCK for learners and instructional sequences, they can begin to make their thinking about teaching and learning explicit. In the absence of reform-minded views of teaching and learning, I recommend that professional development be targeted at: (1) engaging and confronting teacher-centered science teaching orientations, (2) improving teachers' knowledge of inquiry and student-centered instructional sequences such as the 5E instructional model; and (3) increasing teacher knowledge of how students learn science best.

In addition to mentor teacher professional development, university supervisors must play a role in the development of teacher knowledge. In this study, the university supervisor was an underutilized component of the ACP program. University supervisors must be trained so they can: (1) help develop mentor teachers' skills as teacher educators, (2) promote intern teachers' reflection on their teaching practices and student learning,

(3) inform mentor teachers about content taught in science methods courses, and (4) model how to implement reform-based instructional practices in unique teaching contexts.

For Policy

A major policy issue at national, state, and local levels is how to address the teacher shortage while preparing highly qualified teachers. Some groups seek to significantly reduce college and university-based teacher education requirements to simplify the teacher certification process and alleviate teacher shortages. Reducing college and university-based teacher education requirements has been referred to as the “deregulation” agenda (Cochran-Smith & Fries, 2005). In response to the deregulation agenda, ACPs have been designed to provide a faster route to obtaining science teacher certification than traditional teacher preparation programs for individuals who have an undergraduate science degree. However, not all ACPs are equivalent in terms of duration, coursework, and fieldwork (Cochran-Smith & Zeichner, 2005; Darling-Hammond, Berry, & Thoreson, 2001; Zeichner & Conklin, 2005). Some research on ACPs lump privately sponsored programs like Teach for America (TFA) and the Peace Corps together with university-sponsored ACPs that offer teacher certification and Masters of Education (M.Ed.) degrees (Cochran-Smith & Zeichner, 2005; Darling-Hammond, Chung, & Frelow, 2002; Zeichner & Conklin, 2005). This is alarming for educational researchers because there are substantial differences in the coursework and mentoring that occur among university and other ACPs. There are few published studies that investigate teacher learning in an ACP in a specific subject-area like science.

The Missouri legislature recently passed a bill that allows second career individuals to obtain alternative teacher certification through the American Board for Certification of Teacher Excellence by successfully completing the following requirements: (1) sixty hours of classroom observations, including 45 teaching or 60 hours as a substitute teacher, and/or 30 teaching or 60 hours teaching at a private school; (2) 30 hours of professional development; (3) 2 years of a mentoring program; (4) completion of performance based teaching evaluation; and (5) participation in beginning teacher assistance program (Missouri Senate Bill 1066, 2008).

An undergraduate degree may be an indicator of subject matter knowledge, but it does not guarantee that individuals can transform their knowledge in a way that supports students' learning of the content. In fact, there is limited empirical evidence that there is a relationship between content expertise and teaching quality (Zumwalt & Craig, 2006). Some propose that individuals with substantial on-the-job experiences and content knowledge are better equipped to use their knowledge to teach others. However, Scribner et al. (2007) studied the relationship between prior career experiences and instructional quality and reported "content-related career experience was unrelated to standards based teaching. Thus, the assumption that teachers with deeper content knowledge and experience will be better teachers was found to be untrue in this study" (p. 30). Policies that arise from the deregulation agenda must be based on research.

The findings of this study have broad implications for the mentoring component suggested by recent legislation in Missouri. The use of experienced teachers as mentors is common in many school districts. This assumes that experienced mentors will be able to provide the necessary support to novice teachers to help them become highly qualified

to teach science. However, experience alone does not ensure that an experienced teacher is a good mentor. Many experienced teachers do not have the skills, experiences, or knowledge of reform-oriented practices, like inquiry (Anderson, 2002). This study confirms this finding and highlights the powerful role mentors play in the development of their interns' PCK. In order to make sure teacher candidates are highly qualified, mentor teachers need to model appropriate practices, help plan lessons, provide support when prospective teachers teach lessons, and promote reflection on practice. In order to take on these roles, I believe mentors need sustained, subject-specific professional development, and support from university faculty and from other teachers. In addition, mentors need reduced teaching loads so they can co-plan and coteach with their interns. If mentor teachers become the primary source for teacher preparation, as a strategy to alleviate teacher shortages in science education, then school districts will need to provide substantially more support to mentors and prospective science teachers.

The findings of this study open up the deregulation debate to a new set of policy questions regarding the use of experienced teachers as mentors to prepare teacher candidates: (1) who will be responsible for ensuring that prospective science teachers receive a carefully guided mentoring experiences; (2) how will mentor teachers and prospective science teachers be evaluated to make sure they demonstrate high instructional quality- standards based instruction; (3) how will mentor teachers be prepared to support beginning teachers in the enactment of reform-oriented science teaching; (4) what role will university faculty play in teacher preparation and mentor teacher preparation; and (5) how will teacher certification boards ensure that teachers who become certified are highly qualified in their field?

As we prepare teachers, we must consider the content knowledge and science teaching orientations they bring with them, and the PCK they will need to develop for science teaching. While prospective teachers can learn much from mentors, if they lack reform-oriented views of teaching, then they are unable to adequately prepare novice teachers in the vision of the Standards. The findings of this study are valuable to policy makers facing decisions on whether to significantly reduce the role of university teacher preparation in teacher certification.

Recommendations for Future Research

Looking at teacher development during an ACP allowed me to learn that science teaching orientations are critical to the development of knowledge of learners and instructional sequences. However, several aspects of this study limit its comparability to other studies of the development of prospective secondary teachers' PCK. First, studies are needed that focus on teaching a specific science topic. At the beginning of this study, all of the participants created lessons to teach heritable variation within a species. It would have been valuable to interview and observe interns teach this topic during their guided internship. Accounts such as these would be useful for reflection on prospective teachers' development of this topic over time. I believe more research is needed that investigates the development of PCK for a specific topic. By focusing on a specific topic, I think it would be easier to see more nuanced changes over time

Second, I had limited contact with participants during their guided internship (i.e., two observations in the fall and two in the spring). A more extensive observational study would add to our understanding of the development of PCK.

Third, studies are needed that investigate the development of science teaching orientations, knowledge of learners, and knowledge of instructional sequences, into the beginning years of teaching. Investigating how different experiences during the beginning years of teaching influence teacher knowledge would add insight to our understanding of the experiences that influence the development of PCK for the first 3-5 years of teaching.

Fourth, this study involved a small number of participants in a specific area--secondary biology. We could gain a breadth of knowledge about the development of PCK by investigating: (1) prospective teachers in different types of ACPs; (2) ACP teachers in a variety of disciplines (e.g., chemistry, physics, and earth science); (3) ACP teachers at different levels (e.g., elementary and middle); and (4) for different knowledge domains (e.g., assessment and curriculum). Studies such as these are critical in understanding how different experiences influence the development of PCK in a variety of contexts.

Furthermore, I propose new avenues ideas for future research on the development of teachers' PCK. Investigating science teaching orientations is a complex task. The science education research literature does not provide a consistent description of what types of knowledge encompass and influence science teaching orientations. I found my interpretation of science teaching orientations limited by the Magnusson et al. (1999) definition, as have other researchers (Friedrichsen & Dana, 2005). Understanding teachers' "beliefs about the purposes and goals for teaching science (p. 97)," was not enough to capture the complexity of science teaching orientations. I came to understand the teachers' science teaching orientations by investigating a number of different

dimensions that included: views of teaching and learning, views of the teacher/student roles, and central and peripheral goals. I believe researchers must develop more rigorous standards for investigating science teaching orientations by conducting closer analyses of the dimensions used by other researchers and those used in the present study. Based on my literature review, there are similarities and differences across the dimensions researchers choose to investigate to understand science teaching orientations.

Synthesizing how researchers define and describe different dimensions would be a starting point for determining whether additional dimensions are needed to more completely understand science teaching orientations. A more coherent line must be formed in the research literature to expand our knowledge of the role science teaching orientations have on the development of teacher knowledge. Additionally, although data collection techniques (i.e., interviews and observations) were time intensive, they provided detail of the nature and complexity of science teaching orientations that may not be understood through semi-structured interviews and survey techniques alone (see Koballa et al., 2005). If we are to gain deeper insight into the role of science teaching orientations on the development of PCK, researchers must observe classroom practice and use teachers' knowledge of learners and instructional sequence, as a window into understanding science teaching orientations.

Finally, understanding how teacher knowledge develops is a challenging endeavor. In this study, I found my interpretations and data collection were limited by the PCK model. Although the PCK model helped me design interview protocols, it artificially separates PCK for instructional sequences and learners. I learned from data analysis that as prospective teachers gain more experience, the interaction that develops

between teachers' knowledge of learners and their knowledge of instructional sequences becomes more integrated. I interpret this to mean that the integration of PCK components increases with teaching experience. I believe what is needed is a developmental PCK model that considers the integration of knowledge components over time. A developmental PCK model must be flexible and fluid, not treating knowledge as fragmented components.

Conclusion

To provide quality teacher preparation in ACP settings, science educators must understand how PCK develops. In this study I investigated science teaching orientations and PCK development for learners and sequence of science instruction. The teachers in this study benefited from the Secondary Science Methods courses, gaining knowledge of learners and learning. As they taught alongside a mentor, they continued to develop knowledge of learners and learning. Evidence from this study suggests that participants' teaching orientations and their mentor teachers were the most critical factors influencing their PCK development. Prospective teachers gained knowledge of learners from working with students, their mentor, and the Secondary Science Methods courses, but their instructional sequences remained unchanged. The teachers in this study consistently gave priority to transmitting knowledge during the "inform" types of instruction. Even though they learned that students have prior science knowledge, and about the 5E instructional model, they did not draw on this knowledge to design instruction where students were challenged to evaluate what they know in light of new knowledge. Their views of instruction are at odds with the inquiry-based approaches valued in the ACP Secondary Science Methods courses.

Prospective teachers who enter ACPs face the challenge of rethinking their subject matter knowledge from a pedagogical perspective. For many prospective teachers, their incoming orientations to science teaching are largely based on their thousands of hours observing their science teachers. While incoming science teaching orientations could support future learning, they can also act as barriers to the development of knowledge of teaching and learning. Recognizing the nature of prospective teachers' science teaching orientations, and gaps in understanding about science learners and learning and sequencing of science instruction, is critical for improving teacher education. This requires that mostly teacher-centered science teaching orientations be viewed as the starting point in the search for understanding teaching and learning. Searching for greater understanding of teaching and learning requires that prospective secondary teachers find alternative science teaching orientations meaningful. Identifying, confronting, creating dissatisfaction, and promoting acceptance of learner-centered science teaching orientations are fundamental to achieve the vision of reform in science education. Teacher preparation programs that take the teaching orientations of their participants into account may significantly impact teacher practices or student learning.

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APPENDIX A

UNIVERSITY OF MISSOURI-COLUMBIA
PERMISSION LETTER FOR SCHOOL DISTRICTS
PRINCIPLE INFORMED CONSENT

This letter is to follow up on our recent phone conversation about the SMAR²T program and the “Researching Science and Mathematics Teacher Learning” project. Attached is an information sheet that summarizes the components of the project that we discussed.

Please email Sandra Abell, Principal Investigator (abells@missouri.edu) OR complete, sign, and fax the bottom portion of this letter to Dr. Abell at 573-884-2917 indicating whether the team may collect data in your school.

NOTE: if you have reached some other agreement about how permission will be gained, you will need to modify the preceding paragraph.

Thank you so much for your continuing support of MU students and programs.

_____ Yes, I give my permission for the “Researching Science and Mathematics Teacher Learning” researchers to collect data in this school district as indicated in the information sheet provided.

_____ No, I do not give my permission.

School _____

Signature _____ Date _____

Printed Name _____ Title _____

APPENDIX B

UNIVERSITY OF MISSOURI-COLUMBIA
STUDENT INFORMED CONSENT
Researching Science and Mathematics Teacher Learning
in Alternative Certification Models

The purpose of this research study is to investigate how your learning develops during the first two years following your acceptance into the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T) program. The research study will begin in Summer of 2006 and conclude in the Spring of 2008.

INFORMATION

You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to your grades in the SMAR²T program classes. If you decide to participate, you may withdraw from the study at any time without penalty. Your course grades will not be affected by your decision to participate or to decline participation in the study. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION

If you decide to participate, you will agree to:

1. Participate in a pre interview (Summer 2006) and post interview (Spring 2008) in which you will be asked questions about lesson planning. We anticipate that each interview will last approximately 3 hours.
2. Participate in an interview at the end of the Summer 2006 in which you will be asked questions about the lesson planning that you completed at the beginning of the summer.
3. Allow the research team to observe you teaching one class on two consecutive days. These observations will occur each fall and spring for the next two years (Fall 2006, Spring 2007, Fall 2007, and Spring 2008). The process for the observations will include:
 - (a) The development of a written lesson plan
 - (b) An interview prior to the lesson in which we will ask you some questions about the lesson
 - (c) Observation and videotaping of the lessons
 - (d) A post observation interview following each observation in which you will be asked to watch the video and respond to questions about the lesson
 - (e) A final written reflectionWe estimate that each observation cycle will require approximately 8 hours of your time.
4. Allow the research team to display video clips at professional research conferences and other professional meetings. (Your image may appear in these clips.)

BENEFITS

Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for prospective teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated with up to \$1000 per year (approximately 25 hours at \$40 per hour) for your degree of participation in the research to be distributed at the end of each academic year (May). These activities will require no more than 25 hours of your time each year.

CONFIDENTIALITY

Your identity will be kept strictly confidential. Only members of the project team will know your identity. The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a pseudonym. You may view the videotapes on the University of Missouri campus and request that certain video segments not be used. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT

Please read the consent statement below and place an “x” next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_____ I hereby **agree** to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself. I agree to allow my classroom instruction to be videotaped as part of my participation in this study.

_____ **I do not agree** to participate in this research study.

Signed: _____ Date: _____

Printed Name: _____

APPENDIX C

UNIVERSITY OF MISSOURI-COLUMBIA STUDENT INFORMED CONSENT [Revised]

Researching Science and Mathematics Teacher Learning in Alternative Certification Models

The purpose of this research study is to investigate how your learning develops during the first two years following your acceptance into the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR²T) program. The research study will begin in Summer of 2006 and conclude in the Spring of 2008.

INFORMATION

You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to your grades in the SMAR²T program classes. If you decide to participate, you may withdraw from the study at any time without penalty. Your course grades will not be affected by your decision to participate or to decline participation in the study. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION

As part of your initial consent for the ReSMAR²T study, you agreed to:

5. Participate in a pre interview (Summer 2006) and post interview (Spring 2008) in which you will be asked questions about lesson planning. We anticipate that each interview will last approximately 3 hours.
6. Participate in an interview at the end of the Summer 2006 in which you will be asked questions about the lesson planning that you completed at the beginning of the summer.
7. Allow the research team to observe you teaching one class on two consecutive days. These observations will occur each fall and spring for the next two years (Fall 2006, Spring 2007, Fall 2007, and Spring 2008). The process for the observations will include:
 - (a) The development of a written lesson plan
 - (b) An interview prior to the lesson in which we will ask you some questions about the lesson
 - (c) Observation and videotaping of the lessons
 - (d) A post observation interview following each observation in which you will be asked to watch the video and respond to questions about the lesson
 - (e) A final written reflection

We estimate that each observation cycle will require approximately 8 hours of your time.

8. Allow the research team to display video clips at professional research conferences and other professional meetings. (Your image may appear in these clips.)

In addition, the research team requests that you allow:

9. Allow the research team to examine and analyze SMAR²T program application materials and certification materials (e.g., PRAXIS scores).
10. Allow the research team to use your MU coursework from your mathematics and/or science methods courses from 2006-2007 including online discussion forum posts on the WebCT system as part of the research study. Pseudonyms will be used in reporting the findings.

BENEFITS

Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for prospective teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated with up to \$1000 per year for your degree of participation in the research to be distributed at the end of each academic year (May). These activities will require no more than 25 hours of your time each year.

CONFIDENTIALITY

Your identity will be kept strictly confidential. Only members of the project team will know your identity. The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a pseudonym. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT

Please read the consent statement below and place an “x” next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_____ I hereby **agree** to allow the research team to collect the additional data (MU coursework, application materials, and certification materials). I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself.

_____ I **do not agree** to allow the research team to have access to the additional data listed above.

Signed: _____ Date: _____

Printed Name: _____

Thank you. If you have questions at any time, please call Sandra Abell, Lead Project Investigator, at the University of Missouri at (573) 884-9033.

APPENDIX D

UNIVERSITY OF MISSOURI-COLUMBIA MENTOR INFORMED CONSENT Researching Science and Mathematics Teacher Learning in Alternative Certification Models

The purpose of this research study is to investigate your perspective on the learning of your intern in the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR²T) program. This research study began in the Summer of 2006 and will conclude in Spring of 2007.

INFORMATION

You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to you. If you decide to participate, you may withdraw from the study at any time without penalty. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION

If you decide to participate, you will agree to:

1. Participate in an interview (approximately 1.5 hours) once in the fall and spring regarding your perceptions of your SMAR²T intern's learning.
2. Have informal conversations with the research team about your SMAR²T intern's learning during scheduled school visits to observe the intern's teaching.

BENEFITS

Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for prospective teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated with up to \$500 per year (approximately 10 hours at \$50 per hour) for your degree of participation in the research to be distributed at the end of each academic year (May).

CONFIDENTIALITY

Your identity will be kept strictly confidential. Only members of the project team will know your identity. The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a

pseudonym. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT

Please read the consent statement below and place an “x” next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_____ I hereby **agree** to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself.

_____ I **do not agree** to participate in this research study.

Signed: _____ Date: _____

Printed Name: _____

APPENDIX E

STUDENT RELEASE FORM: Researching Science and Mathematics Teacher Learning in Alternative Certification Models

We are investigating how teacher learning develops for individuals in the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T) program. The research team is interested how various factors influence teacher learning. Your child's image may be captured on videotape as a result of his/her presence in a classroom in the study. We seek your permission to analyze the content of the videotapes in which your child's image is captured.

Information: Your participation/release is voluntary; you may choose that your child not participate and there will be no penalty or consequence. You may view the videotapes on the University of Missouri campus and request that certain video segments not be used.

If you sign yes on this form, you give permission for the research team to:

1. Capture your child's image on videotape, and analyze the content of the videotapes for research purposes.
2. Display clips at professional research conferences and other professional meetings. (Your child's image may appear in these clips.)

Privacy: No names or identifying information will be used in reporting the research findings on written documents. However, your child's image may appear in a video clip displayed at professional research conferences and other professional meetings.

Risks: This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

Consent: I have received and read a copy of this form. I understand the above information.

- Yes, I agree to participate. I understand that I can change my mind and withdraw from the project at any time. I understand that I may request that certain information not be used.
- No, I will not participate. If your child's image is captured on video while in the classroom, it will not be displayed or analyzed for research purposes.

Student Signature _____ Date _____

Child's Name _____
Please Print.

Parent Signature _____ Date _____

APPENDIX F

Biology Lesson Planning Task

Background information: We know that students enter the SMAR²T program with ideas about how to teach science. To help us better understand your ideas about teaching, we are asking you to design some science instruction. Don't worry. There are many different ways to complete the following task. We're interested in finding out your ideas about teaching and learning.

Context: You are currently teaching an 8th grade science class with 24 students in a rural school. You sit down to write a 2-day plan focused on introducing the following topic:

Life Science: There is heritable variation within every species of organism.

You plan to teach this sequence on Tuesday and Wednesday. Your school has 50 minute class periods.

Task: Prepare a **detailed** plan for two 50-minute class periods. Assume you can look through and use the available resources in this classroom, but you may not use any textbooks or internet resources.

As you develop your plan for these two class periods, provide as much detail as possible, and be sure to answer the following:

1. What do you want the students to learn?
2. Describe what will happen during the beginning, middle, and end of each class. What will you do? What will the students do?
3. Describe what will be needed for these two class periods.
4. Prepare any handouts or overhead transparencies that you plan to use.

APPENDIX G

Lesson Planning Task Interview Protocol

Say to participant: Thank you again for participating today. During this interview, I will be asking you questions about your plan and what you thought about when you wrote this plan. We are really interested in how you are thinking at this point; there are no right or wrong answers to the questions here.

Start the audio-recorder.

Say to the participant: This is _____ (interviewer's name), interviewing _____ on _____ (date). We are audio-recording this interview. Is that ok with you? (Wait for positive response)

Talking Through the Plan

Say to the participant: The first part of the interview is about the plan you just wrote. We want to make sure that we understand your plan and what you intended for these two days.

Begin with this question:

1. What did you think about as you were designing this lesson?

Then ask the participant to walk you through their plan by asking:

2. Walk me through your plan. How did you start the first day? *Continue to ask clarifying questions; your task is to be able to really understand what the participant intended for each part of the plan. Possible clarifying prompts:*
 - a. What did you mean when you wrote _____?
 - b. Could you clarify what the students are doing during this part?
 - c. Could you clarify what you are doing during this part?
 - d. Could you tell me why you decided to do that?

Probing Participant's Knowledge

Subject Matter Knowledge (SMK/CKT)

Say to the participant: One part of what a teacher needs to know is something that we call content knowledge. In your case, we mean your own understandings of the science that you will be teaching. These next questions are designed to probe what you know about heritable variation within species. Again, there is no right or wrong answers. We are interested in what you know and how you think about heritable variation within species at this point.

3. What are your previous experiences with the topic of heritable variation within species?
 - a. How well do you think you know (this topic)?
 - b. Where did you learn about heritable variation within species?

- c. Have you taught (this topic) previously?
4. What do you think is important for students to know about heritable variation within species?
 - a. Why do you think that is important?
 - b. Tell me about where you learned these things.
 - c. What else do you know about heritable variation within species that students might not need to know?
5. Talk to me about how your plan addresses these things (*Probe for specifics based on the plan*).
6. In what ways does the topic of heritable variation within species fit into the “big science picture” of what students learn about science in middle school and high school?

Knowledge of Students

Say to the participant: Another part of what a teacher knows has to do with how students think about science. The next questions are designed to probe what you know about how students might think about heritable variation within species.

7. What do you think students will already know about this topic?
 - a. Why do you think that they may know that?
 - b. Where do you think they may have learned this?
8. Do you expect students to have difficulty with anything that you have planned?
9. Why do you think they will have difficulty with that?

Knowledge of Instructional Strategies

Say to the participant: We want to know more about how you organized the instruction during these two days. The next questions will help us better understand your decisions about what and how to teach heritable variation within species.

10. From your plan, it appears that you chose to organize the class as _____ (i.e., lecture, experiment, investigation). Talk to me about making that decision.
 - a. Where did you learn about how to teach this way?
 - b. Did you consider organizing the classes in a different way? Why/why not?
 - c. IF NO TO THE LAST QUESTION: Teachers often develop a range of ways to think about organizing their class; why do you think that you just have one way to think about it?
11. I noticed that you used a picture (graph, equation, analogy...) in your plan. Tell me why you used that _____ at that point in your plan.

- a. How do you think this (picture, graph, equation, analogy) helps students learn about heritable variation within species?
- b. Did you consider representing that idea another way?

Knowledge of Curriculum

Say to the participant: These next questions are designed for us to know something about where your ideas for these two days came from.

12. Where did you get your ideas for these two days of class?
 - a. If you had access to other resources, what would you like them to be?
13. Tell me about the materials (handouts, transparencies) you prepared.
 - a. Where did you get the ideas for these materials?
 - b. How do you think these materials will help or hinder achieving the purpose your plan?

Knowledge of Assessment

Say to the participant: The last area I want to ask you about is how you will know what students learn from these two days of class.

14. During the 2 days of instruction, describe how you will know if students are “getting it.”
 - a. In my experience as a teacher, there are inevitably some students who are still confused at the end of each class. How will you know if your students are confused at the end of each day in your class?
 - b. Are there other ways that you might know what your students learn in class on these two days?

Is there anything else about your plans that you want us to know?
Thank you again for participating in this interview.

APPENDIX H

End of Summer Interview

Purpose:

To review the lesson plan from the beginning of the summer, ask about changes participants would make in their lesson plans, and probe for why they would make the changes. NOTE: this interview is “lightly” structured by this protocol. The interviewer needs to be responsive to participants’ lead on changes they would make in their plans from earlier in the summer.

Instructions:

1. Review the plan and the interview for each preservice teacher you plan to contact for the end of summer interview.
2. Contact your preservice teachers and make an appointment for an interview.
3. Send the plan and ask him/her to review it before the interview.
4. If you are doing this as a phone interview, then test the recording device before you make the call.

Begin the interview by saying: “I’m curious about what you think of the plan you wrote at the beginning of the summer, now that you have ‘survived’ the first 8 weeks of classes. When I contacted you, I asked you to review your plan and now I would like you to talk to me about what you like about your plan and what you would like to change.” Follow the lead of the interviewee through one change at a time by asking questions such as:

1. Why are you considering this change?
2. What influenced you to consider this change? (we want to know where they learned what they said in previous question.
3. Was there something from this summer that promoted you to make this change?
4. In what ways are you thinking differently about this now than you were at the beginning of the summer?
5. Do you know of resources you could use to help you?
6. What did you learn about secondary students this summer that might affect your plan?

Keep in mind the categories of knowledge we are investigating: knowledge of students; knowledge of instructional strategies; knowledge of curriculum; subject matter knowledge; and knowledge of assessment

Look for changes in the following categories:

7. Purpose of the lesson,
8. Instructional style (e.g. teacher-directed to exploratory),
9. Instructional strategies (examples/activities/tasks),
10. Assessment of student learning,

If your preservice teacher does not suggest changes to the lesson plan, then ask more leading questions:

11. Would you make changes to the purpose of the lesson? Why/why not?
12. Would you make changes to the instructional style of the lesson (e.g. more exploratory, more teacher-directed)? Why/why not?
13. Would you make changes to the instructional strategies, such as examples used, activities, or tasks in the lesson? Why/why not?
14. Would you make changes to the ways that you assess for student learning? Why/why not?

APPENDIX I

Pre-observation Interview Protocol

Prior to first observation:

Researcher role: Our role is to assume a stance of empathic neutrality. That is, we empathize with the participant and care about him/her. However, our role is to UNDERSTAND, not to Evaluate or Teach. Please keep these ideas in mind during your visit.

Pre-Observation Interview (purpose: to clarify the plans and uncover the intern's CKT and PCK)

Opening Questions

1. Update us about what is going to occur over the next 2 days we are observing.
 - a. What will we see in Day 1? In Day 2?
 - b. What will you be doing?
 - c. What will the students be doing?
 - d. What are your purposes and goals for these 2 days?
 - e. How did you decide on these purposes and goals?
 - f. Why are these purposes and goals important to you?

Subject Matter Knowledge (SMK/CKT)

Say to the participant: One area that we are interested in is what we call content knowledge. In your case, we mean your own understandings of the science/math that you will be teaching.

2. What are your previous experiences with (this topic)?
 - a. How well do you think you know (this topic)?
 - b. Where did you learn about (this topic)?
 - c. Have you taught (this topic) previously?
3. What do you think is important for students to know about (this topic)?
 - a. Why do you think that is important?
 - b. Tell me about where and how you learned these things.
 - c. What else do you know about (this topic) that students might not need to know?
4. How do the science/mathematical ideas in (this topic) relate to other science/mathematical ideas?

Knowledge of Students

Say to the participant: Another part of what a teacher knows has to do with how students think about mathematics/science. The next questions are designed to probe what you know about how students might think about (this topic).

5. Tell me about the students in this class, in terms of science/mathematics.
 - a. Tell me more about your students' attitudes about science/mathematics.
 - b. Tell me about your students' science/mathematical abilities.
 - c. How do you think this particular group of students learn math/science best? Why do you think that?
 - d. How have your experiences with these students influenced the way you teach?
6. What do you think students will already know about this topic?
 - a. Why do you think that they may know that?
 - b. Where do you think they may have learned this?
7. Do you expect students to have difficulty with anything that you have planned?
 - a. Why do you think they will have difficulty with that?

Knowledge of Instructional Strategies

Say to the participant: We want to know more about how you organized the instruction during these two days. The next questions will help us better understand your decisions about what and how to teach (this topic).

8. Talk to me about how your plan addresses the important mathematical/science ideas you talked about earlier (*Probe for specifics based on the plan*).
9. From your plan, it appears that you chose to organize the class as _____ (i.e., lecture, experiment, investigation). Talk to me about making that decision.
 - a. Where did you learn about how to teach this way?
 - b. Did you consider organizing the classes in a different way? Why/why not?
 - c. What other factors influenced your planning decisions?
10. I noticed that you used a picture (graph, equation, analogy...) in your plan. Tell me why you used that _____ at that point in your plan.
 - a. How do you think this (picture, graph, equation, analogy) helps students learn about (this topic)?
 - b. Did you consider representing that idea another way?

Knowledge of Curriculum

Say to the participant: These next questions are designed for us to know something about where your ideas for these two days came from.

11. Where did you get your ideas for teaching (this topic)?
 - a. Tell me about the materials (handout, transparencies) you prepared. Where did you get the ideas for these materials?
 - b. How did you modify these materials for your instruction?
 - c. Why did you make those modifications? What was difficult about your planning?
 - d. How do you think these materials will help or hinder achieving the purpose of your plans?

12. I have some questions for you related to how these plans relate to other topics that you might teach.
 - a. How do you see these 2 days of instruction as related?
 - b. How do these 2 days of instruction fit into the unit you currently are teaching?
 - c. How does that math/science fit into the bigger picture of what students learn in this class?
 - d. How does (this topic) fit into the “big picture” of what students learn about math/science in middle school/high school?

Knowledge of Assessment

Say to the participant: The last area I want to ask you about is how you will know what students learn from these two days of class.

13. During the 2 days of instruction, what are you going to focus on when assessing students?

14. How do you plan to assess these (things)?
 - a. Describe how you will know if students learned what you intended? Why do you think that it important to assess?
 - b. Are there other ways that you might know what your students learn in class on these two days?
 - c. Where did you learn about those strategies for finding out about what students learned?

Is there anything else about your plans that you want us to know?

Thank you again for participating in this interview.

APPENDIX J

Stimulated Recall Interview Protocol

During the Observation

The observer(s) will have selected 3-5 interesting instances to discuss. What constitutes an interesting instance?

Knowledge of Students

Student making a profound comment and the teacher does or doesn't recognize it or misinterprets what the student says or does.

Student makes a comment that demonstrates confusion, and the teacher does or doesn't recognize or misinterprets why the student is confused?

Teacher explicitly recognizes potential student difficulties.

Knowledge of Instruction

The teacher makes an instructional decision that alters the flow of the classroom by asking a question or directing students to perform a particular task.

The teacher uses an example or analogy or representation to clarify an idea.

Knowledge of Curriculum

A particular task is chosen that may or may not elicit the student thinking that was intended.

The teacher modifies the plan "on the fly" based on what occurs in the classroom.

Teacher refers to math/science content in other parts of the course/curriculum (vertical or horizontal curriculum alignment).

Knowledge of Assessment

Teacher implements assessment to ascertain student prior knowledge.

The teacher recognizes that the students are having difficulty with a particular idea.

The teacher uses a low-level assessment strategy such as providing an "exit slip" that requires students to define rather than explain or synthesize.

SMK

Teacher demonstrates particularly strong SMK.

Teacher demonstrates inaccurate SMK.

After each observation:

Stimulated recall interview (*purpose: to have the intern immediately reflect on the instruction as a window into CKT and PCK and connect to pre-interview*).

Stimulated Recall Interview

1. How do you think the lesson went? In what ways was the lesson I observed different than other periods you taught it? Different from your plans?
2. We have selected some parts of the instruction we found particularly interesting. We want to watch them together and ask you some questions about them.

Let's watch this part (interviewer asks questions starting in one of the following categories based on the reason for selecting the specific interesting instance).

- a. What were you thinking when this was occurring? Tell me more about what was happening when you _____.
 - b. **[K of Students]** What do you think the student was thinking? Why do you think the student was having difficulty at that point? What knowledge about students did you use to make instructional decisions? In what ways, did students influence your teaching decisions today?
 - c. **[K of Instruction]** Tell me about that (example/analogy/activity/lab)? Why did you decide to use that? How did this teaching strategy help you achieve your overall goals? Where did that idea come from? How did the students respond? How did that influence what you did next?
 - d. **[K of Curriculum]** Did the activities achieve the purpose you intended? Why do you think that? How did your curriculum materials support or hinder you in implementing your plan?
 - e. **[K of Assessment]** What do you think students got out of the lesson? How do you know? Tell me about how you found out about student learning. Why did you decide to do that? Where did that idea come from? How do you think it worked?
3. Was there a time during the instruction when you changed your plan? Tell me about that.
 4. Based on what happened today, what do you plan to do tomorrow? Will you change anything from your original plans?
 5. **[Orientations]**. In general, how would you describe your teaching style? To what degree, did your instruction reflect your preferred teaching style? Explain.
 - a. What do you think is the teacher's role in a typical lesson?
 - b. What do you think is the students' role?
 - c. Now think of yourself as a math/science learner, how do you best learn math/science concepts?
 - d. How does your teaching style compare to your mentor's teaching style? Explain.
 - e. Compare your teaching style to what you're learning in your SMART courses?
 - f. In what ways have your ideas about teaching changed since you entered the SMART program? Probe for sources of these changes.

APPENDIX K

INTERVIEW WITH MENTOR TEACHERS

Say to participant: Thank you again for participating today. We are interested in the knowledge development of beginning teachers as they move through the SMAR²T program. In particular, we are interested in what SMAR²T students learn through their experiences in their (internship or teaching experience). In addition, we would like to better understand how their interactions with you impact the learning of [insert name]. During this interview, I will ask you questions about your goals for your SMAR²T intern [insert name].

Start the audio-recorder.

Say to the participant: This is _____ (Graduate Student), interviewing _____ on _____ (date). Do I have your permission to audio record this interview? (Wait for positive response)

Probing Instructions Views of Intern Learning

1. What are some things you think [insert name] has learned during his/her time in your classroom? (about the students, science/math teaching, other). Probe for specific examples.
2. What do you think [insert name] has learned about the students during his/her internship? (intentions)
 - a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
 - b. How has [insert name]'s knowledge of students changed since he/she began the internship? (outcome)
 - c. What else about learners have you shared with [insert name]? (Probe participants for all the goals they had for knowledge of learners using the sequence of probes above.)
 - d. If you were to explain to [insert name] how your students best learn math/science, what would you say? Would your answer change for the different types of courses you teach? Probe: Why?
5. What do you think [insert name] has learned about teaching methods from your mentoring during his/her internship? (intentions)
 - a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
 - b. How has [insert name]'s knowledge of teaching methods changed since he/she began the internship? (outcome)

- c. What other teaching methods do you want [insert name] to learn? (Probe participants for all the goals they had for instructional strategies using the sequence of probes above.)
 - d. Why do you think these methods are important? (orientations)
6. What do you think [insert name] has learned about curriculum (for example, standards, scope and sequence curriculum materials) from your mentoring during his/her internship? (intentions)
- a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
 - b. How has [insert name]'s knowledge of curriculum changed since he/she began the internship? (outcome)
 - c. What else about curriculum have you shared with [insert name]? (Probe participants for all the goals they had for curriculum using the sequence of probes above.)
 - d. How do you think curriculum materials help or hinder achieving your instructional purposes and goals? (orientations)
 - e. If you were to give advice to [insert name] about how to decide which subject matter to teach, what would you say? (orientations)
7. What do you think [insert name] has learned about assessment from your mentoring during his/her internship? (intentions)
- a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
 - b. How has [insert name]'s knowledge of assessment changed since he/she began the internship? (outcome)
 - c. What else about assessment have you shared with [insert name]? (Probe participants for all the goals they had for assessment using the sequence of probes above.)
 - d. If you were to explain to [insert name] the reasons why assessment is important, what would you say? (orientations)
 - e. Tell me about the assessments that are used in the classes that (insert name) is in. (orientations)

8. What do you think [insert name] has learned about math/science subject matter from your mentoring during his/her internship? (intentions)
 - a. Tell me about an example where you saw gains in [insert name]'s math/science knowledge. (actions)
 - b. How has [insert name]'s math/science subject matter knowledge changed since he/she began the internship? (outcome)
 - c. What else about math/science subject matter have you shared with [insert name]? (Probe participants for all the goals they had for knowledge of subject matter using the sequence of probes above.)

VITA

Patrick Brown was born in St. Louis, Missouri where he completed his primary and secondary education. He received a Bachelor's degree in biology from Truman State University in Kirksville, MO. Patrick continued his studies in education and received a Masters of Education from the University of Missouri (MU), in Columbia, MO. Shortly thereafter, Patrick accepted a full time teaching position at Mexico High School in Mexico, MO. He worked for two years as a 9th grade physical science and 10th grade biology teacher.

Patrick completed his doctoral program at the MU Science Education Center. During his four years at MU, he worked on several research grants in science education. He also taught numerous science methods courses. Dr. Sandra K. Abell and Patricia M. Friedrichsen were his program advisors and dissertation co-chairs. Patrick and his co-chairs developed a strong collegial relationship over the years through various research projects and teaching positions.

For 2008-2009 Patrick will work as a Post Doctoral Fellow at Washington University in St. Louis, MO. He will be researching peer-led team learning in General Chemistry.