Investigating Teacher Knowledge of Learners and Learning and Sequence of Science Instruction in an Alternative Certification Program

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Abstract

Alternative certification programs (ACPs) have been designed to address the teacher shortage and 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. We constructed profiles of four individuals and generated a set of assertions from a cross-case analysis. Participants demonstrated the consistent belief that science learning should be student-centered and developed knowledge about students’ prior science knowledge, while at the same time maintaining a focus on teacher-centered instructional sequences. Participants’ knowledge was influenced by their participation in the ACP, including coursework and field experiences. Understanding future teachers’ knowledge about science learners and their sequencing of science instruction is critical for improving science teacher education.
Investigating Teacher Knowledge of Learners and Learning and Sequence of Science Instruction in an Alternative Certification Program

Rationale and Purpose

Recently, teacher preparation has become a target of reform efforts intended to promote science literacy and to ensure that all students leave the K-12 classroom with a broad understanding 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). However, preparing teachers to teach in the vision of the reform movement 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 indicated that the greatest teacher shortages are in urban and rural areas (Ingersoll, 1999) and in subject areas like math and science (Abell Foundation, 2001). 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. ACPs provide a faster route to obtaining science teacher certification than traditional teacher preparation programs for individuals who hold an undergraduate science degree. One question that remains is whether or not teachers who go through these faster routes become highly qualified teachers. The purpose of this study was to investigate how teacher knowledge develops in an ACP.

Theoretical Framework

In 1986, Lee Shulman first proposed a model of teacher knowledge emphasizing that teaching is a complex process that requires teachers to apply knowledge from multiple domains. Shulman posited that, to teach effectively, teachers must develop a blend of subject matter and pedagogical knowledge, into knowledge specific to teaching called Pedagogical Content Knowledge (PCK. Grossman (1990) built on these ideas to highlight the relationship among three knowledge domains that influence a teacher’s PCK. These knowledge domains include: (1) subject matter knowledge and beliefs, (2) pedagogical knowledge and beliefs, and (3) knowledge and beliefs about context. According to Grossman, PCK is a type of knowledge that is transformed from these three knowledge domains and is more powerful than its constituent parts. Magnusson, Krajcik and Borko’s PCK model (1999) elaborates on Shulman’s and Grossman’s work and conceptualizes PCK as consisting of five components: (1) orientations toward science teaching, (2) knowledge and beliefs about curriculum, (3) knowledge and beliefs about assessment, (4) knowledge and beliefs of students’ understanding of science, and (5) knowledge and beliefs about instructional strategies. (See Figure 1.)

Research Questions

The research questions that guided this study were grounded in two components of the Magnusson et al (1990) PCK model (a) What knowledge of learners and learning and knowledge of instructional sequencing do teachers have at various points during an ACP? and (b) In what
ways do ACP teachers’ knowledge of learners and learning and their sequencing of science instruction interact?

We used the following descriptions of teacher knowledge components to ascertain PCK for learners and instructional sequences:

Knowledge of Learners. The knowledge of learners component refers to the knowledge teachers must have to help students learn science. The component includes: requirements for learning specific science content, and areas that students find difficult. Additionally, this component takes into consideration teachers’ appreciation for the variations of learners, approaches to science learning, and prior science conceptions that influence science learning.

Sequence of Instruction. This component refers to subject-specific sequences of instruction such as the “learning cycle” and “conceptual change” approach. This study used the learning cycle approach as the theoretical lens for investigating teachers’ knowledge of instructional sequences. The learning cycle approach identifies sequences and necessary phases of instruction to help students learn science. For example, knowing students’ prior conceptions about heredity makes it possible to sequence instruction to begin with engaging scientific questions and explorations where students collect data before formulating explanations.

Literature Review

ACP s have been a controversial topic in the educational policy arena due to the wide variety that exists among the structure of ACP s, the individuals who participate in the programs, and the program outcomes in terms of teacher quality and retention (Cochran-Smith & Zeichner, 2005; Darling-Hammond, Berry, & Thoreson, 2001; Ziechner & Conklin, 2005). Yet, there are few published studies that investigate teacher learning in a subject-specific ACP. Given our research questions and context, the review of the literature focuses on teachers' PCK for instruction and learning in science.

Several researchers reported that many preservice teachers enter teacher education programs with simplistic views of teaching and learning (Geddis & Roberts, 1998; Geddis, 1993; Mellando, 1998; Russell & Martin, 2007). Russell and Martin’s (2007) review of how teachers learn to teach science indicated that teachers without in-depth experiences with students held views that included: (a) teaching is telling, (b) learning is passive, and (c) educational theory is largely irrelevant. Lemberger, Hewson, and Park (1999) reported that preservice teachers held transmissionist views of science teaching and used metaphors like “throwing out” or “taking in” information. They talked about the view that teachers have the responsibility in transferring knowledge to students who received the facts of science (p. 369). Halim and Meerah (2002) found that preservice secondary physics teachers tend to favor “restating their own understanding as their teaching approach” (p. 223).

Overcoming a transmissionist view of instruction is difficult for preservice teachers. In a case study of elementary and secondary student teachers, Mellado (1990) found that teachers implemented an instructional sequence that focused on transmitting knowledge to students. Even though the four teachers in Mellado’s (1990) study held constructivist conceptions of science teaching, they focused on transmissive instructional sequences where teachers provide explanations to students. Davis, Petish, and Smithy (2006) reviewed the challenges new teachers
face and suggested that in general, secondary preservice teachers focus on content, viewing science instruction as the transference of knowledge from the teacher to the student.

Duran, McArthur, and Van Hook (2004) investigated 25 preservice students’ perceptions of a newly designed, reform-oriented physics course. They found that the students struggled with the constructivist nature of the course because it sequenced instruction differently than their prior science learning experiences. Students thought the workload was much greater than in traditional courses and wanted the instructor to give them answers rather than learn through the 5E sequence and inquiry. Additionally, the participants believed that they would not be able to design 5E lessons 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 lessons. These findings suggest that the change from lecture to learning cycle type of instruction takes time and a commitment on behalf of both preservice students and science educators. More research is needed to better understand how teachers’ knowledge and beliefs about sequencing instruction develops.

Some studies found 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, de Jong, and Verloop (2002) researched how PCK about learners develops in preservice teachers who are learning to teach the chemistry topic of “corpuscular characteristics” on the micro and macro levels. The researchers found that, through the act of teaching, 10 of the 12 preservice teachers became aware that high school students had difficulty with this concept. 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.

Even though some studies show that preservice teachers acknowledge that learners have ideas about the content, the research demonstrates that preservice teachers do not consider students’ ideas extensively in their teaching practices. 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. In the Lemberger et al (1999) case study, one of the teachers, Cora, was surprised that students wanted to know the theoretical basis for molecular bonding and were not satisfied just memorizing whether a double bond versus a single bond was needed.

Although PCK has been accepted as a theoretical construct for investigating teacher knowledge, there are few examples in the science literature to illuminate how PCK for learners and instructional sequence develops in preservice secondary teachers. Much of this research has been concerned with understanding specific components of PCK, for a single topic, and at a precise point in time like a methods course or field internship. Few studies look at the interaction among PCK components over time. Veal and MaKinster (2001) suggested that the development of PCK is multifaceted and does not develop in a linear fashion. Longitudinal qualitative studies that combine interviews and observations may shed light into the development of PCK.
Research Design and Data Analysis

A total of 4 teachers participated in this case study--three females and one male. All were future secondary biology teachers enrolled in an ACP at our research extensive institution. The ACP is a 15-month teacher preparation program where teachers take science specific pedagogical coursework while completing a 20-hour a week field internship under the guidance of a mentor teacher. This study took place during the first two semesters of the ACP. To document incoming PCK, we administered a lesson-planning task based on Valk and Broekman (1999). Participants designed two 50-minute lessons for 8th graders that addressed the following topic, “There is heritable variation within every species of organism. Following the lesson planning task, we conducted one semi-structured interview (Patton, 2002; Seidman, 1998) with each ACP teacher targeted at understanding PCK for learners and instruction. At the end of the first summer of the ACP, we conducted a second semi-structured interview to allow the teachers to review, reflect on, and change their initial lesson plan. The observation cycle consisted of the following: a pre-observation interview, 2 consecutive field observations, and 2 stimulated-recall interviews. We also conducted a semi-structure interview with the mentor teacher targeted at understanding their PCK and the support they provided to their intern. All data collection instruments are available at the project’s website.

In case studies, researchers often use a purposeful sampling approach to identify cases that they view to be “information-rich” (Patton, 2002). We purposefully selected individuals with undergraduate degrees in biology who wanted to become secondary science teachers. The focus of case study research is to describe the unique cases and interpret emergent themes that differentiate or unite settings and/or participants. In case studies, the researcher uses multiple data sources to construct a holistic and meaningful representation of personal experiences (Denzin & Lincoln, 2005). The primary data sources for this case study were interviews. The secondary data sources were written documents and artifacts.

Data Analysis

Upon analysis of the primary and secondary data sources, the themes that emerged from these data sources serve as the primary results of the study (Denzin and Lincoln, 2000). The process of constructing cases occurred in two steps. First, we combined the raw data from the multiple data sources into a case narrative in the form of a profile to tell the story of each participant (within-case analysis). Second, we compared themes across the cases (cross-case analysis).

Using the Magnusson et al. (1999) PCK model, we created coding categories for the interview data and lesson plans. The coding scheme consisted of 2 major categories: (a) knowledge of learners; and (b) knowledge of instructional sequences. Triangulation was achieved through multiple data sources, lesson plans, interview transcripts, and field observations (Yin, 1989), as well as through multiple researchers (Denzin & Lincoln, 2005). Each member of the team read and coded a portion of the interviews. The first author read and coded all of the interviews. After the initial coding, we wrote a summary profile for each participant. The summary profile facilitated data reduction and provided a synthesis of each participant's data (Denzin & Lincoln, 2005).

In the second phase of the data analysis, we analyzed the four participants' data for patterns and themes across the data set. The first author generated tentative assertions for each of
the two major categories of teacher knowledge under study. These tentative assertions were tested during group research meetings, with all members of the research team checking the data to look for confirming and conflicting evidence. Data sets for each of the four participants were checked in this manner. We revised the assertions until agreement was reached among the three researchers.

Interpretations

We present our interpretations in two main sections—within-case profiles and cross-case assertions. The profiles include teacher background information, knowledge of learners and learning, knowledge of instructional sequences, and the factors contributing to knowledge development. To capture the similarities between the participants, we present 4 assertions based on a cross-case analysis.

Profiles

1. Mary’s Case

   Background. Mary, age 23, did not set out to become a high school science teacher. Rather, she viewed teaching as a fulfilling and worthwhile career based on her experiences as a tutor and as a nanny. She talked about her experiences tutoring and wrote in her application materials, “Helping others, by explaining ideas and sharing knowledge, gives me great satisfaction.” Mary entered the ACP just after graduating with an undergraduate degree in biology.

   Beginning of the ACP

   Knowledge of Learners and Learning. Even though Mary had not taught heredity before, she believed that students will be familiar with the term “DNA,” and “they’ve probably heard about dominant and recessive from previous classes” (Pre-observation Interview). However, she also said, “I do not feel it’s appropriate for a teacher ever to just assume you [referring to students] have prior exposure” (Pre-observation Interview). Mary primarily believed learning is dependent upon related new content to students’ personal experiences and 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).

   Knowledge of Instructional Sequences. On both days, Mary planned to use an instructional sequence that centered on providing new content knowledge to students during what we have termed the “inform” type of instruction. Mary believed that science learning primarily occurred during lectures and discussion during the “inform” type of instruction. Students were held responsible for knowing science facts and committing them to memory through what we have labeled the “practice” type of instruction. Mary also planned what we have characterized as the “focus” type of instruction to center students’ attention on the lesson. Upon entry into the ACP, Mary’s student-centered views of learning did not align with her teacher-centered sequence of instruction. Table 1 summarizes Mary’s lesson plans.
Investigating ACP Teachers PCK

### Table 1. Mary’s Lesson, Day 1 and 2, Beginning of Summer

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

**Contributing Factors.** Mary attributed much of her knowledge about teaching heritable variation to her past experiences as a K-16 student. According to Mary, “The activity that I planned for my students … was one that I did as a freshman.” Additionally, Mary used what she knew about how her own teachers sequenced instruction. She explained, “Open by reviewing the homework … where teachers … go over the easy stuff then they assign homework” (Pre-observation Interview). Mary used her experiences as a student to design the lecture. She 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).

**End of the Summer**

**Development of Knowledge of Learners and Learning.** Mary continued to think that teachers cannot assume that students have prior science knowledge. While she believed learning is dependent on lectures that build on students’ prior experiences, Mary’s knowledge expanded as a result of the Secondary Science Methods course. Mary believed that students learn science by discovering ideas on their own. She explained, “It’s not really an experiment per se, but 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 group work helps students learn new material because it maintains their interest: “Whenever you have them in groups … it helps facilitate this kind of environment, where 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).

**Development of Knowledge of Instructional Sequences.** Mary planned on using the same instructional sequence to teach the lessons that she designed on the first day of her ACP. She would keep the lecture on the first day; however, she would decrease the time she lectures, from 25 minutes to 15 minutes, so students could stay focused. The sequence Mary planned focused on transmitting information to students through teacher-centered strategies during the “inform” type of instruction. This sequence contrasted with her student-centered views of learning.
Contributing Factors. After 11 weeks in the ACP, Mary’s experiences influenced her ideas about learners and learning. Mary found value in working with other students as 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.” Mary learned about inquiry in the Secondary Science Methods course and believed inquiry helps students discover science on their own. Mary would like to change her lesson but believed the course work was very different from 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). Although the summer coursework expanded Mary’s knowledge of learners, overall, it did not change her teacher-centered instructional sequences.

Fall Semester

Internship Context. Mary was interning in a Human Anatomy class. She felt her placement was problematic because she did not consider herself knowledgeable in the subject area. Her mentor, Melanie, had taught anatomy for 6 years and was working on her Masters degree in Education. Melanie believed that interns learn how to teach by first observing and then mimicking their mentor. When interns teach, Melanie assists by coteaching with them. Melanie expected Mary to observe her teach Human Anatomy during first period, and take the lead by mimicking her in subsequent hours.

Development of Knowledge of Learners and Learning. Mary continued to believe that teachers should not assume that students have prior knowledge about human anatomy. She explained, “None of them are blank slates. They all have some pre-conceived idea … 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). Mary believed that in anatomy and physiology there are only a few ways to help students learn new content. So, she planned to use lectures to connect new content to students’ lives. According to Mary, “In anatomy, lecture is the best way to get that across” (Stimulated Recall, Day 1). Mary also learned from teaching that when students have hands-on opportunities, they better learn the content because they are motivated. She explained: “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).

From teaching Human Anatomy, Mary recognized that students had trouble understanding 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. (Pre-observation Interview) She believed she could help students overcome their difficulties by lecturing and providing opportunities for students to practice the content.

Development of Knowledge of Instructional Sequences. On both days, Mary planned to use an instructional sequence that focused on transmitting knowledge to students through lectures that occurred in the “inform” type of instruction. Mary still had teacher-centered views of science instruction while holding student-centered views of learning. Table 2 summarizes Mary’s lesson plans for Day One and Two.
Table 2. Mary’s Lesson Plan, Day 1 and 2, Fall Semester

<table>
<thead>
<tr>
<th>Day</th>
<th>Sequence</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Focus</td>
<td>• Quiz</td>
<td>• Students write a quiz</td>
</tr>
<tr>
<td>Day 1</td>
<td>Inform</td>
<td>• Lecture</td>
<td>• Teacher lectures on muscular contractions.</td>
</tr>
<tr>
<td></td>
<td>Inform</td>
<td>• Teacher-led discussion</td>
<td>• Mentor teacher reviews a chart on neurotoxins.</td>
</tr>
<tr>
<td></td>
<td>Focus</td>
<td>• Review</td>
<td>• Students grade quizzes and provide feedback.</td>
</tr>
<tr>
<td>Day 2</td>
<td>Inform</td>
<td>• Lecture</td>
<td>• Students take notes on muscle fibers, exercise, and fatigue.</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>• Group work</td>
<td>• Students color and label diagrams of muscle fibers.</td>
</tr>
</tbody>
</table>

**Contributing Factors.** After 4 months in the ACP, Mary’s experiences in the guided internship significantly influenced her knowledge of teaching. She relied heavily on her mentor’s support to teach Anatomy. Mary would observe her mentor teacher lecture in a different class before she attempted to teach the content. She said, “She [referring to 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 said “I guess for me there’s a difference between preferred and comfortable, it is the most comfortable for me …. It is the most comfortable for me since it's what I was raised on” (Stimulated Recall, Day 1). Mary’s experiences in the ACP courses have provided her with knowledge of a variety of inquiry-based teaching strategies. However, Mary prefers to lecture. She said, “I love all that 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).

2. **Amy’s Case**

**Background.** Amy, age 26, did not initially plan to become a science teacher. She graduated from a small liberal arts institution with an undergraduate degree in biology. After graduation, Amy planned to pursue a medical degree; however, after interning in a hospital she decided against attending medical school. Amy also had numerous informal experiences working with youth as a snow board instructor, soccer coach, camp counselor. In these roles, Amy designed programs and activities to pique students’ interests and motivate them to learn. Amy also worked as a substitute teacher but believed this job 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” and she thought she “did a lot of babysitting.”
Investigating ACP Teachers PCK

Beginning of the ACP

Knowledge of Learners and Learning. Amy believed that students have life experiences but was unsure of students’ prior science knowledge. She said, “I think that heritable variation is probably going to be a new term to them, but they see it every single day and it’s surrounding them” (Entry Task Interview). Amy elected to focus on what students know about their characteristics, their peers’ traits, and traits found in their family. She stressed that she could help students learn genetics by relating new concepts to their life experiences.

Knowledge of Instructional Sequences. On the first day, Amy planned to use an instructional sequence that focused on transmitting knowledge to students in the “inform” type of instruction. Amy believed that science learning occurred through teacher-led discussions that took place during the “inform” type of instruction. 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. Amy held teacher-centered views of the sequence of science instruction despite her student-centered ideas about learning. Table 3 summarizes Amy’s lesson plan for Day’s One and Two.

Table 3. Amy’s Lesson Plan, Day 1 and 2, Beginning of Summer

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

Contributing Factors. Amy’s experiences as a secondary student influenced her knowledge and how she planned to teach heritable variation. According to Amy, “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 also learned from her informal experiences mentoring adolescents about the importance of discussions. Amy had success teaching students how to snow board and play soccer by telling students how to do these activities during discussions.

End of the Summer

Development of Knowledge of Learners and Learning. At the end of the summer, Amy planned to evaluate students’ knowledge 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 course. Amy continued to believe that students primarily learn science by discussing content in relation to students’ experiences; however, she learned from the Secondary Science Methods Course that
discussions would not always be enough to help students learn science. Amy’s other beliefs about the requirements of learning included: making observations of phenomena; investigate scientific questions and collect data; hands-on experiences; and coteaching experiences.

Amy reflected on learning about the nature of science and inquiry during the Secondary Science Methods course and thought that students need to collect data and observe variation firsthand. She said, “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 this idea, Amy thought students needed hands-on experiences. She explained: “I think 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 believed another benefit of inquiry is that students work together to teach 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.

Development of Knowledge of Instructional Sequences. 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” and ask more open-ended questions based on her experiences in the ACP coursework. 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? …. So then they’re thinking maybe of all the different traits instead of limiting them. (End of Summer Interview)

Amy still believed that science learning occurs during the “inform” type of instruction where she could transmit knowledge to students through teacher-led discussions and lectures. Amy continued to rely on a teacher-centered instructional sequence despite holding student-centered views of learning.

Fall Semester

Internship Context. During the Fall semester, Amy interned with an experienced mentor, Emily, at Cambridge High School. Emily believed that teachers who taught the same subject matter should meet frequently to design a common curriculum that include lessons, assessments, and unit objectives. Emily’s philosophy on teacher preparation was that interns needed to observe and mimic experienced mentors. Consequently, at the beginning of an internship, Amy watched Emily teach her lessons and mimicked her teaching style in subsequent class periods.

Development of Knowledge of Learners and Learning. Amy knew that students were exposed to popular media portrayals and ethical issues associated with cloning due to recent stem cell initiatives in local elections. She talked about her students “watching the news … listening to the recent debates … and new amendments being passed” (Pre-observation Interview). However, Amy thought that students did not have much prior knowledge because “they have never really taken much biology” (Pre-observation Interview). As a result of working with her mentor, Amy’s built on her prior knowledge and now talked about learning primarily occurring through the combination of: (1) lectures and teacher-led discussions that relate content to students’ lives; and (2) opportunities for students to coteach each other. Amy frequently provided
students with the opportunity to discuss the ideas she had told them during lectures, as she explained:

We give information and we talk about it and then they talk to neighbors and … discuss it. It’s not ever a lot of them just sitting and writing notes … so they do a lot of group work and talking about their work and it’s really helpful. (Pre-observation Interview)

Amy knew from teaching that students have difficulties understanding microscopic phenomena because they do not have firsthand experiences with cells and DNA. She could help them learn the content by lecturing, providing coteaching opportunities and having students practice new terms.

**Development of Knowledge of Instructional Sequences.** On both days, Amy planned to use an instructional sequence that centered on providing new content knowledge to students during a PowerPoint lecture in the “inform” type of instruction of instruction. The other type of instructions she planned served the purpose of focusing students’ attention on the lesson, and providing them opportunities to practice through independent and large group discussions. When Amy was asked about her sequence of instruction on Day One, she talked about lecturing first so students had the necessary background knowledge to do the other activities she planned. Amy commented, “What I was trying to do with the PowerPoint was to give them an overall general feel because whenever they read these more in depth articles, they were able to apply the knowledge that they learned” (Pre-observation Interview). Amy continued to use teacher-centered instructional sequences despite holding student-centered views of learning. Table 4 summarizes Amy’s lesson plans for Day One and Two.

| Table 4. Amy’s Lesson Plan, Day 1 and 2, Fall Semester |
|-------------------|-----------------|---------------------------------|
| **Sequence** | **Activity** | **Description** |
| Focus | Quiz | Students take a quiz that focused students on being in science class. |
| **Day 1** | Inform | Lecture | Teacher uses a PowerPoint to lecture to students about cloning. |
| Practice | Read articles | Students read articles about cloning and answer questions. |
| Inform | Group discussion | Students discuss the pros and cons of cloning based on the articles. |
| Focus | Review | Teacher reviews main points from her lecture on cloning and the articles from Day One. |
| **Day 2** | 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. |
Contributing Factors. Amy’s believed her mentor taught her how to teach science. Amy commented,

“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 mimicking what I’m learning.” (Stimulated Recall, Day 2)

Additionally, breaking up lectures with student coteaching was a strategy her mentor teacher advocated to help students learn the content. In her Secondary Science Methods II course, Amy learned about student-centered instructional strategies like interactive PowerPoints. However, she interpreted the strategy to be a way for the teacher to focus on transmitting knowledge to students. Amy also drew on what she remembered from her ethics classes to have students discuss the pros and cons of cloning.

3. Lilly Case

Background. Lilly, age 23, began her academic career majoring in journalism, but switched 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 Lilly's interests in biology, but she had an impact on Lilly's 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.” Her experience in the biology course helped her decide to become a science teacher. Lilly completed an undergraduate degree in biology then directly entered the ACP.

Beginning of ACP

Knowledge of Learners and Learning. At the beginning of the ACP, Lilly thought “they’ve [referring to students] have 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.” In spite of students’ a lack of prior science knowledge, Lilly believed she could help students learn by relating new concepts to their life experiences through 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).

Knowledge of Instructional Sequences. On both days, Lilly planned to use an instructional sequence that focused on providing new knowledge to students during the “inform” type of instruction. She believed that science learning primarily occurred during the “inform” type of instruction when the teacher introduces new terminology and concepts. Upon entry into the ACP, there was a mismatch between Lilly’s student-centered views of learning and her teacher-centered sequence of instruction. Table 5 summarizes Lilly’s lesson plans for Day One and Two.
Table 5. Lilly’s Lesson Plan, Day 1 and 2, Beginning of Summer

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

Contributing Factors. 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 secondary and post-secondary student primarily influenced her knowledge and how she planned to teach the topic of heritable variation. Drawing on her prior experiences as a K-16 student, she elected to teach like her former teachers. She said, “I kind of took that approach in doing the lesson plan because it’s what worked for me” (Entry Task Interview).

End of Summer

Development of Knowledge of Learners and Learning. Lilly continued to believe that students have few science experiences prior to middle school and learn from teacher-led discussions that relate science facts to students’ lives. However, she also learned that discussions alone would not be enough for students to learn science. Lilly’s other belief about the requirements for learning emerged from her experiences in the Secondary Science Methods. Lilly thought that letting students choose what they want to investigate is fun for students and they take responsibility for learning. She said, “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 … letting them choose kind of the basic content” (End of Summer Interview).

Development of Knowledge of Instructional Sequences. After the first summer of coursework, Lilly planned to use the same teacher-centered instructional sequence as in her original plan; however, she added more terminology to the activities. She would have students do more with the definitions and terms to provide additional practice. Additionally, Lilly planned to modify her initial lesson plans by having students use their textbooks to verify the definitions she gave them during her discussion. She stated 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 chose to use still focused on the teacher providing information through lectures and discussions. There remained a mismatch between Lilly’s student-centered views of learning and her teacher-centered sequence of instruction.

**Contributing Factors.** Lilly’s experiences in courses in the ACP summer courses influenced her views of her initial lesson plans. In the Secondary Science Methods course she learned 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 [referring to Science Methods course], kind of just guiding, I mean 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). The Methods course influenced Lilly’s knowledge of student-centered learning despite not impacting her teacher-centered instructional sequences.

**Fall Semester**

**Internship Context.** During the Fall semester, Lilly interned with an experienced mentor, Linda. 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 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 interns to prepare lessons for two different class periods.

**Development of Knowledge of Learners and Learning.** Lilly used her knowledge of students’ prior ideas about diffusion and osmosis from previous lessons to develop her plans. While Lilly mentioned a number of strategies that students need in order to learn science, she focused on the importance of lectures that relate to students’ experiences and providing multiple exposures to new terms and concepts. Working with students showed her the importance of providing multiple exposures to new content. She explained:

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. These included: making scientific decisions; evidence-based experiences; and hands-on experiences. Lilly learned from working with students that when they have the freedom to make decisions, they believe they are scientists and are more motivated to learn. She commented, “I feel this is something they truly think they’re doing. It seems to help with their interest” (Pre-observation Interview). Lilly also learned that students better understand diffusion and osmosis by collecting data. When asked about how she thought her students would have done on a diffusion and osmosis quiz based on notes and worksheets alone, she said,

I don’t think they would have done very well. The main reason I say that is because 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).

From teaching, Lilly also learned about a number of topic and subject-specific difficulties students have learning science. She reported that students have difficulty remembering the difference between hypotonic and hypotonic solutions. Related to this difficulty, she thought learners have difficulty transferring knowledge between her diffusion and osmosis lectures, labs, and quizzes. She said, “We were kind of 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). From lecturing, Lilly learned that students have trouble remaining focused. She said, “It is hard for them to stay focused for the whole time just listening because that is not fun for anybody even if the material is very interesting, you don’t just want to sit and listen” (Stimulated Recall, Day 1). To help students overcome their difficulties learning science, Lilly planned to break up time lecturing by providing multiple opportunities for students to practice new concepts.

Development of Knowledge of Instructional Sequences. On the first day Lilly planned to use an instructional sequence that centered on providing students with an “elaboration” where they could manipulate a variable during an investigation. The elaboration was based on students’ prior knowledge and experiences that included: (1) prior “inform” types of instruction that involved diffusion and osmosis lectures; and (2) an “investigation” type of instruction during what we have termed “Egg Lab-Part I” where students collected data to verify what Lilly had told students about diffusion and osmosis in her lecture. The sequence allowed students to participate in defining and investigating questions and making scientific claims based on evidence. However, Lilly’s knowledge of instructional sequence centered on providing knowledge to students during the “inform” type of instruction of instruction that occurred prior to the lesson. She still held a mostly teacher-centered view of instruction despite holding a student-centered view of learning. Table 6 summarizes Lilly’s lesson plans for Day 1 and 2.

Table 6. Lilly’s Lesson Plan, Day 1 and 2, Fall Semester

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inform</td>
<td>• lecture</td>
<td>• Teacher lectures over diffusion and osmosis including the terms and concepts: hypertonic, hypotonic, and isotonic.</td>
</tr>
<tr>
<td>Investigate</td>
<td>• Laboratory</td>
<td>• Students follow a procedure to do a cookbook lab that we have termed the “Egg Lab-Part I.” They placed eggs in syrup, vinegar, and water for 24 hours and then recorded change in mass.</td>
</tr>
<tr>
<td>Day 1</td>
<td>Focus</td>
<td>• Quiz</td>
</tr>
<tr>
<td>Elaborate</td>
<td>• Laboratory</td>
<td>• Students design an experiment to explore how a new solution effects diffusion and osmosis in an egg in what we have termed “Egg Lab-Part II.”</td>
</tr>
</tbody>
</table>
Investigating ACP Teachers PCK 18

<table>
<thead>
<tr>
<th>Extend</th>
<th>Homework</th>
<th>Students read an article on snails that relates to what they previously learned about cell membranes and marker proteins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Discussion</td>
<td>Teacher discusses the lab write-up for Part II of the “Egg Lab-Part II.”</td>
</tr>
<tr>
<td>Inform</td>
<td>Discussion</td>
<td>Teacher shows students how to construct line and bar graphs.</td>
</tr>
<tr>
<td>Practice</td>
<td>Student worktime</td>
<td>Students answer discussion questions and write conclusions for the “Egg Lab-Part II.”</td>
</tr>
</tbody>
</table>

Day 2

**Contributing Factors.** Lilly’s expressed a number of times that her experiences in her guided internship had a significant impact on her knowledge of teaching and learning. She talked about how her mentor influenced her views of the importance of providing students multiple to content exposures when learning new content. According to her mentor, “I find for tenth graders many times you do it but you need to come back and readdress it, whether it is a lab or another activity. And that is not the review. That is actually addressing it another way” (Mentor Teacher Interview). Like her mentor, Lilly has learned from working with students that they learn science when they have multiple exposures including: lectures, worksheets, and labs.

4. **Jason’s Case**

**Background Experiences.** 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. In this role he led discussions, acted as a tutor, and mentored students about personal issues in their lives. He talked at length about his background experiences in Young Life where he played a brotherly role. This included teaching Young Life members life lessons and engaging adolescents in discussions about real-world problems. Jason explained that it was his experience as a Young Life leader that made him pursue science teaching. He entered the ACP just after he completed his undergraduate degree.

**Beginning of the ACP**

**Knowledge of Learners and Learning.** At the beginning of the ACP, Jason believed that students have life experiences but not prior knowledge of heritable variation. According to Jason, “I don’t think that they would know too much about it … (they would not know) too much about heritability” (Entry Task Interview). Despite students’ limited science knowledge, he emphasized the importance of learners discovering science and applying science to their lives. He explained, “My facilitation of the 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 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 based on his K-16 experiences. He hoped he could “find a study you know that would show actual data” (Entry Task Interview). He thought “it is just better to see the data behind it so I can see the actual trend
not just someone saying a trend going to the greater side” (Entry Task Interview). Jason thought that once students knew about variation, he could transition to studying variation in other organisms. 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). Additionally, Jason believed that students learn science best when they work together to talk through new material. He explained:

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)

While Jason mentioned a number of requirements for learning, he emphasized the importance of using discussions to help students discover and apply science to life.

Knowledge of Instructional Sequences. In formulating his approach to teaching heritability, Jason thought back to his experiences as a K-16 student and Young Life leader. He tried to move back and forth between his students’ experiences and defining new terms during discussions. For Jason, discussions were a way to motivate students to listen to the new ideas that he was presenting. Although his sequence relied on transmitting knowledge to students during the “inform” type of instruction, he hoped students would approach the content with new insight and apply knowledge to their own lives. While Jason believed students need to discover science on their own, he fell back on familiar instructional strategies from his K-16 experiences that were primarily teacher-centered. Table 7 summarizes Jason’s lesson plan for Day One and Two.

Table 7. Jason’s Lesson Plan, Day 1 and 2, Beginning of Summer

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

Contributing Factors. Jason’s experiences as an undergraduate student greatly influenced his knowledge and how he planned to teach. He drew on his in his Evolution course where the professor talked about corn height, the height of people, and the bird example as an introduction to variability. Jason also found value reading about data and empirical evidence because it
investigating ACP teachers' PCK verified what he was learning. Jason drew on his informal teaching experiences to ask questioning that elicit students' ideas and engage them in discussions. He talked about his experiences as a Young Life leader and asking students questions. According to Jason, “You don’t just jump in and start lecturing because kids … are leaving English class and entering Science class … I think it just gets more kids involved you know when you are just asking them (questions)” (Entry Task Interview).

End of the Summer

Development of Knowledge of Learners and Learning. Jason continued to believe that learners need to discover science on their own. He thought discussing the content in relation to students lives allows them to “lead their own thinking” and “figure it out own their own.” He talked about the benefits of discussions versus lectures: “I could easily say that in three seconds, but I think it is something I think they could definitely figure out, just getting them to bring that out on their own” (End of the Summer Interview). Jason also believed that students need evidence-based experiences to learn science and he planned to find data on different traits in corn plants so he could support different types of variation with empirical evidence.

Development of Knowledge of Instructional Sequences. 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, he would have students brainstorm how corn plants vary as a focus activity. Instead of having the whole class discuss corn heights, he would let them chose the traits they wanted to investigate. After school, he intended on finding data to show students that the traits they choose were variable in corn plants. Jason still felt responsible for providing student with knowledge; however he wanted to fulfill their own interests. On the second day, Jason would have students spend more time at the beginning of class discussing the data he found and how it related to variation within species. He still planned on moving on to sexual selection and variation within his bird example. Jason continued to focus on providing knowledge to students through discussions that occur during the “inform” type of instruction. Although he held student-centered knowledge of learners, Jason relied on familiar instructional sequences from his K-16 experiences that were teacher-centered and focused on transmitting knowledge during the “inform” type of instruction.

Contributing Factors. Jason’s experiences in the Secondary Science Methods course influenced how he planned to teach. Jason talked about only knowing a few instructional strategies like lectures before he entered the summer coursework. The Secondary Science Methods courses 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. (End of the Summer Interview)

Jason believed he was able to make the lesson more student-centered based on his experiences in the ACP coursework. Jason continued to draw on his experiences mentoring youth as he thought about teaching. As a mentor he learned questioning skills and the importance of using questions to focus students on a task. Jason viewed open-ended questions as a way to elicit students’ prior knowledge, motivate students, and focus the lesson.
Fall Semester

**Internship Context.** During the Fall semester, Jason interned with an experienced mentor, Nancy, at Harris High School. Nancy 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 met frequently to design the biology department curriculum, which aligned with state and national standards. All of the biology teachers at Harris used the same unit objectives, assessments, and lessons organized into a packet for students. Nancy insisted that Jason use the materials and met frequently with him to discuss how he planned to teach. Even though Jason used Harris’s common curriculum materials, he reported that he designed some of his own lessons and activities.

**Development of Knowledge of Learners and Learning.** Jason learned from the guided internship that students had prior experiences learning about biology content. For example, he knew that students had learned about cells in an earlier grade, but did not remember the specifics about organelles, etc. He believed this was because students were not engaged in the strategies that some teachers used to present science content. Jason commented,

> I think teachers just present it and think kids are going to take it and move on. And they move on just thinking that since they have taught it that it is their own responsibility in a way. 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. (Pre-observation Interview)

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 experiences with learning about cells and emphasized the importance of discovering science through discussions with student participation. Jason’s other beliefs about the requirements for learning science included: multiple exposures to new content, and having collaborative experiences to build knowledge. To provide students multiple exposures he planned a number of different activities to help students understand terms and concepts. Additionally, Jason talked about collaboration being important in learning science: “It is just 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 ideas off each other” (Stimulated Recall, Day 2).

While teaching the unit on cells, Jason talked about difficulties students had visualizing cellular structures. Students had trouble relating cartoon images to real pictures of cell organelles. He planned to help them overcome these difficulties by using discussions and providing multiple exposures to new content.

**Development of Knowledge of Instructional Sequences.** On both days the instructional sequence focused on presenting factual information during the “inform” type of instruction. Although Jason planned a number of different activities, he continued to hold a teacher-centered view of instructional sequences and lacked specific knowledge of how to get students to explore their own interests and discover patterns in how the world works. Table 8 summarizes Jason’s lesson plans for Day 1 and 2.

**Contributing Factors.** Jason’s experiences in the guided internship impacted how he taught. He believed he must present science facts that were addressed in Harris’s objectives because. Jason said, “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” (Pre-observation Interview). Jason’s experiences with his mentor...
influenced his knowledge of instructional sequences to teach science. He said, “That’s a Nancy thing to always give them their homework right off the bat first” (Pre-observation Interview). Additionally, the flash cards were a strategy his mentor teacher used to teach about cells, and the video was suggested by a colleague in the department. Table 8 summarizes Jason’s lesson plans for Day One and Two.

Table 8. Jason’s Lesson Plan, Day 1 and 2, Fall Semester

<table>
<thead>
<tr>
<th>Day</th>
<th>Sequence</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td></td>
<td>Introduction</td>
<td>Students write lesson objectives and their homework in their planners.</td>
</tr>
<tr>
<td>Inform</td>
<td></td>
<td>Presentations</td>
<td>Students presented a model of an organelle. While students presented, their peers wrote down the functions of the organelle. Additionally, students asked their classmates questions about the structure and function of the specific organelle. Teacher highlights important terms and concepts from students’ presentations.</td>
</tr>
<tr>
<td>Day 1</td>
<td>Practice</td>
<td>Independent practice</td>
<td>Students placed their organelle in either a large plant or animal cell and justified their decision. 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group and independent practice</td>
<td></td>
</tr>
<tr>
<td>Inform</td>
<td></td>
<td>Video</td>
<td>Video of different 3-D images of cell parts and their functions.</td>
</tr>
<tr>
<td>Day 2</td>
<td>Practice</td>
<td>Review</td>
<td>Students reviewed the structures and functions of different organelles.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group practice</td>
<td>Whole class discusses how a cell is similar to a factory.</td>
</tr>
</tbody>
</table>

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. 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)

Jason used other resources that he learned about in the Secondary Science Methods courses to design some of the activities during the lesson. For example, he used the National Science Teachers Association (NSTA) website for ideas on how to engage students in learning about building large models of cells. Jason continued to draw on his K-12 experiences when designing
the lessons. For example, presenting cell parts was something he did as a high school student. 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 and stuff” (Pre-observation Interview).

Cross-Case Assertions

The first 3 assertions include claims about: knowledge of instructional sequences; the knowledge of learners; and the integration of knowledge of learners and instructional sequences. The final assertion is related to sources that contributed to the development of teacher knowledge.

Assertion 1: Over time, 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 instructional sequences aimed at providing new knowledge to students during what we have termed an “inform” type of instruction. These four participants believed that science learning primarily occurred during an “inform” type of instruction where the teacher leads discussions or lectures and relates content to students’ lives. During the End of the Summer interviews, participants continued to focus on presenting information to students through teacher-centered means. Some of the teachers, like Jason and Amy, planned to modify their activities to be more student-centered like they had learned in the Science Methods course. Yet they did not mention changing the overall teaching script that focused on transmitting knowledge. During the Fall semester, Mary’s, Amy’s, Lilly’s, and Jason’s knowledge of instructional activities developed as evident in the lesson plan summaries. However, they continued to hold a teacher-centered view of science instruction and emphasized the importance of providing students with knowledge through lectures and teacher-led discussions. Table 9 summarizes Mary, Amy, Lilly, and Jason’s knowledge of instructional sequences.

Table 9. Summary of Mary, Amy, Lilly, and Jason’s Knowledge of Instructional Sequences

<table>
<thead>
<tr>
<th>Participants</th>
<th>Entry</th>
<th>Day 1</th>
<th>Day 2</th>
<th>End of Summer</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary</td>
<td>Inform</td>
<td>Focus</td>
<td>Inform</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
<tr>
<td></td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Practice</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
<tr>
<td>Amy</td>
<td>Inform</td>
<td>Focus</td>
<td>Inform</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
<tr>
<td></td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
<tr>
<td>Lilly</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
<td>Inform</td>
<td>Focus</td>
<td>Focus</td>
<td>Focus</td>
</tr>
<tr>
<td></td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Practice</td>
<td>Elaborate</td>
<td>Extend</td>
<td>Practice</td>
</tr>
<tr>
<td></td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
<td>Inform</td>
</tr>
</tbody>
</table>
Assertion 2: Over time, prospective teachers developed more sophisticated knowledge of requirements for learning science.

At the beginning of the ACP, Mary, Amy, Lilly, and Jason were unsure of students’ knowledge of heredity; however, they believed they could help students learn science by relating new content to students’ lives through lectures and teacher-led discussions. These were strategies they observed their high school teachers and college professors use, or had used themselves to help students learn science. 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. For three of the participants, Mary, Amy and Lilly—their knowledge of learners expanded as a result of the Secondary Science Methods course. Mary believed students needed the opportunity to discover and do group work; Amy thought students needed to make observations of phenomena, have hands-on experiences, investigate scientific questions and collect data, and coteach their peers; Lilly believed students needed to make scientific decisions. Jason’s initial ideas that students need discovery learning and evidence-based explanations were reinforced through his experiences in the Science Methods course. He continued to focus on providing students with discovery opportunities and evidence-based experiences to help them learn science.

From participating in the guided internship, Mary, Amy, Lilly, and Jason developed more refined knowledge of learners. They expanded their ideas about student prior knowledge and need for first hand experiences. During this time they were exposed to different areas of student difficulties and noticed gaps in their knowledge of learners’ needs. Mary, for example, preferred to use lectures in her classroom. She learned from teaching human anatomy during the internship that she also needed to provide hands-on opportunities so students could learn anatomical structures. Likewise, Amy planned to lecture to students during her cloning unit. Prior to developing her cloning unit, she recognized that students would need the opportunity to coteach and talk through the content with a peer. She frequently broke-up her lectures into smaller fragments to allow students to talk through 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 that lectures were insufficient and students needed multiple exposures to material to commit terms and concepts to memory. During Lilly’s diffusion and osmosis unit, she used PowerPoint lectures, cookbook labs, worksheets, and independent investigations to help students learn the content. Although Jason’s knowledge of the requirements of learners did not seem to grow as much in quantity as the other participants, his ideas about learners also became more refined over time. He believed that teacher-led discussions were not always enough for students to learn the content, and similar to Lilly, thought that students needed multiple opportunities to practice new material. In his unit on cells, he had students justify why their selected organelle was important, identify the similarities and differences between plant and animal cells, create flash cards of organelles function, and describe how a cell is like a factor.

Table 10 summarizes the participants’ knowledge of learners.

<table>
<thead>
<tr>
<th>Jason</th>
<th>Focus</th>
<th>Inform</th>
<th>Focus</th>
<th>Elaborate</th>
<th>Inform</th>
<th>Focus</th>
<th>Inform</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Participant</th>
<th>Entry</th>
<th>End of Summer</th>
<th>Fall Semester</th>
</tr>
</thead>
</table>
| Mary        | • Lectures  
  • Connections to life | • Lectures  
  • Connections to life  
  • Discover new ideas own their own  
  • Group work | • Lectures |
| Amy         | • Teacher-led discussions  
  • Connections to life | • Teacher-led discussions  
  • Connections to life  
  • Making observations  
  • Hands-on experiences  
  • Investigating scientific questions and collecting data  
  • Coteaching experiences | • Teacher-led discussions  
  • Connections to life  
  • Hands-on experiences |
| Lilly       | • Teacher-led discussions  
  • Connections to life | • Teacher-led discussions  
  • Connections to life  
  • Repetition  
  • Make scientific decisions | • Teacher-led discussions  
  • Connections to life  
  • Making scientific decisions  
  • Multiple exposures  
  • Evidence-based experiences  
  • Hands-on experiences |
| Jason       | • Teacher-led discussions  
  • Connections to life  
  • Discover new ideas on their own  
  • Evidence-based experiences  
  • Connections to previous content  
  • Collaborative experiences | • Teacher-led discussions  
  • Connections to life  
  • Discover new ideas on their own  
  • Evidence-based experiences | • Teacher-led discussions  
  • Connections to previous content  
  • Collaborative experiences  
  • Multiple exposures |

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 disposition to how students learn science. However, at no point in time did their instructional sequences fully reflect their stated knowledge of learners. At the beginning of the ACP, all four participants held reasons for their ideas about learning that were
related to either their experiences as learners and or to their experiences mentoring adolescents. Similarly, the prospective teachers’ knowledge of sequencing science instruction was related to the way they were taught. They planned to use lectures and teacher-led discussions and relate new content to students’ lives to help students learn. As Mary, Amy, Lilly, and Jason gained teaching experiences in the guided internship, they integrated specific elements of the knowledge of learners and sequence of science instruction to help students overcome their difficulties. For Mary, Lilly, and Jason this meant purposefully adding “practice” type of instructions to their instruction so students would have multiple exposures to the content. Similarly, Amy responded to her learners’ needs by frequently breaking-up lectures so students could talk through ideas. These cases illustrate a shift in the participants’ knowledge of learners and instructional sequences from encompassing their memories of being a student to drawing on direct teaching experiences to accommodate learners’ needs when designing their teaching script.

**Assertion 4: Prospective teachers’ knowledge was influenced by different factors at different times during the ACP.**

At the beginning of the ACP, Mary, Amy, Lilly, and Jason drew heavily on their background experiences when talking about their knowledge of teaching and learning. Over time, their background experiences were supplemented with other sources that contributed to their knowledge of teaching and learning. After 11 weeks in the ACP, all of the participants mentioned that experiences in the ACP coursework had impacted their knowledge of learners. Mary, Amy, and Lilly gained new ideas, while Jason strengthened his existing beliefs about discovery learning and evidence-based experiences. During the fall semester internship, the mentor teachers strongly influenced the participants’ views of learners and sequence of science instruction. All four participants found themselves teaching in similar ways as their mentor. In their internships, their teaching context was didactic in nature and focused on presenting students terms and concepts through lectures. The participants struggled to embrace other sequences of science instruction and reform-minded practices from the Secondary Science Methods course, but experienced some frustration due to the disparity between the ACP courses and these didactic teaching contexts.

**Discussion**

Mary, Lilly, Amy, and Jason entered the ACP viewing teaching as a teacher-centered process that focused on transmitting science knowledge to students through lectures and discussions. The research literature supports this finding that preservice teachers come into teacher preparation believing teaching is telling (Geddis et al., 1993; Lemberger et al., 1999; Mellado, 1990; Russell & Martin, 2007). There was little evidence in our data to suggest that the participants knew about student-centered ways to sequence science instruction. Jason, for example wanted students to discover science on their own, but consistently relied on teacher-led discussions in his lesson plans so that he could move back and forth between students’ experiences and presenting new content. Similarly, Mary, Amy, and Lilly focused on connecting the content to students’ lives through lectures and teacher-led discussions.

The participants’ experiences in the ACP helped develop their knowledge of learners and learning. After the first 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. This growth in knowledge continued during the guided internship, where the participants built on their prior ideas as a result of working with students. They became aware of student difficulties and changed their instruction to accommodate learners’ needs. This finding is similar to Van Driel, de Jong, and Verloop (2002) who found that secondary preservice teachers became aware of student difficulties and changed their instruction accordingly. However, for three teachers-- Mary, Lilly, and Jason--this meant that they added more opportunities for students to practice terms and content. Their overall sequence of instruction remained teacher-centered. Similarly, Amy continued to hold a teacher-centered view of instructional sequences and helped students learn from her lectures by breaking them into smaller segments and allowing students to talk through the new content in their own words. These findings are similar to those of other researchers who report that secondary preservice teachers do not consider their students in sophisticated ways or think about their students’ knowledge extensively (Geddis & Roberts, 1998; Geddis et al., 1993; Lemberger et al., 1999).

Although it appears that these four participants’ knowledge of learners and learning developed with experiences in the ACP, they consistently held teacher-centered views of instruction. All four teachers held student-centered beliefs about learning while planning and enacting teacher-centered views of instructional sequences. Simmons et al. (1999) study confirms our findings. They reported that teachers who initially espoused student-centered beliefs actually demonstrated teacher-centered actions. The researchers found that, as teachers gained experiences, their beliefs and actions became more congruent. Beginning teachers often “wobbled”, or shifted, between student-centered and teacher-centered beliefs about teaching.

All four participants struggled to implement reform-based practices due to the didactic nature of their teaching context. Other researchers have also reported that the nature of the teaching context overrides preservice and beginning teachers’ abilities to implement reform-minded practices (Adams & Krockover, 1997; Puk & Haines, 1999). 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; (c) students that observed their associate teachers using constructivist approaches they were more likely to implement them themselves. Although preservice teachers learned about inquiry and the learning cycle of 5E in teacher preparation courses, the culture and context of their teaching constrained their ability to implement and embrace reform-minded practices.

This study reinforced the importance of investigating the development of ACP teachers PCK. The teachers in this study benefited from the Secondary Science Methods because they gained knowledge of learners and learning. As they were teaching alongside a mentor, they could develop this knowledge even further and identify additional student needs and areas of difficulties. At this point we can only speculate how the teachers’ knowledge of learners and learning would have developed without the support of the ACP. However, we believe that with such support they are more likely to develop student-centered knowledge of learners and learning. Despite holding student-centered views of learners and learning, these participants consistently held teacher-centered knowledge of instructional sequences that were reinforced by the didactic nature of their teaching context. More research is needed that continues to investigate the development of these components of PCK into the beginning years of teaching.
Implications

For Policy

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 requirements to simplify the teacher certification process and alleviate teacher shortages (Cochran-Smith & Fries, 2006). Reducing college and university-based teacher education requirements by shortening the pedagogical preparedness and the fieldwork component of teacher education has been termed the “deregulation” agenda. 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. We believe the policy argument should not focus on the quantity of courses and field experience students take in order to become certified. Based on the findings of this study, we recommend that ACP teacher preparation be reconceptualized to include ways that integrate science-specific pedagogy courses and fieldwork. The integration of these factors are critical to the development of ACP teachers PCK.

For Research

Understanding how teacher knowledge develops is a challenging endeavor. In doing so, we found that our interpretations and data collection were limited by the PCK model. Although the PCK model helped us design interview protocols, it artificially separates PCK for instructional sequences and learners. We learned from data analysis that as preservice teachers gain more experience, the interaction that develops between teachers’ knowledge of learners and their knowledge of instructional sequences becomes more integrated. We interpret this to mean that the integration of PCK components becomes greater with teaching experience and reflection. We 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. As we expand our analysis to more participants over longer time periods, we plan to use the data to generate and test developmental models of PCK.

For Teacher Education

All of the teachers in this study developed a more refined understanding of learners’ needs by identifying student difficulties and working with mentors. However, the participants consistently sequenced science instruction in teacher-centered ways and relied on transmitting knowledge to students. As the participants gained experiences, they realized that lectures and discussions are not always enough to help students learn science. For example, all of the participants incorporated extra practice as a way for students to overcome their difficulties and learn content. Teacher educators can help teachers broaden their knowledge of the role of learners’ needs and difficulties to influence their design of instruction. For example, 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 move preservice teachers toward implementing student-centered instructional sequences like the learning cycle of 5E instructional model to assist student learning and help students overcome their difficulties learning science. Reflecting on the similarities and differences between teacher-centered and student-centered instructional sequences may be a way to help develop beginning teachers’ knowledge of instructional sequences to teach science.

Additionally, 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 opposition to the reform-oriented practices touted in the ACP. Because many ACPs require a significant amount of experience teaching with a mentor, and because novice teachers lack PCK, preservice teachers are heavily influenced by their mentor teachers’ knowledge and practice. Teacher educators must make greater attempts to select mentor teachers whose knowledge and practices align with the values of the ACP. Additionally, mentor teachers need to be aware of the PCK framework and understand their role in helping beginning teachers build their PCK. If the goal of science education is to promote reform-oriented practices among preservice teachers, then teacher educators must match interns with mentors that value and practice reform-minded science instruction. Acknowledging the similarities and differences between teacher preparation coursework and teaching contexts may be a way to help teachers implement more reform-based practices.

Conclusion

To provide quality teacher preparation in ACP settings, it is critical that science educators understand how PCK for learners and instruction develop in an ACP. In this study we investigated teacher knowledge of learners and learning and sequence of science instruction. Our findings indicate that these teachers tapped into students’ prior life experiences when designing lessons. Their views of learning were largely student-centered, but their instruction was teacher-centered. Even though they learned in the ACP that students have prior science knowledge, they did not draw on this knowledge to design instruction where students are challenged to evaluate what they know in light of new knowledge. Their views of instruction were at odds with the inquiry-based approaches touted in the ACP. Recognizing future teachers’ gaps in understanding about science learners and learning and sequencing of science instruction is critical for improving teacher education (Gess-Newsome, 1999; Johnson, 2006; Loucks-Horsley et al., 2003). Teacher preparation programs that do not take into account the knowledge and beliefs of participants will not significantly impact teacher practices or student learning (Luft, 2001; van Driel, Beijaard, & Verloop, 2001). Given the baseline understanding about ACP participants’ PCK, our next step is to examine how knowledge of learners and learning and sequence of instruction is developed throughout the ACP and into the beginning years of teaching.
References


Figure Caption

Figure 1. Magnusson et al (1990) PCK model for science teaching
Investigating ACP Teachers PCK

PCK

includes

Orientations to Science Teaching

which shapes

Knowledge & Beliefs about Science Curricula

which shapes

Knowledge & Beliefs of Students' Understanding of Science

which shapes

Knowledge & Beliefs about Assessment of Scientific Literacy

which shapes

Knowledge & Beliefs of Instructional Strategies