Does Teaching Experience Matter?

Examining Biology Teachers' Prior Knowledge for Teaching in an Alternative Certification Program

Patricia J. Friedrichsen
Sandra K. Abell
Enrique M. Pareja
Patrick L. Brown
Deanna M. Lankford
Mark J. Volkmann

University of Missouri-Columbia

*contact: friedrichsenp@missouri.edu

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Abstract

Alternative certification programs (ACPs) have been proposed as a viable way to address teacher shortages, yet we know little about how teacher knowledge develops within such programs. The purpose of this study was to investigate prior knowledge for teaching among individuals in an ACP, and compare individuals with and without teaching experience. We selected four biology teachers from a cohort of 14. Two were interns with no teaching experience, completing a yearlong mentored internship. Two were full time secondary teachers, with 1-2 years of teaching experience. Data collection involved a lesson planning task related to the topic of heritable variation and a follow-up interview. Both interns and teachers held didactic teaching orientations and used the same teaching script in their lesson plans: short question and answer period, lecture, followed by guided practice. Both groups displayed general, not topic-specific, pedagogical knowledge. We found subtle differences between the groups in their knowledge of students, instruction, curriculum, and assessment. However, the biggest difference between interns and teachers was in the interplay of their various knowledge components as they designed their lessons. We end with implications for the PCK theoretical construct, for teacher education, and for future research.
Does Teaching Experience Matter? Examining Biology Teachers' Prior Knowledge for Teaching in an Alternative Certification Program

Numerous studies have shown that the classroom teacher is the most important factor in student achievement (National Research Council [NRC], 2001). Indeed, the strongest predictor of how well a state’s students performed on a recent national assessment was the percentage of well-qualified teachers—those who were fully certified and had majored in the subjects they taught (Darling-Hammond, 2000; National Commission on Mathematics and Science Teaching for the 21st Century, 2000). However, U.S. schools face a growing and critical shortage of qualified teachers, even in the wake of a federal mandate that required a “highly qualified” teacher in every classroom by the end of the 2005-2006 school year. The situation is especially desperate in mathematics and science, where the workforce is plagued with an insufficient supply of qualified teachers and retention difficulties. A report by the National Commission on Teaching and America’s Future (2003) emphasized that stronger teacher preparation leads to higher retention of beginning teachers. The report’s authors asserted that quality teacher preparation hinges on careful recruitment, strong academic preparation, extensive clinical practice, and supportive induction programs.

Many U.S. states have responded to the teacher shortage and the need for highly qualified teachers by authorizing alternative pathways to teacher certification. These alternative paths, typically shorter in duration than traditional teacher preparation programs, often place teachers in full-time teaching positions after minimal preparation. By 2003, 46 states and DC had initiated alternative routes to teacher certification, and over 200,000 teachers had been prepared in such programs (Feistritzer & Chester, 2003).
Although these alternative routes have been successful at recruiting a more diverse pool of teachers, they have a “mixed record in terms of the quality of teachers recruited and trained” (Wilson, Floden, & Ferrini-Mundy, 2002, p. 198). Some alternative certification programs (ACPs) have been more successful than others, suggesting that research is needed that goes beyond examining whether or not alternative certification is a viable model of teacher preparation; we need to investigate when, why, and how alternative models of teacher preparation can be most effective. Investigating these questions requires a careful examination of what alternative certification candidates bring into the program, what they learn, and what facilitates and constrains their learning. Ultimately, a better understanding of the development of teacher knowledge within the context of alternative pathways will facilitate the development and implementation of more effective teacher preparation programs that produce larger numbers of qualified mathematics and science teachers. Thus, to ensure that we are preparing the highest quality teachers, it is imperative that we study the development of teacher knowledge in ACPs.

The purpose of this study is to document beginning biology teachers’ prior knowledge for teaching heritable variation upon entry into an ACP, and to compare the prior knowledge of individuals with and without teaching experience. This study is part of a larger, longitudinal study examining the development of science and mathematics teacher knowledge within an ACP. The findings of this study will establish a baseline for studying teacher knowledge development throughout the ACP.

Theoretical Framework

Our beliefs about knowledge for teaching are grounded in the work of Lee Shulman and his colleagues (Grossman, 1990; Shulman, 1986, 1987; Wilson & Wineburg, 1988). Shulman proposed seven categories of teacher knowledge: knowledge of content; pedagogy; curriculum;
learners and learning; contexts of schooling; educational philosophies, goals, and objectives; and pedagogical content knowledge. According to Shulman, pedagogical content knowledge (PCK) is what distinguishes the teacher from the content specialist, and includes “an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction” (1987, p. 8). Grossman (1990) reorganized Shulman’s model of teacher knowledge to emphasize the interaction of PCK with subject matter knowledge (SMK), general pedagogical knowledge (PK), and knowledge of context (K of C). She defined K of C as knowledge of the specific school district's expectations, the culture of the school building, departmental guidelines, and knowledge of specific students and their background and PK as “a body of general knowledge, beliefs, and skills related to teaching” (p. 6), including the categories of learners and learning; classroom management; and curriculum and instruction. She defined PCK as “knowledge that is specific to teaching particular subject matters” (p. 7) and included conceptions of purposes for teaching subject matter, knowledge of student’s understanding, curricular knowledge, and knowledge of instructional strategies as the components of PCK. In science education, Magnusson, Krajcik, and Borko (1999) added the component of knowledge of assessment to Grossman’s definition of PCK.

Our theoretical framework for teacher knowledge is derived from a combination of the Grossman and Magnusson et al. models (see Figure 1). We used the Magnusson et al. (1999) description of the components of PCK as the foundation for data collection and analysis in this study. We summarize those descriptions below.

[Insert Figure 1 about here]

- Science Teaching Orientations: knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. An orientation is a “general way of viewing
or conceptualizing science teaching” (p. 97), including activity-driven, didactic, discovery, conceptual change, academic rigor, process, project-based, inquiry, and guided inquiry.

- Knowledge of Student Understanding of Science: knowledge of what students know about a topic, including common misconceptions; requirements for learning the topic; how students learn that topic best; and areas of difficulty for student learning.
- Knowledge of Science Instructional Strategies: knowledge science-specific approaches, and topic-specific activities and representations.
- Knowledge of Science Curriculum: knowledge of learning goals, instructional materials, and the sequencing of instruction across particular topics.
- Knowledge of Assessment in Science: knowledge of what and how to assess student learning as related to stated goals.

Literature Review

The development of teacher knowledge is the central goal of teacher education (Borko & Putnam, 1996) A recent review by Abell (2007) reported the science education research on teacher knowledge and its importance in the preparation and continued development of science teachers. Her review was framed around the components of the teacher knowledge model in Figure 1. Another recent review, by Davis, Petish and Smithey (2006), was based on the INTASC standards and identified five main areas in which beginning teachers develop understanding: (a) science subject matter knowledge; (b) knowledge of learners; (c) knowledge of instruction; (d) knowledge of learning environments; and (e) professionalism. The first four are relevant to this study. The following review of the literature, based on these two sources, is organized using the components in our theoretical framework (Figure 1).
Science Teaching Orientations

Science education researchers studying orientations have used a variety of terms such as “conceptions of science teaching” (Hewson & Hewson, 1987; Koballa, Upson, & Coleman, 2005), “functional paradigms” (Lantz & Kass, 1987), “world images” (Wubbels, 1992), “preconceptions of teaching” (Weinstein, 1989) and “approaches to teaching” (Trigwell, Prosser & Taylor, 1994). These researchers have examined the orientations of both preservice and practicing science teachers. For example, Roth (1987) studied 13 experienced junior high school life science teachers and found three teaching orientations: fact acquisition, conceptual development and content understanding. Koballa et al (2005) identified five "conceptions about science teaching," held by science teachers in an ACP: (a) presenting science content to students, (b) providing students with a sequence of science learning experiences, (c) engaging students in hands-on science activities, (d) facilitating the development of students’ understandings about science, and (e) changing students’ science-related conceptions. Many individuals enter teacher education programs with simplistic views of teaching and learning, believing that teaching is transmitting new concepts to students. Geddis, et al. (1993) reported that preservice teachers viewed teaching as transmitting subject-matter knowledge to students--if the teacher could clearly articulate ideas through lectures and verification laboratories, then students would have little difficulty learning science.

In addition to defining orientations, some researchers considered the influences on these orientations and the correspondence between orientations and practice. Friedrichsen and Dana (2005), in a study of exemplary, experienced secondary teachers, reported that orientations are influenced by multiple factors, including teachers' beliefs about learners and learning, their prior work experiences, professional development, the classroom context, and time constraints. While
the teachers held a dominant conception of science teaching, it was possible to hold multiple conceptions simultaneously. Simmons et al. (1999) studied a group of beginning teachers during their first three years of teaching. They reported that beginning teachers' beliefs and attitudes guided their instructional decision-making, and that these beliefs were shaped by their teaching experiences. Although beginning teachers described their beliefs as student-centered, they acted in teacher-centered ways. Koballa et al. (2005), on the other hand, reported that ACP teachers' conceptions about science teaching guided their instructional decision-making and were consistent with their teaching practice.

According to the research, multiple orientations can be held simultaneously and are often context-specific (Friedrichsen, 2002; Friedrichsen & Dana, 2005). In addition, orientations to science teaching can change over time (Anderson, Smith, & Peasley, 2000) and can be influenced by teacher education programs, including ACPs (Koballa et al., 2005). Thus, it is important to document teachers’ orientations upon entering an ACP and to examine the development of them throughout the teaching career.

Knowledge of Learners

According to Davis et al. (2006), although experienced teachers’ understanding of learners influences their instructional decision-making, the research on preservice teachers shows no single consistent pattern. Abell (2007) pointed out that the research in the area has focused primarily on teacher knowledge of alternative conceptions, teacher images of the ideal student, and more general views of science learning.

Regarding preservice elementary teachers, Abell, Bryan, and Anderson (1998) reported that while they give significant considerations to their students as learners, they failed to do so in extensive or careful ways, focusing on student interest or motivation rather than learning. Meyer,
Tabachnick, Hewson, Lemberger, and Park (1999) found that although preservice secondary teachers considered identifying students' prior knowledge as important, they did so for different reasons: (1) to determine what students had failed to learn, (2) to motivate students and to pay attention to them, or (3) to help students become more responsible for their own learning by realizing what they did not know.

In a study by de Jong and van Driel (2001) on the design and implementation of lessons by prospective chemistry teachers, fewer than half reported any concerns related to student learning. In another study of preservice chemistry teachers, van Driel and his colleagues (van Driel, de Jong, & Verloop, 2002; van Driel & Verloop, 2002) found that actual classroom teaching experience played a major role in developing teacher understandings of students' prior conceptions.

According to the research in this area, knowledge of learners relates to teacher use of instructional strategies (Tabachnick & Ziechner, 1999; van Driel, et al., 2002). Furthermore, teacher perceptions of science learning is influenced by teaching orientations (Abell, 2007). Thus, it is important to examine the nature of teachers' knowledge of learners, and how this knowledge is used in instructional decision-making.

Knowledge of Instructional Strategies

Research on science teacher knowledge of instructional strategies has addressed the use of both subject-specific strategies (e.g., the learning cycle) and topic-specific teaching methods (e.g., teaching chemistry concepts) (Abell, 2007). Researchers have compared the relation of teaching experience to knowledge of instructional strategies. For example, de Jong, Acampo, and Verdonk (1995) found that experienced teachers had difficulties designing viable instructional strategies on redox reactions. Yet Clermont and his colleagues (Clermont, Borko, & Krajcik,
1994; Clermont, Krajcik, & Borko, 1993) found that experienced teachers discussed more science demonstrations and provided more detail about them when compared to novices who only occasionally discussed inappropriate content or pedagogically unsound demonstrations. These researchers hypothesized that knowledge of instructional strategies is linked to subject matter knowledge and knowledge of learners.

Experiences in addition to teaching also influence knowledge of instructional strategies. For example, Eick and Reed (2002) found that preservice teachers’ experiences learning science were a major influence on how they chose to teach science during an internship. One of the teachers who they frequently observed using inquiry strategies that actively involved students, acknowledged that she had negative experiences learning science through lecture. The choice of instructional strategies is also influenced by constraints such as adherence to the local curriculum and high stakes testing (Haney & McArthur, 2002); classroom management issues (Zembal-Saul, Krajcik, & Blumenfeld, 2002); and university coursework (van Driel, de Jong, & Verloop, 2002). Thus it is important to understand the prior knowledge of instructional strategies that science education students bring into their teacher preparation programs.

Knowledge of Curriculum

Teachers need to be able to differentiate between major concepts and trivial facts as they make decisions regarding how much time they will spend teaching particular topics. When teachers lack discrimination in this area, they either spend too much time on trivial topics or too little time on important concepts (Geddis et al., 1993). Curricular knowledge affects instructional decisions (Haney & McArthur, 2002) and is an essential component of preservice teacher reasoning around lesson planning (Peterson and Treagust, 1995). However, this area of research has received little attention from science education researchers (Abell, 2007), or teacher
education researcher in general (Davis et al., 2006). There is a need to determine what knowledge of curriculum teachers bring to bear on lesson planning and instructional decision-making.

**Knowledge of Assessment**

There is little research on teacher knowledge of assessment in science (Abell, 2007). Although some researchers have studied methods of assessment used by teachers (Pine, Messer, & St. John, 2001), knowing the methods used does not tell us how or why assessment is enacted. In one study, Sanders (1993) found that South African teachers used different criteria to mark test answers resulting in wide distributions of scores. Moreover they looked exclusively for correct answers, ignored wrong answers, and failed to provide feedback to students.

There are few studies of preservice or beginning teachers’ understandings of assessment. Kamen (1996) reported on factors influencing one beginning teacher’s adoption of different assessment strategies including performance assessment, logs, scrapbooks, and interviews. He found that the teacher's implementation of new assessment strategies was facilitated by administrative support, close contact with students' parents, and through assistance from university faculty. The teacher's use of formative and alternative assessments allowed her to better understand what her students were learning. Briscoe (1993) found that a teacher’s ability to change his assessment strategies was influenced by what he understood about teaching and learning. Because a teacher’s beliefs about teaching and learning are related to his/her knowledge and use of assessment (Briscoe 1993) it is important to determine the interplay of these knowledge components among teacher education students.
Pedagogical Knowledge

Science education researchers point out that general pedagogical knowledge (PK) also influences pre-service teachers' instructional decision-making (Lederman, 1999; Lederman, Gess-Newsome & Latz, 1994). Mellado (1998) found that pre-service teachers' primary source of pedagogical knowledge came from their experiences as students. Mellado reported that teacher education courses did not significantly change pre-service teachers' beliefs that teaching is essentially a “sequence of transmissive instruction” consisting of explanations, application exercises, and questioning (p. 204).

Research findings have demonstrated different levels of teacher knowledge (PCK and PK) which vary with teacher background and teaching context. Furthermore, researchers have begun to uncover some interaction among the different components of these knowledge bases. We believe that more research is needed to establish a baseline about the prior knowledge of individuals entering teacher preparation programs, to consider the interactions of different knowledge components in their thinking, and to understand the role of teaching experience in developing a teacher’s knowledge for teaching.

Research Design

In order to examine the prior knowledge for teaching of teacher education students with and without teaching experience, this research was designed as a comparative case study. Below we describe the research questions that guided the study, the context of the ACP in which the study took place, the research participants, and data collection and analysis methods.

Research Questions

The purpose of this study was to investigate the following questions: (a) What is the nature of beginning ACP teachers’ science teaching orientations and prior knowledge of learners,
instructional strategies, curriculum, and assessment? and (b) How does the prior knowledge for
teaching of ACP teachers with teaching experience compare to those lacking formal K-12
teaching experience?

The Research Context: A-STEP

The study took place in A-STEP, an ACP at a research extensive university. A-STEP is a post-baccalaureate program for students seeking certification in middle or secondary science teaching. Admission requirements include: (1) an undergraduate degree in a science discipline or a closely related field (e.g., engineering), (2) high undergraduate grade point average overall and in science courses as well as a strong GRE score, and (3) letters of recommendation. Students have to achieve a passing score on the PRAXIS II (>150 for biology) and successfully complete program requirements to be recommended for certification. When students enter the program, they select one of two tracks. The only point of departure for the tracks is the type of internship and the time required to finish the program. In the mentored internship track, students are placed in local secondary classrooms for a year-long internship. The interns observe and teach 20 hours a week in a mentor teacher's classroom. These students complete the program in 15 months. Participants in the independent internship are full-time teachers teaching with temporary certification who have complete responsibility for a middle or high school science classroom while they are taking A-STEP courses. In the independent internship, coursework is spread out and teachers typically finish the program in 24 months. In the internship for both tracks, A-STEP provides a university supervisor, a graduate student with secondary science teaching experience, who observes the interns and teachers on a monthly basis. (The A-STEP program is described in more detail in Abell et al., 2006).
Participants

When students entered A-STEP in the summer of 2006, they were invited to participate in the research study. Thirteen of the 14 students (12 females and 1 male) in the cohort agreed to participate. Two of these students were in the independent internship track (i.e., teachers) and the remaining 11 students were in the mentored internship track (i.e., interns).

To be able to compare the prior knowledge of participants’ in the two tracks, we used purposeful sampling. First, we examined the characteristics of the two teachers in the independent internship track (Helen and Maggie). Both had undergraduate degrees in biology, high GRE scores, and high passing scores on the PRAXIS II. Before entering A-STEP, Helen had one year of teaching experience as a full-time long-term substitute in high school biology, and Maggie had been teaching high school biology for two years. Next we examined the academic records of the interns in the guided internship track who were seeking certification in biology. We selected two interns, Erin and Susie, who had undergraduate degrees in biology and similar GRE and PRAXIS II scores to Helen and Maggie, but who lacked formal high school science teaching experience.

Data Collection

On the first day of the program, participants completed a lesson planning task (Valk & Broekman, 1999). For this task, we asked our biology participants to design plans for two consecutive days of teaching the state standard "there is heritable variation within every species of organism." Participants were instructed to plan for a class of 24 eighth grade students in a rural school. They were given one hour to complete the task and did not have access to science textbooks, other curriculum materials, or the Internet in completing the task. We placed these restrictions on the participants because we wanted to document their prior knowledge for
teaching, rather than having them rely on an external authority. We asked the participants to provide as much detail as possible and to address the following: (a) what they wanted student to learn; (b) a description of the beginning, middle, and end of each class; (c) a description of the teacher and students' roles; (d) a list of the materials they would need; and (e) any handouts or overhead transparencies they planned to use.

Immediately following the lesson planning task, we conducted a 1-hour, semi-structured interview with each participant (Patton, 2002). In the first part of the interview, we asked the participant to review her plans. We asked probing questions to elicit details of what the teacher and the students would be doing in each part of the lesson, and why the participant chose to design the plan in that way. In the second part of the interview, we asked participants a series of questions about their subject matter knowledge, science teaching orientations, and their knowledge of students, instructional strategies, curriculum, and assessment. The interview questions were designed to probe more deeply into specific components of the participant's knowledge for teaching as defined in our theoretical framework, as well as the sources of their knowledge. The interviews were audio-taped and transcribed verbatim. (All data collection tools are available by request at www.resmar2t.missouri.edu.)

Data Analysis

We coded the lesson plan and interview data using NVivo qualitative research software based on the Grossman (1990) categories of SMK, PK, and the Magnusson et. al. (1999) PCK components: (a) science teaching orientations, (b) knowledge of students' understanding of science; (c) knowledge of instructional strategies; (d) knowledge of curriculum; and (e) knowledge of assessment. We developed subcodes for each of these categories. We did not code for K of C because the teaching scenario was hypothetical and the participants could not have
specific knowledge of the rural middle school classroom in the lesson planning scenario. To facilitate within-case analysis, two researchers were assigned to independently code a participant's data. After the initial coding, each of the researchers wrote a summary profile for that participant. The summary profile facilitated data reduction and provided a synthesis of findings for each participant (Denzin & Lincoln, 2005). The researchers compared summary profiles and negotiated any discrepancies. Next, the entire research team read and discussed each summary profile and verified the data set for accuracy. Thus, we triangulated the data from the two data sources, lesson plans and interview transcripts, as well as through multiple researchers (Denzin & Lincoln, 2005; Yin, 1989).

In the second phase of the data analysis, we performed a cross-case analysis by examining all four cases for patterns and themes across the data set. We independently generated tentative assertions in terms of our theoretical framework. We tested these tentative assertions during group research meetings, with pairs of researchers checking their assigned participant's data to look for confirming and conflicting evidence. We revised the assertions until we reached consensus among the researchers.

Interpretations

Our overall research goal is to understand the development of teacher knowledge within two different tracks of an ACP. To develop a baseline understanding, this study focused on the prior knowledge of ACP teachers and interns. The first research question related to the nature of ACP participants’ prior knowledge. To address this question, we report the within-case analysis findings of each participant's knowledge for teaching. Our second research question sought to understand differences in knowledge among interns and teachers in the ACP. We provide these comparisons in the form of assertions in the cross-case analysis section.
Within-Case Analysis

Nature of Knowledge for Teaching Science: Lesson plans revealed a lack of topic-specific PCK. Instead participants relied primarily on general PK to address the lesson planning task.

The nature of each of the participants' knowledge for teaching is summarized in Table 1. Participants primarily drew on general knowledge that was not specific to teaching heritable variation. The participants were not aware of specific student misconceptions or difficulties associated with genetics concepts. The participants lacked knowledge of specific curriculum and curricular goals for teaching genetics to middle school students. Some of the participants were able to suggest a sequence of topics, but only on a general level. For example, Erin thought students needed to understand genetics before they could understand evolution. All of the participants lacked knowledge of topic-specific assessment strategies. We did find limited examples of topic-specific knowledge (PCK) in the instructional strategies component of their knowledge for teaching. In general, the participants' drew primarily on their PK to complete the lesson planning task, and showed little evidence of PCK for teaching heritable variation.

[Insert Table 1 about here]

Cross-Case Analysis

In this section, we compare the prior knowledge of participants with K-12 teaching experience to those lacking formal teaching experience. Maggie and Helen (teachers) had previous K-12 teaching experience and were enrolled in the independent internship track of the ACP, while Susie and Erin (interns) lacked K-12 teaching experience and were enrolled in the guided internship track. We begin the section with our interpretations of their science teaching orientations, followed by knowledge of learners, instructional strategies, curriculum, and
assessment. Throughout this section, the reader should keep in mind that much of the participants' prior knowledge was PK, not PCK in nature.

*Science Teaching Orientation:* Participants in both tracks held a didactic science teaching orientation focused on transmitting basic information to students to prepare them for the next level.

All of the participants viewed the goal of middle school science to be one of preparing students for high school science courses. Maggie (teacher) considered what she wanted her high school students to know at the beginning of the year. She worked backwards from that point to design the two lessons for middle school. Susie (intern) echoed the same goal for middle school students, stating, "They really need to have a solid foundation because if they miss stuff, like knowing about how DNA can change... they're not really going to get a lot of the more advanced stuff when they get to high school."

To provide middle school students with a strong foundational base of genetics knowledge, the participants viewed their role as transmitting information to the students, primarily through lectures. The majority of time in each lesson plan was for teacher lecture. These lectures focused mainly on genetics terminology. Susie (intern) summarized this perspective when she described that she designed her lessons to "try to cover the most ways to impart information."

All of the participants began their lessons with a short question and answer session; the interns used this activity to motivate the students to listen to the lecture. Erin (intern) explained her lesson plan in the following way:

Well each class day I wanted to start off with an introductory activity that sort of sparked their interest or made it sort of entertaining so that they would want to learn about it or at least they would begin class by paying attention, instead of just starting with lecture
where I would lose a lot of them right off the bat. I wanted to do something to get them involved, that they might find enjoyable. And then right after that I would go into the actual explanation part, the sort of lecture part of class that they all need to understand the material. (Erin, intern)

The teachers, Maggie and Helen, also engaged students in a brief discussion at the beginning of each lesson. However, the teachers used the discussion to gauge the students' prior knowledge to determine where to start their lectures. Maggie explained, "That [the initial discussion] would lead me into how in-depth I needed to get with the lecture and practice . . ." Nevertheless, all four participants focused on teacher-directed didactic instruction.

Although the participants held didactic teaching orientations, there was some evidence that they also held peripheral orientations. For example, Susie (intern) held a peripheral activity-driven orientation. She had the goal of making science fun for students and she thought students would have more fun with hands-on activities. Other participants discussed wanting to find hands-on activities for their students. In all cases, however, the didactic orientation was central.

Knowledge of Learners: Participants in both tracks acknowledged that students have prior experiences with phenomena, but do not have explanations for them. Interns did not anticipate that students would have any difficulties with their lessons, and based their understandings of middle school learners on their own K-16 experiences. The classroom teachers, drawing on their experiences teaching high school, anticipated that students might experience some difficulties.

During the interviews, the participants discussed how their lesson plans elicited student prior knowledge of heritable variation. They believed middle school students would be aware of human variation, but would not have explanations of the phenomenon. Helen (teacher) articulated this position:
I think that at a maybe unconscious level they realize there are variations. I mean, there are birds, but there are different kinds of birds. And there is hair, but there are different colors of hair. But to get them to understand why and how, and why that even makes any point in their life, you [the teacher] have to start talking about the basic genetics. (Helen, teacher)

In their lesson plans, three of the four participants--Maggie, Helen and Erin--asked students to compare their physical traits to those of their parents. This strategy was used to motivate students, but the participants did not think students would explanations for why they looked similar to, but different from their parents. Only Helen was aware that students might have misconceptions, but she was unfamiliar with common student misconceptions in genetics (e.g., many students believe dominant traits are more common). Consequently, all of the participants felt that they, as the teacher, needed to give the explanation of the phenomenon to the students.

All of the participants equated teaching with giving information to students. Susie and Erin (interns) were confident in their ability to give clear explanations, and consequently, believed that middle school students would have no difficulty with their lessons. In two 50-minute lessons, Susie planned to cover the following information: random variation caused by mutations, including deletions, insertions and substitutions; as well as the advantages of sexual reproduction, including Mendel's pea plants, monohybrid and dihybrid crosses, and incomplete dominance. When asked if she thought the students would have any difficulty with the lessons, Susie replied that she thought it would be fairly easy for them. Based on Erin's experiences tutoring friends and siblings, she was confident in her ability to explain things clearly so that students would have no difficulty understanding the lessons. Both Erin and Susie drew on their
own successful K-16 science learning experiences as they planned their lessons, assuming that students would be similar in terms of motivation, knowledge, and attitude to themselves as learners. Susie explained how she planned her lessons, "I really just drew off of what I really liked in high school, when we started talking about genetics and stuff like that."

During the interview, classroom teachers acknowledged that middle school students might experience some difficulties with the lessons. The teachers based this belief on their experiences teaching high school students. Helen realized that students varied in their learning styles, stating, "Different students learn in different ways, maybe some have to see the pictures, maybe some have to do the activity." Maggie believed abstract concepts, like dominance, would be harder for middle school students to understand. She felt that middle schools students would have an easier time learning concrete concepts that they could observe. Maggie also felt that students might struggle with some of the terminology used in genetics. Although the teachers anticipated that middle school students might have some difficulty learning the material, they identified more general learning difficulties, such as abstractness and terminology, rather than topic-specific learning difficulties associated with genetics (e.g., the difference between alleles and genes).

**Knowledge of Instructional Strategies:** Participants in both tracks used the same teaching sequence: a short questioning period, followed by lecture, and ending with guided practice. Interns relied on individual guided practice, while classroom teachers included small group work as part of guided practice.

One striking similarity across the four participants' lesson plans was their reliance on the same teaching sequence. They all began their lessons with a brief question and answer session, followed by a lecture, and closing with guided practice. The purpose of the questioning strategy
was not to build upon students’ prior knowledge, but for participants to focus the students on the lecture, to motivate the students to want to listen to the lecture, and to determine the starting point of the lecture. Helen (teacher) explained her use of questioning at the beginning of the lesson: “They may already know a lot and you're just going to bore them. So you just start with a question and get their input and start focusing them on what you’re going to talk about that day.”

Following the initial questioning, all four participants implemented teacher-centered, didactic instruction to transmit knowledge to students; equating teaching with telling. The participants viewed the lecture as the central part of their lesson with an emphasis on vocabulary terms (e.g., heterozygous, homozygous). Erin (intern) explained that students were more likely to grasp new concepts and terms if lectures were slow and sequential, “So, you sort of have to teach them slowly and one step at a time then they can understand it . . .” Maggie (teacher) described her lectures in a similar manner. “I like to be able to write it on the board one statement at a time, then if they get the statement, good. If not, then we’re going to do some illustrations or some examples or some explanation of that statement.” Participants relied on the same instructional strategy, repeating their explanation, if students failed to understand the explanation the first time. Even though two of the participants, Helen (teacher) and Erin (intern), expressed some concern that lecturing might not be the most effective instructional strategy, they had limited knowledge of alternative strategies.

In all of the lesson plans, the lecture material was re-enforced by guided practice (i.e., students completed worksheets). However, participants in the two tracks differed in student grouping during the guided practice. The interns asked students to work individually in completing the worksheets, handing them in at the end of class to be graded by the teacher. The teacher was viewed as the sole source of information in the classroom; the interns did not
consider that students might be able to explain the concepts to each other. The teachers differed from the interns in that they planned to have students work in small groups to complete the guided practice. Maggie designed a practice game in which students, working in pairs, moved around the room completing Punnett squares at different stations. Helen used group work as a management strategy, realizing that she could not answer all student questions at once. She wanted students to try to come to consensus on the worksheet answers before asking her questions. She believed that students who were struggling might benefit from the explanations given by their classmates. Both the interns and teachers viewed teaching as telling; however, the classroom teachers believed that students might also learn from hearing their classmates' explanations.

The instructional sequence of beginning with a short questioning period, followed by lecture, and closing with guided practice, reflects the participants' general PK. The participants used this sequence in both of their lessons. In the interviews, they described this sequence as a standard teaching script for any lesson. Although the participants relied primarily on their general PK to write their lesson plans, we did find a few examples of instructional strategies that were specific to teaching genetics (PCK). All participants used Punnett squares to represent and teach heritable variation, describing their use as a concrete, hands-on activity. The second example of PCK involved asking the students to compare their physical traits to their parents. Three of the four participants included this instructional activity in their lesson plans. Helen used it as a homework assignment, while two other participants (Maggie and Erin) used the activity informally in the short questioning period at the beginning of class.

Knowledge of Curriculum: Interns equated curriculum with the textbook. Classroom teachers had an expanded view of curriculum that included district and state guidelines.
The interns' views of curriculum were limited to the scope and sequence of concepts in a textbook. During the interviews, the interns did not refer to national, state, or school district curriculum guidelines. The interns did recognize the need for a logical sequencing of genetics topics. However, without a textbook, they were uncertain of the scope and sequence of topics appropriate for middle school students. Lacking knowledge of middle school science curriculum, the interns drew on their own learning experiences in high school and college science courses. During the lesson planning task, the interns felt hindered without a middle school science textbook, and equated the textbook with the science curriculum.

Although the classroom teachers relied heavily on textbooks in their teaching, they were aware of state and district curriculum guidelines. Of the two classroom teachers, Maggie had a more sophisticated understanding of curriculum. As a first year teacher, Maggie had been involved in her school's revision of the science curriculum. Based on this work, she was familiar with the state grade level expectations (GLEs) and their role in guiding curriculum development. She explained, “I’d look at the GLEs and make sure that the curriculum was even covering what the GLEs were telling us to cover. But obviously you don’t want to follow just the GLEs or that kind of thing, because those change.” Maggie regretted the time required to revise the curriculum guide, but saw the final product as useful.

But I like it [the curriculum guide], because now I have a better idea of what I should be doing next year, and a better idea of how I can fix things to help the students hopefully learn a little bit more about what they, in theory, they should know according to the state and the higher powers that be. (Maggie)

Because of Maggie's work in revising the school's curriculum, she viewed curriculum as generated by teachers but needing to align with the state GLEs. Helen's K-12 teaching
experience was limited to long-term substitute teaching. She was aware of district and state guidelines, but viewed curriculum as being generated externally and given to teachers.

**Knowledge of Assessment:** None of the participants included assessment in her lesson plans. When prompted, teachers planned to ask questions to informally assess throughout the lesson, while interns planned to grade student worksheets at the end of the lesson. Participants in both tracks used assessment to determine if they needed to repeat their explanations.

Assessment strategies were missing in all of the participants' lesson plans. In the interviews, the participants were asked how they would know if the students had learned the concepts in the lesson. In response to this prompt, teachers and interns described a limited set of general assessment strategies (e.g., quizzes, tests, and homework) to evaluate student progress; none of the participants described topic-specific assessment ideas.

The teachers and interns differed in the type of assessments they discussed and their timing. Maggie and Helen (teachers) described the use of informal questioning to assess their students' understanding throughout the lesson. Helen described how she assessed students in the following way, “You're walking around the room while they are working; you're listening to what they are saying . . . you ask questions to see if they can answer them.” Helen also paid close attention to her students' facial expressions and general body language to gauge their understanding. Maggie also used informal questioning to determine the students' understandings. She explained, "I'd kind of be asking different people, different groups of people, different questions to see where they were at." In general, the teachers said they would rely on verbal questioning throughout the lesson to assess students' understanding.

During the interviews, it was apparent that Susie (intern) had not considered how she would assess student understanding when she wrote her lesson plans. When prompted by the
interviewer, Susie decided that she could look at the students' Punnett square worksheets after class. In the interview, Erin indicated that she had considered assessment while writing the lesson plan. "I wanted to end the class with an individual activity so that I could make sure that everyone individually is understanding how to do the Punnett square." Erin planned to look at the students' worksheets at the end of the day. In contrast to the teachers, the interns did not discuss on-going assessment during their lessons; rather they planned to grade worksheets at the end of the day to inform subsequent lessons.

Although the teachers and interns differed in their use of assessments, both in type (informal questioning vs. grading worksheets) and timing (on-going vs. end of the lesson), all the participants used assessments for the same purpose -- to determine if they needed to repeat parts of their lecture. By using informal questioning during the lesson, teachers indicated that they would stop the lesson and repeat their explanations if they determined that students were not understanding. In contrast, the interns waited until the end of the day to assess their students' understanding based on worksheet grades, using this information to determine if they needed to repeat the lecture the next day. Erin explained that she would look at the worksheets to determine “what the majority of the people do not understand or do understand and so that the following day I can build upon that or re-explain certain concepts that most the class didn’t grasp the day before.” The participants in both tracks had limited views of the purposes of assessment that did not include helping students' monitor and assess their own learning. Rather, participants in both tracks viewed assessment solely for the purpose of informing their instruction, i.e., to determine if they needed to repeat their explanations.

*Integration of Knowledge Bases:* Classroom teachers showed evidence of integration of knowledge bases, while interns lacked integrated knowledge bases.
In the interviews, participants were asked to reflect on their instructional decision-making as they planned their lessons. The teachers' explanations were more elaborate, drawing on multiple knowledge bases as they explained their thinking; this did not appear to be the case for the interns. To show this difference between individuals in the two tracks, we generated new representations of their knowledge for teaching, as evidenced in the lesson planning task. We illustrate these differences by contrasting two individuals: Helen (teacher), who demonstrated the most highly developed teacher knowledge of the group, and Susie (intern), with the least developed teacher knowledge. (See Figures 2 and 3, which are explained in greater detail below.)

Four things should be noted about these representations. First, all 4 of the participants were selected for their strong SMK, and all strongly relied on their SMK in their lesson planning task. The contribution of SMK thus is represented with a thick arrow. Second, the didactic teaching orientation acted as a filter for the participants' PCK as well as their PK. Therefore, we have moved the placement of teaching orientations to reflect its influence on both PK and PCK. Third, none of the participants had knowledge of the specific context, because the lesson planning task was for a hypothetical rural middle school science class. Consequently, we have chosen not to include K of C in these particular representations. Fourth, the box representing PK is not to scale, having been expanded to show different categories within this knowledge base.

*Helen (teacher): integration of knowledge bases.* Helen's knowledge for teaching is represented in Figure 2. The participants with prior teaching experience (Helen and Maggie) were similar in that they showed a degree of interaction between PK categories, which we represent using overlapping circles. Helen’s PK of learners overlapped with her PK of assessment. She understood that students often give visual cues about their level of understanding, therefore she claimed to watch students’ facial expressions and body language
carefully to gain insight into their comprehension. Helen explained, “You see that on their face or they say it, then you work through enough examples, then they relax and they realize that it’s really kind of easy.” Helen also thought that students would learn from one another and designed assessment strategies that used peer instruction. She explained a part of her lesson, “So they’ll turn to each other and check and if anyone had a problem, they usually just work it out. Once they see what someone else did, they usually understand it.” Helen also connected her knowledge of learners to curricular decisions. For example, she decided to limit the number of concepts in her lesson plans, explaining,

> I thought, well maybe, they want you to go with that whole curve, the range of variation you see. Then I thought, that’s probably a little bit harder for anyone at the eighth grade level to understand, especially if they don’t have the basics first. (Helen, interview)

Although Helen's interview included multiple examples of interactions among general PK of learners, curriculum, and assessment, she made few connections to instructional strategies. We indicate this lack of interaction by keeping the circle of PK of instructional strategies have any strategies to challenge these misconceptions. Instead, based on her didactic orientation, she planned to re-explain the concept if students had misconceptions. Even though Helen’s general PK of assessment was more sophisticated than that of the other participants, she did not use her PK of assessment to inform her choice of instructional strategies. Helen's didactic teaching orientation and her limited repertoire of instructional strategies presented barriers to forming connections across all the knowledge components.
Susie (intern): lack of integrated knowledge. Susie's knowledge for teaching is represented in Figure 3. Susie had worked in a molecular genetics lab and possessed a great deal of knowledge about genetics and recombinant DNA techniques. Susie drew primarily on this subject matter knowledge to complete the lesson planning task, as represented by the thick arrow in Figure 3. Susie's PK was based on her experiences as a high school student; and consequently, this knowledge was limited to instructional strategies she recalled that her former science teachers used. Susie thought teachers should lecture and give worksheets. Lecturing, as an instructional strategy, was re-enforced by her college science experiences. Susie wanted to make the lesson more hands-on, and she felt that the worksheet accomplished this goal. Susie lacked knowledge of assessment (other than grading worksheets), middle school learners, and middle school science curriculum (indicated by dashed circles in Figure 3). This lack of knowledge was evident in her lesson plans. In her lesson for the first day, she planned to teach abstract concepts such as gene function and mutation to eighth graders. In her second lesson, after introducing students to monohybrid crosses, she designed a practice worksheet of dihybrid genetics problems, without having introduced dihybrid crosses to the students.

[Insert Figure 3 about here]

Susie loved science and drew on her own experiences as a science learner. She assumed that students would find the information "fun" and that they would have no difficulty understanding the material. Lacking knowledge of assessment, middle school learners, and curriculum, Susie drew on her strong subject matter knowledge and her general PK of instructional strategies to plan her lessons. Susie's PK knowledge was filtered through her didactic teaching orientation as she selected instructional strategies that primarily relied on telling students the information.
In summary, the teachers showed evidence of interaction among PK components. However, these interactions were limited, in that knowledge of assessment did not inform instructional decision-making or the use of alternative teaching strategies. The interns had knowledge of PK for instructional strategies, but lacked significant knowledge of other PK components (i.e., learners, assessment, and curriculum). Consequently, the interns relied primarily on their SMK to develop their lessons.

Discussion

We set out in this study to document the prior knowledge for teaching of biology preservice teachers upon entering an ACP, and to determine whether or not teaching experience was related to that knowledge. Like other researchers (e.g., Lee, Brown, Luft, & Roehrig, 2007), we found that teachers entering our alternative teacher certification program possessed limited prior PCK for science teaching (in this case for teaching heritable variation). Topic-specific knowledge about science learners, instruction, curriculum, and assessment was lacking. Furthermore, our participants’ knowledge for teaching, especially that of the interns, was based on their own experiences as learners, which Mellado (1997) also documented.

As predicted by Grossman (1990) and Magnusson et al. (1999), our findings indicate that a teacher’s science teaching orientation filters her understanding of learners; and knowledge and selection of instructional strategies, curriculum, and assessment. Whereas, Grossman and Magnusson placed teaching orientations as a filter to PCK, we found that the participants' didactic orientation also served as a filter for their PK knowledge. In our representations of the participants' knowledge for teaching, we have changed the placement of science teaching orientations to better reflect the powerful influence it had on our participants' PK and PCK. The four participants in this study entered the ACP with didactic science teaching orientations,
equating teaching with telling. The research literature supports this finding that pre-service teachers tend to believe that science teaching is teacher-centered (Mellado, 1998). Koballa (2005) found that ACP teachers held dominant and "back up" conceptions of science teaching. In our study, several participants held a peripheral activity-driven orientation, with the goal of making science fun for students. Although the activity-driven orientation seemed on the surface to contradict their didactic orientation, the purpose of the activities was motivational, not cognitive. Participants believed that students would still need to “learn” from the teacher’s lecture.

The participants' didactic orientation guided their thinking about learners, instruction, and assessment. Both teachers and interns believed that learners would have prior knowledge and experiences related to the genetics topic. They started each class by asking students questions which they claimed were about their prior knowledge. However, their questions were typically too broad or vague (e.g., “What do you know about heritable variation?”) to be successful in eliciting student knowledge. Instead, it appeared that asking questions was part of an instructional script, the purpose of which was to motivate and focus students prior to the lecture, rather than for the purpose of diagnosing students' existing conceptions to inform practice. This finding confirms Meyer’s (1999) report that pre-service teachers used pre-assessment for: a) determining where to begin the lecture; b) motivating students; and c) encouraging students to take responsibility for their learning by realizing what they do not know.

The didactic teaching orientation held by participants was exemplified in their use of similar instructional scripts in their lesson plans. All of the participants began their lessons by asking questions as discussed above, followed by a lecture focused mainly on terminology. After the lecture, students engaged in guided practice designed to verify the lecture material. This
sequence is similar to the Inform-Verify-Practice teaching sequence described in the science education literature as the traditional form of science instruction (Renner, 1982).

Consistent with a didactic orientation, participants perceived assessment mainly as summative, consisting of tests and quizzes to find out what students could repeat back from the lessons. Interns did not include assessment in their lesson plans because the lesson plans were only two days long, not long enough for a unit test. When prompted, they stated that they would use assessment to determine if they needed to repeat an explanation. The participants’ limited repertoire of instructional and assessment strategies, influenced by their didactic orientation, limited their instructional decision-making options.

In addition to our documentation of the orientations for science teaching and the knowledge of learners, instruction, curriculum, and assessment held by these ACP participants, we wanted to know if teaching experience matters. The common wisdom is that teachers learn to teach by teaching. This would lead us to expect the teachers in our sample to demonstrate greater knowledge than the interns. Yet Munby and Russell (1994) warn that teaching experience alone might not be sufficient in building knowledge; teachers also need to bring the authority of experience to bear on learning to teach through reflection.

Our findings indicate many similarities between teachers and interns in their orientations and other knowledge components. However, we did find some subtle differences between teachers and interns. For example, teachers anticipated that students might have difficulties with the lessons, while interns did not. However, the teachers could not point out topic-specific difficulties that students would have. Teachers included small group work as part of guided practice, while interns did not. Teachers were familiar with state standards, while interns were not. Teachers were more prone to use formative assessment in their instruction than were interns.
Yet the biggest difference between teachers and interns could not be discerned by looking at individual knowledge components. When we constructed a holistic picture of each teacher’s knowledge (see Figures 2 and 3), we found that the most striking difference between teachers and interns had to do with the integration of various knowledge components.

In this study, we used the Magnusson et al. (1999) PCK model to inform our data collection and analysis. The PCK model identifies the various components of PCK (science teaching orientations, knowledge of learners, instruction, curriculum, and assessment) that one would expect to find as part of an experienced teacher's PCK for teaching a specific topic. The components of the model formed the basis for our interview questions and analysis. However, the PCK model became problematic. In interviews, participants (especially the teachers) would often refer to multiple components of the model when they responded, making it difficult to collect data by categories consistent with the model. For example, when asked about instructional strategies, the teachers talked about their beliefs about how middle school students learn based on their experiences teaching high school students.

When using the PCK model categories during data analysis, two problems occurred. First, using the categories led to deficit thinking about what the participants did not know. For example, the interns lacked knowledge of assessment and curriculum, and the classroom teachers had limited knowledge in these two categories. Because we found this PCK deficit, we needed to return to the data with a revised framework that required analysis for PK as well as PCK. Second, when data analysis focused on individual PCK components, we failed to represent an important difference between participants in the two tracks. The classroom teachers' data indicated that they made instructional decisions based on an integration of different components of the PK knowledge base (e.g., learners and curriculum). This finding demanded that we generate new
representations of their knowledge for teaching to illustrate the differences between individuals the two tracks.

The knowledge models we presented for Helen and Susie are modifications of the teacher knowledge model in our theoretical framework (Figure 1). These representations portray the differences between the interns and classroom teachers. For the teachers, there was interaction among several components of teacher knowledge, specifically components of PK. For example, Helen’s knowledge of learners informed her thinking about assessment. However, these interactions were limited, in that knowledge of assessment did not inform instructional decision-making or the use of alternative teaching strategies. The interns did not demonstrate any connections among the teacher knowledge components, but relied on their SMK to develop their lessons.

The findings from this study provide indicators of interns’ and teachers’ initial teacher knowledge. Their initial knowledge for teaching was dominated by their subject matter knowledge, their orientations to science teaching, and their PK. We predict that, as these individuals move through the ACP, their knowledge for teaching will continue to develop. We hypothesize that this development will move from separate to integrated PK, to a science-specific PCK (Veal & MaKinster, 1999) to, eventually, an integrated PCK for teaching individual science topics. The continued development of teacher knowledge will require continued modifications to our representations of that knowledge. It will be important to document if the small differences between the interns and the teachers at the start of the ACP influence their continuing development of teacher knowledge.

Does teaching experience matter in the development of teacher knowledge? Our findings, although limited, indicate that teachers had knowledge for teaching that interns did not have, and
they were able to integrate their knowledge bases when making instructional plans. Our findings concur with those of other researchers who have found that teaching experience matters in the development of teacher knowledge (e.g., van Driel, Beijaard, & Verloop, 2002). However, we exercise caution. We know that learning from teaching experience is not a straightforward proposition (Munby & Russell, 1994). We need to investigate teacher knowledge development throughout and beyond the ACP in order to understand the interplay of teaching experience with formal teacher preparation experiences.

Implications and Conclusion

The participants in this study had limited PCK coming into the ACP. We believe, along with Shulman and colleagues, that the development of teacher knowledge, and in particular PCK, is the primary goal of science teacher education. Thus, we recommend that science teacher educators use PCK as an explicit framework in their courses for planning, implementing and evaluating instruction. In addition, we recommend making the PCK framework explicit to our teacher preparation students. This could lead to the development of shared expectations for their learning and help them reflect on the development of their own knowledge for teaching (Loughran, Berry, & Mulhall, 2006) in formal coursework and in field-based experiences.

The participants in this study held a didactic teaching orientation – one that is incongruent with reform-based inquiry-oriented teaching. All four participants designed lessons in terms of an implicit 3-step script: motivate, lecture, and practice. They characterized teaching as telling students what to learn and learning as students memorizing what they were told. This didactic orientation filtered their knowledge for teaching. We believe this orientation is strongly held and difficult to change. However, as science teacher educators, it is our job to challenge teacher views of teaching and learning and help them shift to an inquiry orientation. To do this,
we must help them become dissatisfied with Inform-Verify-Practice as the predominant teaching script and provide alternative scripts that put explaining after exploring (e.g., the learning cycle, Abraham & Renner, 1986; the 5E model, Bybee, 1997). Drawing on their peripheral activity-driven orientations may be a way to help teachers develop a more student-centered science teaching orientation.

In this study, the participants with teaching experience were better able to integrate their various types of PK to inform practice than those without teaching experience. Because we found that teaching experience promoted the integration of knowledge for teaching, we believe that teacher education programs must design meaningful field experiences which include effective mentoring (Abell, 2006). These mentored experiences need to include explicit attention to teacher knowledge development. Thus it is important for interns to be engaged in communities of practice where teachers work together to assess student work, reflect on practice, challenge common myths of teaching, and share best practices. Effective school-based mentors would understand the model of knowledge for teaching espoused by the teacher education program and share common goals for beginning teachers with university faculty. This will be especially challenging for ACP programs where full time teachers may not have access to school-based mentors or time to take advantage of communities of practice.

The research on science teacher knowledge remains inadequate (Abell, 2007). We believe that large longitudinal datasets are needed to generate and test models of PCK development. What types of experiences influence PCK development? How do we best represent the dynamic nature of the inter-relationships among PCK components? Do other types of knowledge for teaching develop first, before topic-specific PCK can develop? In what ways do teaching orientations influence PCK development? What happens to PCK development when
orientations shift over time? What types of teacher education experiences support PCK development? To answer these questions, we need to develop substantiated models of science teacher knowledge development.

Recognizing future teachers’ knowledge for science teaching is critical for improving science teacher education. As other researchers have suggested, we believe that understanding beginning teachers’ knowledge development, including their knowledge upon entry into teacher preparation, must be the foundation for traditional and alternative teacher education program design (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 cannot significantly impact teacher practices or student learning (Luft, 2001; van Driel, Beijaard, & Verloop, 2001). Given the baseline established in this study, the next step in our research is to examine how teacher knowledge, and PCK specifically, is developed throughout an ACP and into the beginning years of teaching, paying attention to what facilitates and constrains teacher learning.
References


National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it’s too late: A report to the nation from the National Commission on*


Figure Captions

Figure 1. Theoretical framework of knowledge for teaching

Figure 2. Knowledge for teaching representation: Helen

Figure 3. Knowledge for teaching representation: Susie
Knowledge for Teaching, 47

Knowledge of Facts and Concepts

Syntactic and Substantive Knowledge

Includes

Subject Matter Knowledge

Includes

Instructional Principles
Classroom Management
Learners & Learning
Educational Aims

Includes

Pedagogical Knowledge

Influences

Orientations

Includes

Curricular Knowledge for a Particular Topic
Knowledge of Assessments for a Particular Topic

Includes

Pedagogical Content Knowledge (Topic Specific)

Includes

Knowledge of Instructional Strategies for a Particular Topic
Knowledge of Students Understanding within a Particular Topic

Includes

Knowledge about Context

Includes

Students
School
Community
District
Didactic Science Teaching Orientation

- Subject Matter Knowledge
- Pedagogical Knowledge
  - Knowledge of Instructional Strategies
  - Knowledge of Assessment
  - Knowledge of Learners
  - Knowledge of Curriculum

PCK for Heritable Variation

- Instructional Strategies:
  - Punnett squares
  - Familial traits

Lesson Planning Task
Didactic Science Teaching Orientation

Subject Matter Knowledge

Pedagogical Knowledge

Knowledge of Instructional Strategies

Knowledge of Assessment

Knowledge of Learners

Knowledge of Curriculum

PCK for Heritable Variation

Instructional Strategies:
- Punnett squares
- DNA sentence analogy

Lesson Planning Task
<table>
<thead>
<tr>
<th>Participant</th>
<th>Teaching Orientation</th>
<th>PK/ PCK</th>
<th>Knowledge of Learners</th>
<th>Knowledge of Instructional Strategies</th>
<th>Knowledge of Curriculum</th>
<th>Knowledge of Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helen (teacher)</td>
<td>Didactic PK</td>
<td>Aware that students have prior knowledge and might hold misconceptions</td>
<td>Elicits students' prior knowledge to avoid boring them in lecture</td>
<td>Views curriculum as dictated to the teacher by outside source: school district and textbook</td>
<td>Assessment missing from lesson plan</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Students' learning styles vary</td>
<td>Lecture as primary strategy, followed by textbook reading</td>
<td>Aware of existence of state standards</td>
<td>Relies primarily on informal and on-going assessments: looking at students' body language, listening to their questions and explanations</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sources: High school teaching experience</td>
<td>Aligns strategies with lesson objectives</td>
<td>Curriculum should be relevant to students</td>
<td>Uses informal assessment to determine if she needs to repeat her explanation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Talks about the need to vary strategies to avoid student boredom and potential management problems</td>
<td>Source: High school substitute teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCK</td>
<td></td>
<td>For homework, students identify common family genetic traits</td>
<td>[Aware that she is unfamiliar with 8th grade genetics curriculum]</td>
<td>Compiles student data to look for patterns within the class to introduce dominant and recessive alleles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use of Punnett Squares for monohybrid crosses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maggie (teacher)</td>
<td>Didactic</td>
<td>PK</td>
<td>Middle students would find it easier to learn concrete concepts rather than abstract ones. Students often forget basic terminology learned in previous classes.</td>
<td>Elicits students' prior knowledge to determine the starting point of her lecture and to make connections with their past experiences. Lecture as primary strategy, followed by small group guided practice.</td>
<td>Views curriculum as being negotiated and written by teachers in the school with state standards as guidelines. Views middle school curriculum as preparation for high school courses.</td>
<td>Assessment missing from lesson plan. Relies on on-going, informal assessment during class discussions to determine what she needs to teach or if explanations need to be repeated. Purpose of assessment is to determine if students have met the state guidelines and district objectives.</td>
</tr>
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<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Susie (intern)</td>
<td>Didactic</td>
<td>PK</td>
<td>Unfamiliar with middle school learners' knowledge but thought it important to keep them physically moving. Teacher must provide students with explanations. Did not anticipate middle school students having difficulty with complex college-level concepts.</td>
<td>Opening question to stimulate interest. Lecture as primary strategy, followed by independent guided practice (worksheets).</td>
<td>Equates curriculum with textbook. Unaware of district and state guidelines. Lacked knowledge of appropriate scope and sequence for middle school science.</td>
<td>Assessment missing from lesson plan. When prompted, replied she could look at the worksheet answers after class.</td>
</tr>
</tbody>
</table>

**Note:**
- PCK refers to Pedagogical Content Knowledge.
- PK refers to Pedagogical Knowledge.
- Didactic refers to an approach that emphasizes direct instruction and the transfer of knowledge from the instructor to the learner.
- Other goal: Having fun indicates a secondary objective besides the primary didactic goal.
<table>
<thead>
<tr>
<th>Erin (intern)</th>
<th>Didactic</th>
<th>PK</th>
<th>PCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will not be able to develop explanations of the phenomenon</td>
<td>Begins lesson with exploration of the phenomenon to motivate students and connect to their prior experiences</td>
<td>Equates curriculum with textbook</td>
<td>Assessment missing from lesson plan</td>
</tr>
<tr>
<td>Students must be motivated by the teacher before they are ready to learn</td>
<td>Lecture as primary strategy, supported by textbook readings.</td>
<td>Unaware of district and state standards</td>
<td>When prompted, replied she would assess by using tests and looking at worksheet answers at end of lesson</td>
</tr>
<tr>
<td>Teacher motivates students by making material relevant and by grades</td>
<td>Independent guided practice (worksheets) after lecture</td>
<td></td>
<td>Purpose of assessment is to determine if she needs to repeat the explanation</td>
</tr>
<tr>
<td>Clear lecture explanations lead to student learning</td>
<td>Small group activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sources: High school and college science learning experiences</td>
<td>Aware that she should not lecture the entire class period, and used guided practice as an alternative strategy</td>
<td></td>
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<tr>
<td></td>
<td>Compare individual students' traits to parents' traits</td>
<td>Students need to know about traits and Punnett Squares to comprehend evolution and inherited human diseases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use of Punnett Squares fundamental to understanding inheritance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coin toss activity to teach probability</td>
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</tbody>
</table>
Author Note

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