The PCK of Future Science Teachers in an Alternative Certification Program

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Conference Paper is available at http://www.coe.missouri.edu/~volkmannnmj/narst07.doc

This material is based upon work supported by the National Science Foundation Teacher Professional Continuum (TPC) program under Grant No. 0202847. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
Abstract

Alternative certification programs (ACPs) have been proposed as a viable way to address teacher shortages. This study is part of a larger, longitudinal study examining the development of pedagogical content knowledge (PCK) within an ACP designed for post-baccalaureates seeking secondary science certification. Four individuals were selected from a cohort of 15 ACP students for this study; two biology interns, completing a yearlong mentored internship, and two full time biology classroom teachers not paired with a mentor. Data collection involved a lesson planning task and a follow-up interview. Both teachers and interns held didactic teaching orientations and used the same teaching script in their lesson plans: short question and answer period, lecture, followed by guided practice. However, classroom teachers implemented collaborative guided practice. Both groups acknowledged that students had prior experiences with the phenomenon but not explanations. Neither group included assessment strategies in their lesson plans. In regard to curriculum, the interns equated curriculum with the textbook, while teachers had a more expanded view of curriculum. Interns drew on their own K-12 learning experiences when considering middle school learners while the teachers drew on their teaching experiences with high school students. Implications for research and teacher education are included.
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Rationale and Purpose

Alternative certification programs (ACPs) have been proposed as a viable way to address teacher shortages. However, researchers have found mixed results regarding the extent to which ACPs produce “highly qualified” teachers. For example, Darling-Hammond, Chung, and Frelow (2002) found that teachers in traditional programs felt more prepared to teach than teachers in ACPs. ACP teachers in the Teach for America program relied on instruction that encouraged memorization and following rules more than their traditionally certified counterparts (Decker, Mayer, & Glazerman, 2004). In contrast, Gomez and Stoddart (1992) found that ACP teachers held higher expectations for underprivileged students, leading to the potential for increased student achievement.

Much of the research has compared outcomes of traditional and alternative programs. However, Stoddart and Floden (1996) argued that the choice between a traditional program and an alternative route is not a choice between some professional preparation and no preparation. Instead the argument is about the timing and institutional context for teacher education and how best to help teachers develop the knowledge and skills to be “highly qualified.” In particular, further research is needed to understand teacher learning within the context of specific ACPs. This study is part of a larger, longitudinal study examining the development of teacher knowledge within an ACP designed for post-baccalaureates seeking secondary science or mathematics certification. This qualitative case study specifically focused on documenting beginning biology teachers' pedagogical content knowledge (PCK) related to teaching genetic variation when they entered the ACP.

Theoretical Framework

In this study, we use Magnusson, Krajcik and Borko's (1999) PCK Model, which is based on the work of Grossman (1990) and Shulman (1986). PCK results from the integration of knowledge about students, curriculum, instructional strategies, and assessment that are related to the content. (See Figure 1.) For example, suppose a high school biology teacher decides to engage students in learning about the concept of genetic dominance. That teacher needs to know something about the misconceptions that students may bring to class – for example, many students believe that dominant traits are stronger than recessive traits. Biology teachers with strong content knowledge know that dominance is a hold-over from Mendel’s observations of pea plants. Mendel’s selection of terminology supports a naïve version of genetics that experienced teachers challenge. This same biology teacher needs to know what curriculum materials and instructional strategies are particularly effective in engaging students in learning about dominance. Finally, the teacher needs to understand how to effectively assess student learning about dominance.

Our framework is based on four assumptions: (1) PCK is knowledge that is transformed and more powerful than its constituent parts (Gess-Newsome, 1999); (2) teacher knowledge influences classroom performance and student learning; (3) experienced teachers draw upon
multiple knowledge types simultaneously as they make instructional decisions; and (4) novices
draw on a smaller number of knowledge types as they make instructional decisions. Below we
describe how we defined each of the knowledge categories alluded to above. Additionally, we
describe how science teaching orientations filter these knowledge bases. We use these definitions
to ascertain relative PCK for each participant in our study.

Science Teaching Orientations

Magnusson et al. (1999) used the label “orientation,” as a way to categorize disparate
approaches to science teaching. Magnusson et al defined orientation as teacher knowledge of the
purposes and goals for teaching science at a particular grade level, after Grossman (1990), but
also called an orientation a “general way of viewing or conceptualizing science teaching” (p. 97).
Their list includes nine orientations: activity-driven, didactic, discovery, conceptual change,
academic rigor, process, project-based, inquiry, and guided inquiry.

Knowledge of Student Understanding

Student understanding refers to what students know about a topic, how students learn
best, and what science topics and science ideas are difficult for students to learn. Knowledge of
student understanding means the teacher knows what knowledge and skills students need in
order to learn specific content, common misconceptions students bring to instruction, and ideas
students find difficult to learn. Each of these is described below.

Knowledge and skills. Knowing what concepts and skills students bring to a topic helps
the teacher know where to begin with instruction. For example, knowing that students have
studied Mendelian genetics in an earlier course helps the teacher plan meaningful lessons that
build on models of simple dominance.

Common misconceptions. Knowing common misconceptions helps the teacher plan and
challenge student thinking. For example, many students believe that male offspring inherit traits
from the male parent and female offspring inherit traits from the female parent (Driver, Asoko,
Leach, Mortimer, & Scott, 1994). Knowing this, the teacher can challenge students to predict
what traits male and female kittens will have, given a long hair mother cat and a short hair father
cat. Most students predict that all male offspring will have short hair and all female offspring
will have long hair. Observation followed by explanation forces the students to reconsider how
fur length is transmitted from parents to offspring.

Difficult ideas. Ideas that include abstract explanations or detailed knowledge are
sometimes difficult for students to learn. Knowing what students find difficult helps the teacher
plan special interventions designed to support student learning. For example, students typically
find sex-linked traits difficult to understand. A study of feline fur coloration provides several
straightforward sex-linked variations that students can investigate. Combining the Punnett square
notation with chromosome diagrams (see Stewart, Cartier, & Passmore, 2005) provides clever
representations to support student understanding of sex-linked inheritance. Understanding what
students find difficult helps the teacher decide what strategies to use.

Knowledge of Curriculum

Curriculum may be defined in a number of ways. For example, curriculum could be
defined as what students learn (the received curriculum) or what teachers teach (the delivered
curriculum) or what gets assessed (the assessed curriculum) or what the textbook says (published
curriculum). However, none of these contexts is particularly effective in revealing teachers’
knowledge of curriculum. For this reason, we define curriculum in terms of what the teacher
intends to teach. The intended curriculum is indicative of what the teacher knows about goals,
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Instructional materials, and the sequence of those materials. We use these three key areas to refine our definition of knowledge of the curriculum below.

**Goals.** Goals define what is to be taught. The teacher’s subject matter knowledge contributes to the selection of appropriate factual, conceptual, and skill-based goals. The teacher should be aware of resources that inform when and how much to teach. These resources include local, state, and national science education standards, as well as exemplary programs that provide models for consideration. Finally, the teacher should engage in long-term and short-term planning that uses goals to guide instructional decisions.

**Instructional materials.** Typically, the text is the resource that most teachers describe as the primary instructional material. However, there are additional resources that teachers use to replace or supplement the text. Sources include other teachers, state and national conventions (NSTA), funded institutes or summer academies, the internet, other programs, and prior experiences teaching the topic. Knowledge of the history of science curriculum reform may provide important background information about useful instructional materials from the past (Atkin & Black, 2003), as well. Knowledge of these sources contributes to the teacher’s knowledge of curriculum.

**Sequence of instruction.** Understanding what students learn over the course of several years makes it possible to vertically articulate scientific knowledge in a planned sequence of instruction. A similar approach can be used within a course (from unit to unit), to sequence instruction in an organized fashion. Finally, awareness of what is being taught in other subject areas makes it possible to sequence instruction that supports learning cross-discipline ideas (horizontal articulation). For example, knowing when students study the history of eugenics in social studies, makes it possible to sequence inheritance at a similar time.

**Knowledge of Instructional Strategies**

We define instructional strategies as the approach and the activities teachers choose to support student learning. The approach is akin to orientations, described above. The activities are the instructional events the teachers use in the class to teach specific lessons. For example if a teacher believes that students learn best through careful listening (didactic and rigor orientation), then the teacher will likely choose lecture as the most appropriate strategy. If the teacher believes that students learn best through investigations (project or process orientation), then the teacher might choose laboratory activities as the most appropriate strategy. Finally, if the teacher feels that students learn best when they encounter scientifically oriented questions to answer (guided inquiry or conceptual change orientations), then the teacher may decide to ask the students to solve difficult science problems. These three examples are subject-specific.

Teachers may elect to use topic specific instructional strategies, as well. For examples, the teacher may use a modeling approach using pedigree charts to teach PKU inheritance in humans. Another example of a topic specific strategy is the Punnett square used by biology teachers to demonstrate probability distribution of phenotype traits in a given population.

**Knowledge of Assessment**

We define assessment as finding out what students know in relation to the goals of instruction. Knowledge of assessment includes knowing the purposes and strategies of assessment and the abilities to construct and implement them. The purposes of assessment include (1) evaluating students in order to grade their performance; (2) informing instructional decision making; and (3) supporting student metacognition. The strategies of assessment are discussed below in terms of each purpose.
Evaluating students. Traditional assessment, consisting of paper and pencil activities, can come during instruction (in the form of quizzes) and at the end of instruction (in the form of a test or exam). Regardless of when they are used, both are designed to reveal what students have learned in terms of the goals of instruction and at what level they have learned those goals (see Bloom, 1956). Examples of traditional assessment strategies include multiple choice, true/false, fill in the blank, and short answer essay. Non-traditional evaluation consists of activities that resemble instruction. For example, students may be asked to complete a portfolio or investigate a local problem as a culminating activity. A rubric is invented by the teacher and is used to evaluate student learning and to grade progress.

Informing instructional decision-making. Teachers who are aware that students bring prior ideas to the classroom and that those ideas interfere with learning are also aware that teachers must monitor student understanding continuously in order to help students build scientific explanations (Fennema, 2002). A number of assessment strategies have been developed over the past ten years that are designed to reveal student understanding as a seamless process of instruction and assessment (see Volkmann & Abell, 2006). These strategies are used before, during and after instruction. Examples of assessment strategies include brainstorming, concept mapping, interviewing, and science notebooking. These strategies provide information to the teacher that informs next-step decisions or next-year decisions, depending on when they are used.

Supporting student metacognition. Metacognition means becoming aware of themselves as information processors (Donovan & Bransford, 2005). Ideally, a student will compare what he/she has learned to the instructional goals and know what to do next to achieve understanding. Metacognition is enhanced when teachers use self assessment tools such as exit slips and self check quizzes.

The ability to construct and implement assessment at the right time for the right purpose is a challenging task. An expert teacher uses the instructional goals as a guide to design and implement traditional tests and quizzes. The expert designs rubrics to use in the evaluation of alternative forms of assessment. The expert teacher uses assessment strategies to reveal student learning at every instructional step. The assessment is designed to instruct the student while providing information to the teacher about next steps. Knowledge of assessment includes knowing what strategies to use to elicit prior ideas, gauge student progress, inform instructional choices, and to produce reliable evaluation of student learning.

Literature Review

Alternative teacher certification has been a controversial topic in teacher education (Darling-Hammond, Berry, & Thoreson, 2001; Stoddart & Floden, 1995; Zeichner & Schulte, 2001), yet both alternative certification and traditional programs aim to develop beginning teachers' knowledge. Our review of the literature on pre-service and beginning teachers' knowledge is organized using the components of the Magnusson et al. (1999) PCK model.

Science Teaching Orientations

Teaching orientations have been identified in the literature using a variety of terms. Gurney (1995) identified four different "views of learning" held by pre-service teachers, which included teaching as delivery, enlightenment, change, or humanic. Koballa, Glynn, Upson and Coleman (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. Koballa reported the teachers' conceptions about science teaching guided their instructional decision-making and were consistent with their teaching practice. While the teachers held a dominant conception of science teaching, it was possible to hold multiple conceptions simultaneously. When the ACP teachers attempted to implement reform-oriented instruction, it created tension with their existing conceptions about science teaching. Koballa argued that ACP teachers' conceptions about science teaching were formed by their prior experiences; these existing conceptions acted as barriers as the teachers were reluctant to re-consider their conceptions about science teaching. 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. Simmons et al. reported that beginning teachers described their beliefs as student-centered, yet they acted in teacher-centered ways. Friedrichsen and Dana (2002), in a study of exemplary, experienced 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.

Knowledge of Learners

Experienced teachers’ understanding of learners is one of the factors that influence their instructional decision-making (Davis, Petish, & Smithey, 2006). Abell, Bryan and Anderson (1998) reported that while pre-service teachers give significant considerations to their students as learners, they failed to do so in extensive or careful ways (e.g., focusing instead on student interest or motivation rather than learning). Moreover, Meyer, Tabachnik, Hewson, Lemberger and Park (1999) reported that while pre-service teachers considered identifying students' prior knowledge as important, they did so for different reasons. The pre-service teachers in the study acknowledged that students had a range of ideas and that it was important to elicit these ideas. However, each pre-service teacher elicited students' ideas for a different reasons; those reasons were: (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 didn't know. Southerland and Gess-Newsome (1999) found that pre-service teachers assumed students had fixed abilities and designed their instruction accordingly. When considering learners, pre-service teachers' instructional decision-making is often hindered by their limited repertoire of instructional strategies (Tabachick & Zeichner, 1999).

The pre-service teacher literature on understanding students as learners shows no single consistent pattern (Davis, 2006). This finding may be partially explained by de Jong and van Driel's (2001) study of prospective chemistry teachers' concerns as they designed and implemented chemistry lessons. Less than half of the pre-service teachers in the study reported any concerns related to student learning. In another study of pre-service chemistry teachers, van Driel, Beijaard and Verloop (2002) found that actual classroom teaching experience played a major role in the development of pre-service teachers' understandings of students' prior conceptions, and also influenced their instructional decision-making as related to the use of macro and micro-level representations of chemistry concepts. Given these findings, it is important to examine the nature of ACP teachers' knowledge of learners, particularly when some
of the teachers had significant prior teaching experiences, as well as other factors influencing their knowledge of learners, and how this knowledge is used in instructional decision-making.

**Knowledge of Instructional Strategies and Subject Matter Knowledge**

Research on pre-service science teachers’ view of teaching and learning shows that many enter teacher education programs with simplistic views of teaching and learning, and believe teaching is transmitted new concepts to students. Geddis, Onslow, Benyon & Oesch (1993) reported that pre-service teachers viewed teaching as transmitting subject-matter knowledge to students and if the teacher could clearly articulate ideas through lectures and verification laboratories, then students would have little difficulty learning science. Eick and Reed (2002) found that pre-service teachers’ prior experiences were a major influence in how they chose to teach science during an internship. One of the teachers was frequently observed using inquiry strategies that actively involved students. This teacher acknowledged that she had negative prior experiences learning science by lecture. The choice of instructional strategies is not only influenced by prior experiences and teaching orientations (as discussed earlier), but also by constraints placed by adherence to the local curriculum and high stakes testing (Hanley & McArthur, 2002); classroom management issues (Zemba-Saul, Krajcik & Blumenfeld, 2002); and university coursework (van Driel, de Jong & Verloop, 2002). Individuals who enter ACPs tend to be older and represent more diverse backgrounds and experiences (Fuller & Alexander, 2004). Therefore, in order to understand teachers' PCK development within an ACP, it is important to consider their prior teaching and learning experiences, and how these experiences influence their choice of instructional strategies.

Both subject matter knowledge (SMK) and pedagogical knowledge (PK) influence pre-service teachers' instructional decision-making (Lederman, Gess-Newsome & Latz, 1994), although PK is likely to have a greater influence on student learning (Goldhaber & Brewer, 2000; Guyton & Farokhi, 1987; Monk, 1994; Rowan, Chiang, & Miller, 1997). Moreover, Monk (1994) suggests that there is a threshold to the influence of SMK on student achievement. 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 an explanation, application exercises and questioning (p. 204).

**Knowledge of Assessment**

There are few studies on pre-service or beginning teachers understandings of assessment. However, Kamen (1996) reported on factors influencing one beginning teacher’s adoption of different assessment strategies including performance assessment, logs, scrapbooks and interviews. Kamen 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. In the study, the teacher's use of formative and alternative assessments allowed her to better understand what her students were learning.

**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 a concept. 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). Geddis et al. found that two pre-service elementary teachers, who lacked knowledge of the major concepts in the school curriculum, would occasionally spend additional time teaching non-essential or trivial concepts. Southwell and Gess-Newsome (1999), in a study of 22 pre-service teachers, reported that pre-service teachers tended not to question the school's curriculum. Despite knowing that curricular knowledge affects instructional decisions (Haney & McArthur, 2002), there is a lack of research on ACP teachers' prior knowledge of curriculum and how that influences their learning about teaching.

**Influence of Teaching Experience in Teacher Education Programs**

We found no ACP studies that examined the differences between teachers with and without formal K-12 teaching experience. However, Russell (2000) (as cited in Russell and Martin, 2007) reported on the effect of teaching experience in a pre-service teacher education program. By adding teaching experience as a requirement prior to entering the program, the pre-service teachers' perceptions about teaching and learning were changed to more constructive frames. Teaching experience changed the teachers' attitudes toward instruction. Prior to teaching, the teachers considered discussion and students' opinions as irrelevant to learning. After teaching experience, discussion was seen as crucial to learning. More importantly, the teachers changed their views from learning as being passive to learning as an active process. While this study looks at pre-service teachers' learning, the influence of their experiences as learners, is likely to influence their beliefs as teachers (Geddis et al., 1993; Koballa, 2005; Meyer, 2002).

Many factors influence beginning teachers' instructional decision-making. However, the research on ACPs has primarily focused on: (a) the characteristics of individuals participating in ACPs (i.e., gender, age, race), (b) the comparative performance of ACP teachers and traditional teachers in terms of student achievement, (c) the impact of ACPs on traditional programs, and (d) teacher retention (Zeicher, 2001). Missing in the literature is research on teacher learning within an ACP. This study is part of a larger longitudinal study intended to examine teachers' PCK development within a particular ACP with two tracks: interns with no teaching experience and full-time classroom teachers with prior K-12 teaching experience. This study examines the interns' and teachers' PCK for teaching a specific topic when they enter the ACP.

**Research Questions**

The purpose of this research is to investigate the following questions: (a) what is the nature of the participants' science teaching orientations, as well as their knowledge about learners, instructional strategies, assessment, and curriculum when they enter an ACP; and (b) How does the PCK of participants with teaching experience compare to that of interns lacking formal K-12 teaching experience as revealed in the lesson planning task?

**The Context: Alternative Certification Program**

The study took place in an ACP at a research extensive university. The ACP is a post-baccalaureate program for students seeking certification in middle or secondary mathematics or science teaching. The ACP's admission requirements include: (1) an undergraduate degree in a science or mathematics discipline or a closely related field (e.g. engineering), (2) an undergraduate grade point average of 3.0 or higher (on a scale of 4.0), (3) a score of 150 or higher on the PRAXIS II exam (for biology teachers); and (4) letters of recommendation. When
students enter the program, they select one of two tracks. 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. The mentor teacher closely supervises the intern throughout the school year. The intern track is the most popular track and is similar to traditional student teaching in an undergraduate pre-service program. The second track, the independent internship, is for individuals who are full-time classroom teachers teaching with emergency certification. In both tracks, the ACP provides a supervisor, a graduate student with secondary science teaching experience, who observes the students on a monthly basis. Students enter the program as a cohort and complete 35 hours of coursework, including three science methods courses, one integrated science and mathematics methods course, as well as coursework in educational psychology and special education. The only part of departure within the ACP is the type of internship and the time required to finish the program. In the mentored internship, students complete the program in two summers and an academic year. In the independent internship, teachers are given additional time to complete their master's thesis project and typically finish the program in 24 months. At the end of the program, students in both tracks are granted full state certification and a Masters degree in Education (M.Ed).

Research Design & Data Analysis

When students entered the ACP in the summer of 2006, they were invited to participate in the research study. Fourteen of the 15 students (13 females and 1 male) in the cohort agreed to participate. Three of these students were in the independent intern track (i.e., classroom teachers) and the remaining 11 students were in the mentored internship track (i.e., interns). On the first day of the program, participants completed a lesson planning task (Van Der Walk & Broekman, 1999). For this task, participants were asked to design two consecutive days' lessons for teaching a selected middle school science concept. We selected a concept for each science discipline using the following criteria: concept was supported in both the National Science Education Standards (1996) and the state's grade level expectations; topic had a range of applicability, and would most likely be familiar to the participants.

In this paper, we report the results from a sub-set of the participants who were seeking certification in biology. The selected biology concept was "there is heritable variation within every species of organism." Participants were instructed to plan two 50-minute lessons for a class of 24 eighth grade students in a rural school. Participants were given 1 hour to complete the task and were allowed to look at available resources in the science education classroom. However, the participants did not have access to science textbooks or the Internet. We placed these restrictions on the participants because we wanted to document their incoming knowledge base for teaching, rather than have participants rely on a textbook or an internet-based lesson as 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 the materials they would need; and (e) any handouts or overhead transparencies they planned to use. (See Appendix A for the lesson planning task.)

In case studies, researchers use multiple data sources to construct a holistic and meaningful representation of personal experiences, with the primary data source being interviews. Immediately following the lesson planning task, we conducted a one hour, semi-structured interview with each participant (Patton, 2002). In the first part of the interview, the
participant was asked to share their lesson plans. The interviewer asked probing questions to elicit details of what the participant and the students would be doing in each part of the lesson. In the second part of the interview, participants were asked a series of questions about their subject matter knowledge, science teaching orientations, as well as their knowledge of students, instructional strategies, assessment, and curriculum. The semi-structured interview questions were designed to probe more deeply into specific components of the participant's PCK, as well as the sources of their knowledge. (See Appendix B for the interview protocol.) The interviews were audio-taped and transcribed verbatim.

When choosing cases, researchers often use a purposeful sampling approach to identify cases that they view to be “information-rich” (Patton, 2002). The focus of case study research is to describe the unique cases and describe themes that emerge that differentiates or unites settings and or participants. For this study, we selected a sub-set of the participants seeking biology certification. This decision was based on the participants in the independent track, two of whom were seeking certification in biology. (The third classroom teacher was the only research participant seeking physics certification, so there was no comparison group in the mentored internship track.) To compare the incoming knowledge of participants in each of the two tracks, we selected 2 interns from the 10 participants in the mentored internship track. We selected interns who lacked formal K-12 teaching experience but had similar educational backgrounds to the classroom teachers (i.e., an undergraduate biology major with no post-graduate biology coursework). Therefore, this case study examines the incoming teaching knowledge of 2 participants in the mentored internship track and 2 classroom teachers in the independent internship track, all of whom are seeking biology certification in an ACP.

Data Analysis

We coded the lesson plan and interview data using the five categories of the Magnusson et. al. (1999) PCK model: (a) science teaching orientations, (b) knowledge of students' understanding of science; (c) knowledge of instructional strategies; (d) knowledge of assessment; (e) knowledge of curriculum. Triangulation was achieved through multiple data sources, lesson planning task and interview transcripts (Yin, 1989), as well as through multiple researchers (Denzin & Lincoln, 2005) The data analysis team consisted of the first 5 authors. Each member of the research team read all of the participants' interview and lesson plan data. To facilitate coding, two researchers were assigned to independently code a participant's data using NVivo. After the initial coding, each of the two researchers wrote a summary profile for that participant. The summary profile facilitated data reduction and provided a synthesis of each participant's data (Denzin & Lincoln, 2005). The two researchers compared summary profiles and negotiated any discrepancies. Next, the summary profile was read and discussed by the research team and verified for accuracy. After writing the initial summary profiles, we added the category of "sources of knowledge," re-analyzed the data and revised the profiles to include this addition.

In the second phase of the data analysis, we analyzed the four participants' data for patterns and themes across the data set. We independently generated tentative assertions for each of the five major categories listed above. These tentative assertions were tested during group research meetings, with pairs of researchers checking their assigned participant's data to look for confirming and conflicting evidence. Each of the four participants' data was checked in this manner. The assertions were revised until agreement was reached among the five researchers.
Each researcher wrote one assertion, supported with evidence from the data set. The rest of the research team verified the evidence used to support the assertion.

Interpretations

Our interpretations are subdivided into two sections, with the first section consisting of summary profiles for each of the 4 participants. The profiles include background information, their science teaching orientation, a summary of the participant's lesson plans and their incoming knowledge in each of the following categories: knowledge of learners, instructional strategies, assessment, curriculum. All participants have been given pseudonyms. To capture the similarities and differences between the participants in the two tracks (the mentored internship and the independent internship), we present our cross-case analysis in the forms of assertions for each of the five major categories.

Profiles

Helen (Classroom Teacher)

Background information. When Helen entered the ACP, she had signed a teaching contract to be a full-time classroom teacher in the fall. She had been working as a full-time substitute science teacher the previous year, and was hired as a full-time teacher in the same school district. Helen was in her mid-thirties with an undergraduate degree in educational studies. As an undergraduate, she planned to become a science teacher, but, due to family concerns, was unable to complete the program. Since graduation, Helen had completed several graduate-level education courses at another institution. As a substitute teacher, she participated in the school district’s professional development workshops. When Helen entered the ACP, she was confident in her subject matter knowledge, but less confident in her teaching skills. She felt that she struggled as a teacher, and was seeking additional help. Helen realized that understanding the subject matter was different from being able to teach effectively. Helen also needed to complete a certification program to qualify for a regular teaching certificate.

Science teaching orientation. Although Helen discussed multiple instructional strategies in the interview, she primarily used lecturing strategies in her lesson plan. One of Helen's goals was for students to find science interesting and to avoid boring students. She tried to achieve this goal by making science relevant to students' lives. She explained, “The point would be to get them to feel like a scientist and do it themselves and see that there is a real-world application.”

Lesson Plans. Helen's lesson plan has clearly written learning objectives based on measurable student outcomes. She viewed each day's lesson as having three parts, which she labeled as "opening," "middle," and "end." In the opening section of each lesson, she engaged the students in an activity to show the relevancy of the topic to their lives. After the engagement, Helen used lectures to transmit information to the students, which was followed by guided practice and independent practice of the concepts.

On the first day, Helen began her lesson by writing the objectives on the board and questioning students about heritable variation. Next, she planned a short activity linking heritable variation with family inheritance, stating her goal was to "connect" with her students. She asked students to stand or sit based upon variation in physical traits such as eye color and hair color. In the middle section of the lesson, Helen planned a short lecture on Gregor Mendel and Punnett squares. After the lecture, the students engaged in guided practice completing monohybrid
crosses using plant and human traits. Next, students completed an independent practice and then compared answers with a classmate. Helen ended the lesson by giving a homework assignment asking students to identify inherited physical traits in their own families.

On the second day, Helen began by asking a few students to share their homework assignments. Next, Helen used all of the students' data to generate graphs on the board for each physical trait. The graphs were intended to "drive home point of dominance and recessive." (Note: This activity re-enforces the misconception that dominant traits are more common.) The rest of the time was spent practicing Punnett squares. Students would complete more monohybrid crosses and design their own problems to solve. At the end of the lesson, Helen gave an overview of the textbook reading assignment. She viewed the textbook as a way for students to review the lesson material. Helen also planned to prepare the students for the next day's lab which involved counting kernels of colored corn.

Knowledge of learners. During the interview, Helen's responses emphasized her focus on student learning. She stated, “Different students learn in different ways, maybe some have to see the pictures, maybe some have to do the activity.” She was aware that students came to her class with their own ideas and used an introductory activity to elicit students' ideas. “It’s something that I’ve learned in other classes, that they may have misconceptions, they may already know a lot and you’re just going to bore them.” Helen used this information to avoid boring the students, rather than building on prior knowledge or confronting their misconceptions. She noted variations in student learning, stating, “Some students seem to learn with the 'hands on' but then a lot of other students would just like completely miss the whole point.” When Helen discussed using graphs and Punnett Squares, she explained, “with the graph you would be working it together, so I think if you stopped at some point and would ask them to summarize what they are seeing, some kids would catch on right away.” Helen drew on her substitute teaching experience as the source of her knowledge of learners.

Knowledge of instructional strategies: Helen's lesson plan included a variety of instructional strategies that closely aligned with her lesson objectives. Helen's lesson plan design reflected her desire to avoid boredom. She stated, “I try to break up the hour with as many different things, because I get really bored, and if I’m bored, I know they’re bored.” Helen used variety to avoid student boredom and potential classroom management problems, rather than to meet her students' diverse learning needs. Even though Helen talked about multiple strategies in the interview, her lesson plan relied primarily on lecturing to transmit information. Helen also discussed strategies for helping students comprehend the textbook reading. Helen thought textbook readings should be assigned after she has taught the material. Helen was sensitive to the learning needs of her students and tried to make learning experiences relevant. Helen explained a homework assignment in her lesson plan, “You actually have them look at simple human traits just the real simple ones like attached earlobes or widows peak . . . . Students will conduct research into their own family inheritance.” Even though Helen varied her instruction and utilized representations such as Punnett squares and graphs, she primarily relied on lecture to transmit information to her students.

Knowledge of assessment. In the interview, Helen discussed multiple ways of assessing students’ understanding. Helen described carefully listening to students' explanations and ideas as one means of assessing students' learning. She also studied students' facial expressions and general body language to gauge their understanding. When asked how she knew if students understood a concept, Helen stated, “I think that, well part of it, probably, just look at their faces.” Helen also felt the nature of students' questions provided a window into students'
understanding. “You are 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 felt that by moving around the room and interacting with students on a one-to-one basis, she could accurately assess students’ understanding. Helen used informal assessments to determine if she needed to re-teach the information. In re-teaching, Helen implied that she would repeat the explanation given earlier and did not discuss the use of alternative instructional strategies. In the interview, Helen showed great concern for students and described assessment as being on-going and informal.

Knowledge of curriculum. Helen’s knowledge of curriculum was limited; she followed the school district's science curriculum. She was aware of the state's GLEs and realized that the school's curriculum needed to meet the state guidelines. However, Helen indicated that she was uncertain about what 8th grade students should learn about heritable variation. She stated that “the simple crosses are usually just one thing dominant and one thing recessive . . . I didn’t know with 8th grade what they’d know or be able to handle.” Helen's knowledge of curriculum came from her substitute teaching experience using the school's textbook, and conversations with colleagues. Helen indicated that she viewed curriculum as something dictated to the teacher from an outside source, rather than being teacher generated.

Integration of knowledge bases. During Helen's interview she indicated that she was emphatic to her students' needs and possessed a rich knowledge of her students. Helen gained information about her students through informal assessments of students' questions and observations of students' facial expressions and body language. Being sensitive to her students' interests, Helen tried to make science relevant to her students' lives. Even though Helen focused on students' interests and needs, she did not appear to use information from formative assessments to re-design her instruction, rather she used formative assessment to determine if she needed to re-explain the concept to students. This response may be due to Helen's limited knowledge of instructional strategies. She relied primarily on lectures to transmit information and used classroom activities and laboratories to have students practice and verify concepts. Helen's knowledge of curriculum was limited to her experience substitute teaching in the middle school.

Maggie (Classroom Teacher)

Background. Maggie entered the ACP with two years of experience teaching high school biology and chemistry. After earning an undergraduate degree in biology, Maggie's career plans were uncertain. She took a job as a camp counselor and found that she enjoyed working with young people. Based on this rewarding experience, Maggie decided to become a secondary science teacher. She explored different state teaching requirements, and applied for a teaching position in a state that would grant her an emergency teaching certificate. As part of the requirements of the emergency certification, Maggie needed to enroll in a program to complete the requirements for regular certification.

Science teaching orientation. Maggie's teaching orientation was didactic in nature, as she primarily used lecture to transmit information to the students. As a high school teacher, Maggie viewed the goal of middle school science as preparing students for high school science courses. Maggie thought that middle school students would need more concrete experiences, so she focused on using Punnett squares.

Lesson plan. Maggie’s lesson plan objectives stated that she wanted students to "explain how different traits can be passed to offspring of the same parents." She began each lesson with a
brief discussion, either to introduce the material or review the previous day's material. The initial discussion was followed with a lecture, focused on vocabulary terms and how to complete Punnett squares. Each lesson ended with guided practice using worksheets.

On the first day, Maggie began the lesson by asking students about physical differences between themselves and their siblings and parents. Next, Maggie planned to lecture on Mendelian genetics, specifically dominant and recessive traits. She focused on the convention of using a capital letter for a dominant trait and a lower case letter for recessive traits. Next, she intended to assign homework to have the students' practice these conventions.

On the second day, Maggie planned to collect the students' homework, allow time to answer any questions and review the material from the previous lesson. Next, she planned to lecture on how to complete a Punnett square. The lecture was followed by guided practice on the board. Students continued to practice monohybrid crosses by moving around the room and going to different stations. Maggie referred to this activity as a "Practice Game" as each station had a different monohybrid cross to complete.

Knowledge of learners. Maggie described her planning process in this way: “So all along the way I would have to be a couple lessons ahead of the game so that I could (prepare) …What am I going to tell them? ... you have to take a step back and pretend that they know nothing”. When prompted, Maggie indicated that students would have some knowledge of inheritance through everyday observations. She assumed that students would know some basic terminology, including organism, parent, and offspring. Yet Maggie thought it was unlikely the students would remember very much from previous classes. In teaching inheritance, Maggie believed an abstract concept, such as dominance, would be harder for middle school students to understand. Maggie felt that middle school students would have an easier time learning concrete concepts that they could observe. “Some of these concepts with the passing on traits they like a lot better because they can actually see …” Maggie thought the students would also struggle with terminology. She stated, “I think a lot of the terminology in the genetics unit is a little more complex than terminology in a lot of the other units. Also it’s not something people usually talk about in everyday language.” Maggie drew on her experiences teaching high school students to anticipate the needs of middle school learners.

Instructional strategies. Maggie primary instructional strategy was lecturing. However, before she lectured, she elicited students' prior knowledge. She used this strategy for two purposes. First, Maggie wanted to know what students remembered from their previous classes, to see if she needed to include this material in her lecture. Second, Maggie wanted to engage students by relating their past experiences to the material. After the initial engagement, Maggie planned to lecture. “I was going to move into the lecture … so we were going to use the whiteboard and I would write the notes on the board and they would copy it into their little notebooks”. Next, she planned to have the student practice filling out Punnett Squares, reinforcing the procedural aspects.

Assessment. Maggie was aware that students brought prior knowledge to her classroom, and used informal discussions to elicit students' prior knowledge. Maggie used that information to “…lead me into how in depth I needed to get with the lecture and the practice.” In the second day of her lesson, she used informal discussion to assess student learning and remind students of the previous day's material. She stated, “…just get the terminology back in their head and the ideas back in their head.” While Maggie thought the homework assignment would give her some information about student learning, she thought the students' explanations of inheritance would be the best indicator of their learning. “I’d have a test or a quiz question where
they had to actually write a short answer type question and explain to me how they understood that traits are passed from the parents to the offspring.” Maggie appeared to rely primarily on informal, formative assessments, such as asking questions during lecture. She stated, “I’d kind of be asking different people, different groups of people, different questions to see where they were at. And at that point I’d know they were confused about the day before …” Maggie used this information to determine which explanations she needed to repeat.

Curriculum. Maggie defined curriculum as a school document, stating, “Typically, there is a binder that has different objectives of main goals for each topic that the student should be able to achieve.” Maggie began her first year of high school teaching with no prior K-12 teaching experience and no coursework in education. At the beginning of the school year, she was handed the school district's curriculum guidelines, which she found cumbersome and confusing. In response, she asked her colleagues to help modify the document. “Why don’t we fix this? So we’re working together on the whole department’s curriculum to make sure it’s user friendly for new incoming people.” Through the science department's curriculum revision process, Maggie became familiar with the GLEs and knew that the GLEs should inform district curriculum guidelines. She explained, “Well, hopefully the curriculum would narrow it down some. I’d look at the GLEs and make sure that the curriculum was even covering what the GLEs were telling us to cover.” Maggie viewed the GLEs as a useful source for her understanding of what students should learn “because now I have … 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 even recognized that the concept for the lesson planning task came directly from the state GLEs. Because of her involvement in the science department's curriculum revision, Maggie viewed curriculum as guided by the state GLEs, but negotiated by the teachers in the school district.

When asked to discuss where heritable variation fit into the curriculum, Maggie suggested that this concept would be followed by molecular or microscopic-level material, such as the study of DNA and chromosomes. She stated that biological classification and natural selection were alternative topics to teach inheritable variation. She explained, “I would go either with the actual traits and the Punnett Squares or I would go with the natural selection, the classification. I think those would be the two main branches I would go with it.” Maggie's source of knowledge of curriculum came from her experience teaching high school biology and her work helping revise the school district's science curriculum guidelines.

Integration of knowledge bases. Maggie elicited students' prior knowledge but only for the purpose of determining the starting point for her lectures. She was unaware of potential student misconceptions and didn't consider the role of prior knowledge in learning new concepts. Maggie believed that 8th graders would have difficulty with abstract concepts, so she tried to think of hands-on activities for the students. She viewed solving Punnett squares as a hands-on activity. In spite of these beliefs, Maggie's primary instructional strategy was lecturing, followed by guided practice solving Punnett squares. In the interview, Maggie expressed a willingness to try new things in the classroom. Maggie described her teaching in the following way, “I’m just kind of a big trial and error person and I go with what’s working for me and what’s working for the kids.” Maggie connected assessment to determining if students had met state GLEs and the curriculum objectives. She discussed both formative assessment (i.e., asking students questions during lecture) and summative assessments (written tests). Maggie was not familiar with middle school science curriculum. In the lesson planning task, Maggie based her choice of concepts on what she expected her students to know when they came to high school. Maggie explained, “So I
thought, imagining what I would want somebody to do, to prepare them to come to my classes, would be something I’d like them to do before that.”

Susie (Intern)

**Background.** Susie was in her mid-twenties and recently earned an undergraduate degree in biology. After graduation, she worked in a plant genetics research lab. As part of her responsibilities, she trained new students on laboratory protocols. Susie also worked as a nanny for a family, and enjoyed interacting with children. When Susie entered the ACP, she was unsure of the grade level that she wanted to teach, so she sought dual certification in middle and secondary science teaching. Susie did not have any K-12 teaching experience, and had not written a lesson plan prior to entering the ACP.

**Science teaching orientation.** Based on the lesson planning task and interview, Susie exhibited a didactic teaching orientation. She saw her role as one of imparting knowledge to the students. She also viewed middle school as preparation for more advanced work in high school. Susie felt that students needed to gain a solid foundation in middle school in order to understand the more advanced high school topics. Susie also wanted the students to have fun in science classes, a goal she repeated throughout the interview. She stated, “I think sometimes science can get bogged down in facts and we forget to make it fun, because science is fun.” Using a student perspective, Susie thought that anything that wasn’t note-taking would be perceived as fun. Susie thought students would find science fun if they saw real world connections. She wanted students to relate TV news to things they learned in her class. She stated, “My goal for teaching science is to make them notice stuff in the world around them, not just in the classroom. Because science is awesome.”

**Lesson plans.** Susie wrote a broad teaching goal for each day’s lesson plan. She started each lesson with an opening question, intended to stimulate interest in the day’s lesson. Next, she introduced terms and concepts, which was followed by having students complete worksheets. She ended each lesson with a teacher summary of the day’s concepts.

On the first day, the goal was to teach about basic random genetic variation. The opening question was, “What is genetic variation? What does it do?” Next, Susie planned to lecture on chromosomal deletions, insertions and substitutions. The worksheet used the analogy of a sentence, “I like milk chocolate.” In the worksheet, students would delete, substitute and insert different words into the sentence.

On the second day, the goal of the lesson was “to move beyond the actual mutations to how they are passed on. More of a focus on simple genetics.” She planned to introduce sexual reproduction by lecturing on Mendel’s pea plants and showing how to use Punnett squares for monohybrid crosses. She chose to use an incomplete dominance example to introduce monohybrid crosses. Next she posed the question, “How is sexual recombination better than random mutation?” Following this teacher-led discussion, students would complete a worksheet of dihybrid problems, although this type of problem was not introduced in the lecture. She finished the lesson with the following summary, “Sexual reproduction is a way all advanced species can pass on heritable genetic variation” (LP, p. 1).

**Knowledge of learners.** Although Susie planned to teach Mendelian genetics in one 50-minute class period, she didn’t think middle-school students would have any difficulty with the material. In the interview, Susie did not talk very much about middle school students as learners. When prompted to discuss learners, Susie made comments regarding student preference rather than student learning. For example, Susie described an activity she had considered for her lesson...
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plan but eliminated due to time constraints. In this activity, students line up and model a DNA chain. She liked this idea because, “I just think, especially for the younger kids, really need to be moving. They don’t do well when they’re just sitting.” Susie stated that she didn’t know very much about middle school students so she drew on her own learning experiences. However, Susie questioned if this was appropriate. “Because I know what makes sense to me, but what makes sense to me doesn’t make sense to every eleven year old out there.” After working in a plant genetics lab, Susie felt far removed from middle school students' understandings of genetics. She said, “I forget what it’s like to not know any of this, so I’m like oh we’ll just do that. I just assume they know things, and I don’t know if those assumptions are correct.”

Knowledge of instructional strategies. Susie relied primarily on instructional strategies to transmit information to the students, followed by engaging the students in guided practice. To transmit information, Susie used “open discussion” and lectures. These two strategies were similar, as evidenced in Susie's description of open discussion, “I probably would be writing stuff on the board, they would be writing stuff down at their desks, talking, just really informal.” Susie planned to “recap” at the end of each lesson. When asked what would be happening during the “recap,” Susie envisioned that she would be “Probably standing and talking.” When prompted to describe what students would be doing, she replied, “not necessarily note taking, but just kind of, you know, it’d be more like discussion-based.” On the second day, Susie introduced recombination by sexual reproduction following a similar instructional sequence as the first day. She planned to use red and white pea plant flowers and show that this cross resulted in pink flowers. In the interview, she discussed the student worksheet with Punnett Squares for dihybrid crosses. Susie summarized her instructional sequence as “opening questions, definitions, worksheet.” During the interview, Susie was asked if she considered other ways of organizing the lesson. She replied, “I mean it would be fun to kind of mix it up a little bit, but I don’t really know about all those different teaching methods yet.” In planning the lessons, Susie drew on her own experiences as a college student.

Knowledge of assessment. Susie's lesson plan did not include any form of assessment, formative or summative. During the interview, she was asked to describe how she would know if the students understood the concepts. After considering the question, Susie indicated she would look at the students’ worksheet answers and listen to the type of questions they asked. Based on that information, she stated, “You can really, kind of, do a little shuffle to see if you need to spend more time on one thing or move on faster.” When prompted to discuss additional assessment, Susie thought she would use questions directed to the whole class to see if the students understood the lesson.

Knowledge of curriculum. Susie did not have experience with middle school science curriculum and found it difficult to complete the lesson planning task. Susie felt confident in her content knowledge but didn’t know how to sequence concepts. She stated, “It was difficult . . . to figure out what information they need to know first, and what they already know and what is the logical order all this goes in.” She added, “Even though I know everything, I do not know what the best order to teach it in.” Susie equated curriculum with a textbook, and felt that the lesson planning task would have been much easier if she had been given a textbook to follow. She was not aware of district or state curriculum guidelines.

Integration of knowledge bases. Susie lacked knowledge of middle-school science learners, assessment strategies, and middle school science curriculum. In designing her lessons, she drew upon her experiences in her college biology courses. As a result, her lesson plan was more appropriate for college students than middle school students. Susie also drew upon her high
school and college experiences as the source of her knowledge of instructional strategies. Susie primarily used lectures to transmit information to the students, followed by student worksheets.

**Erin (Intern)**

**Background.** Erin was in her mid-twenties and earned her undergraduate degree in biology. As both a high school and college student, Erin enjoyed informally tutoring other students. After college graduation, she continued to tutor her younger siblings. She enjoyed tutoring and thought she would enjoy being a full-time teacher. Although Erin did not have K-12 teaching experience, she did have some teaching experience beyond tutoring. As an undergraduate, Erin was the student leader for a freshmen student interest group. These groups are designed to support freshmen during their first year of college. As a student leader, Erin was responsible for leading a weekly seminar. Erin was also a member of a military reserve unit, where she taught classes. Erin indicated that her ideas about teaching were influenced by these two experiences.

**Science teaching orientation.** Erin's teaching orientation was didactic in nature as she primarily relied on lecturing to transmit information to the students. One of her primary goals for middle school students was to prepare them for high school biology. She said, “I think my job, for this specific class, would just [be] to give them a foundation and a basic understanding of the simple examples and how everything happens. Just to sort of build that base.” She explained that students should know this information so that “other teachers in their future can build upon it."

**Lesson plans.** She began each lesson by engaging the students in a ten-minute activity intended to focus their attention and motivate them to listen to her lecture. Next, Erin introduced new vocabulary terms and planned to lecture over the material in the students' textbook. Erin relied primarily on lectures to transmit information and to clarify information in the textbook. Erin didn't think she should lecture for the entire class period, so she included some small group activities and student worksheets. In her lesson planning, Erin used the following instructional sequence: (1) students explore the phenomenon; (2) teacher introduces vocabulary terms and explains the concepts related to the phenomenon; and (3) students verify and practice the lecture material through collaborative and independent practice.

On the first day, Erin's goals were for students to “learn and understand the concept of genes, allele frequencies, genotypes, phenotypes, and dominant and recessive traits in relation to inherited traits.” Erin's lesson had the following sequence: (1) have students identify their physical traits and determine which parent they inherited these traits from; (2) lecture on genes, alleles, genotype/phenotype, and dominant and recessive traits using the textbook as a reference; (3) small group work investigating probability using a coin toss activity; and (4) individual student work using Punnett squares for monohybrid crosses.

On the second day, Erin's goal was “For students to build on their understanding of genotypes and phenotypes and to learn and understand the concept of incomplete dominance in relation to inherited traits.” Erin began class by posing the following problem: a plant with red flowers is crossed with a plant with white flowers producing offspring with pink flowers. Students worked in small groups to try to develop explanations, which they shared with the whole class. Erin didn't think students would be able to explain the phenomenon, but used the activity to motivate the students to listen to her lecture on genotype/phenotype, dominant and recessive traits, and incomplete dominance. She planned to follow the textbook closely as she lectured, having the students follow along looking at diagrams and pictures in the textbook.
Knowledge of learners. To facilitate student learning, Erin believed instruction should be engaging to motivate students to want to learn the material. She planned to engage students in identifying their own heritable traits before lecturing or introducing the textbook. She stated, “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.” Erin thought if students saw connections to their own lives that they would be more interested in listening to her lectures. Erin viewed student grades as another source of motivation, stating, “when their grade is on the line then they are more apt to actually try it and not just get it done and turn it in.” After students have explored the science concept, through discussion or activities, Erin planned to give a lecture on the terminology and explanation of the concepts. Based on her tutoring experiences, Erin was confident in her ability to explain things clearly so that students would have no difficulty understanding.

Knowledge of instructional strategies. Erin's primary instructional strategy was lecturing, although she included several other strategies in her lesson plans. She began each of the lessons with an engagement activity. On Day 1, she had students compare a list of their physical traits to a list of their parents' traits. On Day 2, she started the lesson by posing a genetic problem for the students to explore. After the engagement activity, Erin planned to lecture, going over vocabulary terms and explaining the major concepts. As part of her lecture, Erin planned to include the textbook, having students look at pictures and diagrams in their book. Erin realized that she shouldn't lecture for the entire class period. On the first day, after the lecture, Erin planned to have students work in small groups to do a coin toss activity and then work individually on a worksheet of genetics problems.

Knowledge of assessment. Erin's written lesson plan did not include assessment strategies. During the interview, Erin indicated that she planned to assess students' understanding through formal assessments, such as tests, and by informal means, such as walking around the room looking at students' work. For the first day's lesson, Erin explained, “I wanted to end the class with an individual activity so that I could make sure that everyone individually is understanding how to do a Punnett square.” She planned to look at the students' worksheet answers to determine whether she needed to re-teach the material the next day. During the interview, Erin described several different strategies she might use to assess student learning, including asking questions to the whole class, giving a quiz, or playing a Jeopardy game. Erin would use the information from these assessments to determine if she needed to repeat her explanations of the concept.

Knowledge of curriculum. Erin was confident that heritable variation was a topic taught in 8th grade and that being able to use Punnett squares was fundamental to understanding topics students would encounter in high school biology. For example, Erin thought that students needed to know about traits and Punnett squares to be able to comprehend human diseases and the evolution of traits. However, Erin was unsure of 8th graders prior experience with this topic and the extent to which she should cover heritable variation. Erin was unaware of school district curriculum guidelines or the state GLEs, and equated the textbook with curriculum.

Integration of knowledge bases. Erin’s knowledge of assessment and instructional strategies was related to her knowledge of learners. She knew that she needed to use assessments to determine if she needed to repeat explanations. Additionally, Erin realized the importance of making connections with students' prior experiences before she introduced new terminology and facts. In both of her lesson plans, she used an "Explore-Explain-Verify" instructional sequence. However, Erin doesn't use the outcome of the explore activities to build student understanding,
rather she follows the explore activity with a lecture. Thus, the degree to which her knowledge of learners influenced her instruction was limited. Erin lacked knowledge of middle school science curriculum and relied on her own high school and college experiences to complete the lesson planning task.

Cross-Case Assertions

This section is organized around each of the components of the Magnusson et al. (1999) PCK model, beginning with science teaching orientations, following by knowledge of learners, instructional strategies, assessment, and curriculum. In some of these areas, the assertions show similarities across the two tracks (mentored internship and independent internship), while other assertions highlight the differences between the two tracks.

Science Teaching Orientations Assertion: All participants held didactic science teaching orientations that focused on transmitting basic information to students. By making the lecture material relevant to students' lives, the students would be more interested in the lectures.

All of the participants viewed the goal of middle school science to be one of preparing students for high school science courses. When Maggie wrote her two lessons, she 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. Erin articulated a similar perspective:

So, I think my job, for this specific class, would just to give them a foundation and a basic understanding of the simple examples and how everything happens. Just to sort of build that base for when they go to high school and then go to college so that they remember that they understand how this works and other teachers in their future can build upon it. (Erin, intern)

Susie echoed this same goal for middle school science. She stated, "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 give middle school students a strong foundational base of knowledge, the participants thought their role was to transmit information to the students, primarily through lectures. Although all of the participants began their lessons with a short, engaging discussion, the interns used the activity to motivate the students to listen to the lecture. Erin 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 . . . " Participants in both tracks perceived their role as one of transmitting information to the students, primarily by
lecturing. Susie summarized this perspective when she described how she designed her lessons: "Try to cover the most ways to impart information."

Participants thought students would be more interested in their lectures if they found the material relevant. Susie wanted to have the students read an article about Darwin's finches. She thought that assignment would show "real life stuff." Susie explained her goal:

It takes stuff out of the classroom and into, maybe then they’ll notice something in the news or on TV about something and they’ll be like 'oh, we totally learned about that,' and that, to me, is my goal for teaching science is to make them notice stuff in the world around them, not just in the classroom. (Susie, intern)

Helen planned to include a colored corn lab as her third lesson. She explained, "The point would be to get them to feel like a scientist and do it themselves and see that there is a real world application." All of the participants wanted students to gain basic information and to see that the material was relevant to their lives. They relied primarily on lecturing as a means to transmit this basic information to the students.

Knowledge of Learners Assertion: Both groups acknowledge students have prior experiences but not explanations (so as teachers, they need to give students explanations). Interns based their understandings of middle school learners on their own K-16 learning experiences, while the classroom teachers drew on their experiences teaching high school students.

When making instructional decisions based on their knowledge of learners, all four individuals made reference to eliciting students' prior experiences with the phenomenon. While they recognized that students had prior experiences with the phenomenon (in this case, genetic variation), they failed to understand that students might have constructed their own personal explanations as well. All of the participants felt that they, as the teacher, needed to give the explanation of the phenomenon to the students. In the lesson planning task, participants felt that the middle school students might be aware of variation, but they would not have any explanations for the phenomenon. Helen 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, classroom teacher).

The participants believed that learning is mostly the acquisition of facts. The interns believed that the students would have no difficulty with the material, while the classroom teachers anticipated some student difficulty. The classroom teachers thought understanding scientific explanations of phenomena was the most difficult aspect of learning. In the case of heritable variation, the classroom teachers believed that, while students would readily relate to and thus easily remember examples of observable genetic variation, they were unlikely to remember more abstract explanations.

I think that would be a part where quite a few of them would get hung up and we’d have to spend some time describing how something can be dominant and take over and show up but something else be recessive and not show up.” (Maggie, teacher)
Another salient difference between the two tracks was the sources of their knowledge about learners. The interns drew upon their own experiences as K-16 learners, assuming that most students will somehow be similar in terms of motivation, knowledge and attitudes and thus plan their instruction accordingly;

“Because I know what makes sense to me, but what makes sense to me doesn’t make sense to every eleven year old out there. I forget what it’s like to not know any of this, so I’m like oh we’ll just do that. I just assume they know things.” (Susie, intern)

While on the other hand teachers drew on their experiences with high school students. During the interviews, the teachers used their prior teaching experiences as a rationale to support their reasoning. Helen, for example, believed that students are unlikely to realize they actually know some of the facts or explanations she wants to use as a basis for her instruction.

“I mean, if you continually ask them what do you know about this before you start, you’ll get some sort of idea. But I’ve found too that some kids will act like they don’t know anything about it, and then you’ll start and they actually do know it, they just didn’t feel like saying anything.” (Helen, teacher).

Individuals in both tracks acknowledged that students might have prior experiences with a given phenomenon (i.e., genetic variation), but they did not think students would have explanations for the phenomenon. Interns drew on their personal experiences to anticipate what middle school students might know, while classroom teachers drew on their experiences with high school students.

**Knowledge of Instructional Strategies Assertion: Participants in both tracks used the same teaching sequence: a short questioning period followed by lecture and closing with individual guided practice. Classroom teachers included small group work as part of guided practice.**

One striking similarity across the lesson plans of the four participants 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 a guided practice format. 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 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 kind of 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, the participants in both tracks implemented teacher-centered, didactic instructional strategies to transmit knowledge to the students; equating teaching with telling. The participants perceived their lecture as the central part of their lesson. Erin (intern) explained this segment of her lesson, “I would go into the actual explanation part, the sort of lecture part of class that they all need to understand the material.” Erin underscored her didactic focus by explaining that students were more likely to grasp new concepts 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.” Maggie relied on the same instructional strategy, re-explaining the concept, 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 may not be the most effective instructional strategy, they still relied primarily on lectures to teach the concepts to students.

Participants in both tracks followed their lectures with guided practice. However, the two tracks differed in student grouping during the guided practice. The interns had students work individually to complete the worksheets. The completed worksheets would be handed in at the end of class and graded by the teacher. The teacher was viewed as the sole source of information in the classroom, and 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 also believed that students could explain concepts to each other. After completing the worksheets on their own, Helen planned to put the students in groups to compare worksheet answers. Helen used group work as a management strategy, realizing that she couldn't answer all the students' questions at the same time. She wanted students to try to come to consensus on the worksheet answers before asking her questions. By putting students in small groups, 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.

*Knowledge of Assessment Assertion: Across the cases, assessment strategies are not included in their lesson plans. When prompted, interns planned to assess student work at the end of the lesson, while teachers planned to informally assess through the lesson. Participants in both tracks used assessment to determine if they needed to repeat their explanations.*

Assessment strategies were not included in any of the participants' lesson plans. The participants discussed assessment only when prompted during the interviews. When prompted, both teachers and interns described a limited set of assessment strategies that the teacher could use to evaluate student progress. None of the participants used assessment strategies designed to help students assess their own understanding. Maggie (teacher) focused on formal assessments and said she would have students show their understanding of the topic, “on a test or quiz, in a short answer response.” In a similar fashion, Susie (intern) planned to determine whether students understood the lesson by looking at their completed worksheets. In both tracks, participants focused on traditional forms of assessment like graded worksheets and tests.

Both teachers and interns used assessment of student work to decide if they needed to repeat lecture material. Erin (intern) explained 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.” Similarly, Maggie (teacher) stated she would use assessment at the beginning of class to determine what content students remembered from the previous day. From the student responses, Maggie would decide whether she needed to re-explain parts of her previous lecture. She said she used informal questioning to “see where they were at and where I needed to take it.
That would lead me into how in-depth I needed to get with the lecture and the practice.” In both tracks, participants used assessment to determine whether they needed to repeat their explanations.

Between the two tracks, participants differed in the timing of their assessments. Teachers discussed more frequent, on-going assessments to inform whether they needed to re-teach. For example Helen (teacher) mentioned, “While they’re working, you’re listening to what they’re saying, you take up small homework activities that they do. You ask questions, see if they can answer them. And finally I mean, in the end, you’ll test them on it, see how they handle that.” Helen planned to listen to students throughout the lesson to decide whether students understood the new material and if she needed to stop and re-explain any concepts. Maggie (teacher) stated, “I wouldn’t move on until at least most of their confusion was cleared up, depending on how completely confused they were.” The teachers used frequent assessments so they could determine if they needed to re-teach parts of the lesson.

In contrast, the interns considered using assessment only at the end of a lesson to inform subsequent lessons. Erin (intern) said, “I wanted to end the class with an individual activity so that I could make sure that everyone, individually, is understanding how to do a Punnett square.” Erin planned to use the completed student worksheets to determine whether she needed to re-teach any material the next day. Susie didn't anticipate that students would have any difficulty. When prompted during the interview, she said that she could look at the students’ worksheet to see if they understood Punnet squares. Interns waited until the end of the lesson to assess student understanding to decide if they needed to re-teach the lesson the next day, while teachers assessed students' understanding through the class. However, both participants in both tracks used assessments in the same way, to determine if they needed to repeat their explanations.

**Knowledge of Curriculum Assertion:** Interns equated curriculum with the textbook, while 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. This is not surprising as neither of the interns had K-12 teaching experience. The interns did recognize the need for a logical sequencing of 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. The interns clearly equated the textbook as the science curriculum.

Although the classroom teachers relied heavily on textbooks, 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 was involved in her school's revision of the science curriculum. Based on this work, she was familiar with the state 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 [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 being 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.

Discussion

Science teaching orientations play a critical role in PCK, filtering a teacher's knowledge and selection of instructional strategies, understanding of learners, use of assessment strategies and selection of curriculum. The four participants in this study entered the ACP with didactic science teaching orientations. They equated teaching with telling. The research literature supports this finding in that pre-service teachers tend to believe that science teaching is teacher-centered (Mellado, 1997). Although the participants held didactic teaching orientations, there was limited evidence that they also held other peripheral orientations. Susie, for example, also had a 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. Koballa (2005) also found that ACP teachers held dominant and "back up" conceptions of science teaching. Drawing on peripheral activity-driven orientations may be a way to help teachers develop a more student-centered science teaching orientation.

The participants' didactic orientation influenced their thinking about learners. Both teachers and interns believed that learners would have prior knowledge and experiences related to the genetics topic. However, determining students' prior knowledge and experiences was an exercise to motivate and focus students at the beginning of the class, and to determine the starting point of the lecture, rather than for the purpose of challenging students' existing conceptions. This finding confirms Meyer (1999) report that pre-service teachers use assessment for three reasons: a) determining where to begin the lecture; b) motivating students; and c) encouraging students to take responsibility for their learning by realizing what they don't know. While our findings confirm that both groups draw from their own K-12 experiences to understand their students, the teachers were more likely to draw upon their teaching experiences. This is similar to findings by both Mellado (1997) and Haney & McArthur (2002) who found that teaching experience informs understanding of students.

The four participants had didactic teaching orientations and used the same instructional script in designing their lesson plans. All of the participants began their lessons by asking students questions to determine a starting point for the lecture. After the lecture, students engaged in guided practice designed to verify the lecture material. De Boer (1991) reported that, for the past 50 years, science teachers have typically used teacher-centered instruction following an Inform-Verify-Practice sequence. Even though two of the participants, Helen and Erin, expressed dissatisfaction with lecturing, they knew of few alternatives. Participants were generally puzzled when asked if they considered other ways to organize their lesson plan. Erin explained that she listed all the instructional strategies she knew and then incorporated all of the strategies into her lesson plan. The participants were limited in their knowledge of instructional strategies. One difference between the two tracks was that the teachers incorporated group work into the guided practice, while the interns planned to have students work individually. The interns viewed the teacher as the sole source of knowledge in the classroom. Unlike the interns,
the teachers designed small group guided practice, which would allow students to repeat the teacher's explanation to classmates who didn't understand the concept.

Assessment strategies were missing from all the participants' written lesson plans. During the interviews, interns were asked how they would know if students understood their explanations. With this prompting, the interns said they would grade the students' worksheets. Generally, beginning teachers' teaching knowledge is based on their own experiences as learners, which were largely traditional in nature (Mellado, 1997). From their own experiences as students, interns perceived assessment as being summative, consisting of tests and quizzes. They didn't include assessment in their lesson plans because the lesson plans were for only two days, not long enough for a unit test. Teachers responded to the interview prompt in a different way. They tended to see assessment as ongoing throughout the lesson and were more likely to describe observing individual student's facial expressions and body language to gauge student understanding. However, all participants used assessment for the same purpose, to determine if they needed to repeat an explanation. The participants' limited repertory of instructional strategies and their teaching orientations limited their instructional decision-making options. None of the participants viewed assessment as a way to support students' metacognition, indicating a need to expand their goals for assessment. In addition, the participants need to develop a repertory of formative assessment strategies that can better inform their instructional decision-making.

In regard to curriculum, the interns were unfamiliar with the existence of state and national guidelines. The interns equated the textbook as source of the curriculum. Our findings support Southland and Gess-Newsome (1999) who reported that pre-service teachers do not question the curriculum. In our study, the interns expressed that they needed the textbook to know what to teach. However, the two teachers in the study demonstrated a willingness to reflect upon the relevance of their school's curriculum. Unlike the interns, the teachers were more likely to question the curriculum. In addition, the teachers’ view of curriculum went beyond the textbook and included knowledge of district and state guidelines. Knowledge of curriculum has been largely ignored in the literature on beginning teachers’ knowledge (Davis et al., 2006).

PCK Model

In this study, we used the Magnusson et al. (1999) PCK model as both our theoretical and analytical framework. The PCK model identifies the various components of PCK (i.e., science teaching orientations, knowledge of learners, instruction, assessment, and curriculum) that one would expect to find as part of an experienced teacher's highly developed PCK for a specific topic. The components of the model formed the basis for our interview questions. However, the PCK model became problematic in both data collection and data analysis. During interviews, participants would often refer to multiple components of the model when they responded to an interview question, making it difficult to collect data in a categorical manner consistent with the model. For example, when asked about instructional strategies, participants might talk about their beliefs about how middle school students learn based on their experiences teaching high school students. During data analysis, we used the PCK model categories as coding categories. Again, problems arose trying to decide how to code the data, with much of the data being tagged with multiple codes. Using the PCK model categories, two issues occurred during data analysis. First, the model became a deficit model for what our participants, particularly the interns, did not know. The interns lacked knowledge of assessment and curriculum, and the classroom teachers
had very limited knowledge in these two categories. Second, the data analysis failed to represent an important difference between participants in the two tracks. The classroom teachers’ data indicated that they made connections between the PCK components, and that these interactions informed their lesson plans. We believe this to be an indicator of their initial PCK development, as the interns exhibited few connections between the PCK components. We generated new representations of their PCK to illustrate the differences between the two tracks. We illustrate these differences by contrasting two participants: Helen, who demonstrated the most highly developed PCK, and Susie, with the least developed PCK.

**Helen's connections between PCK components.** Helen demonstrated strong subject matter knowledge and, based on her long-term substitute teaching experiences, she possessed some knowledge of the middle school context and general pedagogical knowledge. (This knowledge is represented by arrows in Figure 2.) Within the PCK components, we overlap circles of some components to indicate the degree of interaction between these components. Helen’s knowledge of learners overlaps with her knowledge of assessment. She understands that students often give visual cues as to their level of understanding and watches her 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 connects her knowledge of eighth grade students to curricular decisions. 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)

Helen also thought that students would learn from one another and designed assessment strategies that used peer instruction. She explained that 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.”

Although Heather's interview included multiple examples of interactions between knowledge of learners, curriculum and assessment, we saw few connections to instructional strategies. For example, Heather was aware that students' might have misconceptions, but she didn't appear to have any strategies to challenge these misconceptions. She fell back on her didactic orientation and planned to provide additional examples and re-explain the concept. This is important because it indicates that even though Helen’s knowledge of assessment was more sophisticated than Susie’s, she did not use her knowledge of assessment to inform her choice of instructional strategies. Heather's didactic teaching orientation and her limited repertory of instructional strategies presented barriers to forming connections between all the PCK components.

**Susie's lack of connections between PCK components.** Sarah drew primarily on her subject matter knowledge to complete the lesson planning task. In Figure 3, this source is represented with a thick arrow. Sarah had worked in a molecular genetics lab and possessed a great deal of knowledge about genetics and recombinant DNA techniques. In her lesson plan, she tried to teach as many concepts as possible and, in the interview, she described recombinant techniques that she would include if she had time. Susie has limited knowledge of general pedagogical strategies, which we represent with a dashed arrow. Based on her high school
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Susie wanted to make the lesson more hands-on, and she felt that the worksheet accomplished this goal. Lecturing, as an instructional strategy, was re-enforced by her college science experiences. Susie lacked knowledge of the context (a middle school science classroom) as well as knowledge of middle school learners and middle school science curriculum. In one lesson, she planned to teach such abstract concepts as gene function and mutation to eighth graders. In her second lesson, after teaching introducing students to monohybrid crosses, she designed a practice worksheet of dihybrid genetics problems. Sarah 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. When asked if students would have any difficulty with the lessons, Sarah replied:

But I think for the most part it would be fairly easy and it would be kind of an easier way to get them thinking about how, what’s happening and how this is impacting the flow of information. So I think it’d be fairly easy.

(Susie, interview)

When prompted to explain how she would know if the students were understanding the lesson, Susie described very general assessment strategies, such as the teacher giving a test at the end of the unit and grading worksheets. Lacking knowledge of assessment, middle school learners and curriculum, Susie drew on her strong subject matter knowledge and her general pedagogical knowledge. This knowledge was filtered through her didactic teaching orientation and she selected instructional strategies that primarily relied on telling students the information. Sarah's diagram (Figure 3) represents the interns' lack of knowledge of specific components of PCK as well as a lack of connection between the components.

In this section, we presented modified representations of Magnusson et al.'s PCK model. These representations better portray the differences between the two tracks, interns and classroom teachers. For the teachers, there was interaction between some components of the model. For example, knowledge of learners informed their thinking about assessment. However, these interactions were limited, in that knowledge of assessment did not inform instructional decision-making and the use of alternative teaching strategies. The overlapping circles represent the degree of interaction between components. The interns did not demonstrate any connections between the components of the PCK model. While these modifications to the PCK model may not serve long-term as useful representations of PCK development, they do help better represent the differences between the participants in the two tracks of the ACP.

Conclusion

To provide quality teacher preparation in ACP settings, it is critical that science educators understand the entering PCK of ACP students. In this study we studied beginning ACP students, identifying their entering PCK for teaching heritable variation to eighth graders. Our findings indicate that these teachers used their prior experiences as students, and in some cases as teachers, in planning instruction. Their science teaching orientations were largely didactic and teacher-centered. These individuals lacked understanding of students’ potential learning difficulties, could not yet gauge age-appropriate content goals, had difficulty employing multiple types of instructional strategies, and were limited in designing and using assessments. They began instruction by assessing student prior knowledge, but that information was used to determine the starting point of lectures. Although these individuals held strong content
knowledge about genetics, they were limited in translating this content knowledge into plans for teaching.

Recognizing future teachers’ gaps in understanding about science teaching is critical for improving science teacher education. As other studies suggest, categorizing and understanding beginning teachers’ PCK must be considered when teacher education programs are designed (Gess-Newsome, 1999; Johnson, 2006; Loucks-Horsley et al., 2003). Teacher preparation programs that do not take the knowledge and beliefs of participants into account do not significantly impact teacher practices or student learning (Luft, 2001; van Driel, J.H., Beijaard, D., & Verloop, N., 2001). For example, knowing that ACP students tend to use a teaching sequence of questions, lecture, and guided practice, science educators should demonstrate 5E instructional models that first give students' experience with the phenomenon and supports student explanations of the data, prior to teacher explanations. Given this baseline knowledge, the next step in our research is to examine how PCK is developed throughout the ACP and into the beginning years of teaching, paying attention to what facilitates and constrains teacher learning.

Implications

For Research

From our use of the Magnusson et al. PCK model, we identified limitations when the model was applied to beginning teachers. The model acted as a deficit model, identifying what the novices did not yet know. Across the two tracks of the ACP, we saw distinct differences that we attributed to the early PCK development of the classroom teachers. The modified Magnusson et al. PCK model that we generated helped us better represent the differences we saw between the two tracks. However, these modifications will probably be insufficient as we move beyond documenting incoming knowledge to understanding PCK development during the ACP. We suspect that both the interns and the classroom teachers in this study represent closely placed starting points on the continuum of PCK development. In the PCK research field, large datasets of longitudinal data 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 between PCK components? Do separate knowledge bases 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 experiences within the two tracks support PCK development? To answer these questions, we need to develop substantiated models of PCK development.

For Teacher Education

The participants in this study held a didactic teaching orientation – one that is incongruent with reform-based inquiry-oriented teaching. All four designed lessons in terms of an implicit 4-step script: motivate, lecture, practice, and test. All four characterized teaching as telling students what to learn and for the students to memorize what they were told. This didactic orientation filtered their thinking about instruction. We believe this orientation is strongly held and difficult to change.

However, as science teacher educators, it is our job to teach student how to teach and how to think. It is our job to challenge their orientations and to shift their thinking to a
constructivist perspective. We need to find ways to challenge their content-focused thinking and help them to feel dissatisfied with lecture as the predominant teaching strategy. We need to provide alternative conceptual change scripts, such as engaging, exploring, explaining, elaborating and evaluating and to advocate for a shared vocabulary in teaching to be able to "capture, portray and share knowledge of practice in ways that are articulable and meaningful to others" (p. 15). We recommend that teacher educators use PCK as an explicit framework in their courses. The framework would not only provide a shared vocabulary, but could serve as a tool to help teachers reflect on the development of their own knowledge for teaching.

Loughran, Berry and Mulhall (2006)

Finally, our research has helped us make a value judgment about teachers’ PCK. Namely, that those with teaching experience had more PCK than those without teaching experience. The implication is that since experience promotes the integration of PCK, we believe that teacher education programs must surpass the traditional field experience to include more meaningful experiences. For the field experience to be successful, our data suggest that it is important for interns to be engaged in communities of practice where teachers work together in professional learning teams. We believe that teacher education would be enhanced if teacher-mentors took on new roles as clinical faculty who shared responsibility in the goals of the program with faculty. As equal players, we believe our shared vision of teacher development would change in a positive, reform-based direction.
References


Appendix A

Biology Lesson Planning Task

We know that students enter the SMAR²T program with ideas about how to teach science. To help us better understand your ideas about teaching, we are asking you to design some science instruction. Don’t worry. There are many different ways to complete the following task. We’re interested in finding out your ideas about teaching and learning.

**Context:** You are currently teaching an 8th grade science class with 24 students in a rural school. You sit down to write a 2-day plan focused on introducing the following topic:

Life Science: There is heritable variation within every species of organism.

You plan to teach this sequence on Tuesday and Wednesday. Your school has 50 minute class periods.

**Task:** Prepare a detailed plan for two 50-minute class periods. Assume you can look through and use the available resources in this classroom, but you may not use any textbooks or internet resources.

As you develop your plan for these two class periods, provide as much detail as possible, and be sure to answer the following:

- What do you want the students to learn?
- Describe what will happen during the beginning, middle, and end of each class. What will you do? What will the students do?
- Describe what will be needed for these two class periods.
- Prepare any handouts or overhead transparencies that you plan to use.
Appendix B

Interview Protocol

Say to participant: Thank you again for participating today. During this interview, I will be asking you questions about your plan and what you thought about when you wrote this plan. We are really interested in how you are thinking at this point; there are no right or wrong answers to the questions here.

Start the audio-recorder.
Say to the participant: This is _______ (interviewer's name), interviewing _____________ on ________________ (date). We are audio-recording this interview. Is that ok with you? (Wait for positive response)

Talking Through the Plan

Say to the participant: The first part of the interview is about the plan you just wrote. We want to make sure that we understand your plan and what you intended for these two days.

Begin with this question:
• What did you think about as you were designing this lesson?

Then ask the participant to walk you through their plan by asking:
• Walk me through your plan. How did you start the first day? Continue to ask clarifying questions; your task is to be able to really understand what the participant intended for each part of the plan. Possible clarifying prompts:
  o What did you mean when you wrote ________________?
  o Could you clarify what the students are doing during this part?
  o Could you clarify what you are doing during this part?
  o Could you tell me why you decided to do that?

Probing Participant’s Knowledge

Subject Matter Knowledge (SMK/CKT)
Say to the participant: One part of what a teacher needs to know is something that we call content knowledge. In your case, we mean your own understandings of the science that you will be teaching. These next questions are designed to probe what you know about heritable variation within species. Again, there is no right or wrong answers. We are interested in what you know and how you think about heritable variation within species at this point.

1. What are your previous experiences with the topic of heritable variation within species?
   • How well do you think you know (this topic)?
   • Where did you learn about heritable variation within species?
   • Have you taught (this topic) previously?

2. What do you think is important for students to know about heritable variation within species?
• Why do you think that is important?
• Tell me about where you learned these things.
• What else do you know about heritable variation within species that students might not need to know?

3. Talk to me about how your plan addresses these things (*Probe for specifics based on the plan*).

4. In what ways does the topic of heritable variation within species fit into the “big science picture” of what students learn about science in middle school and high school?

**Knowledge of Students**

*Say to the participant:* Another part of what a teacher knows has to do with how students think about science. The next questions are designed to probe what you know about how students might think about heritable variation within species.

1. What do you think students will already know about this topic?
   - Why do you think that they may know that?
   - Where do you think they may have learned this?
2. Do you expect students to have difficulty with anything that you have planned?
   - Why do you think they will have difficulty with that?

**Knowledge of Instructional Strategies**

*Say to the participant:* We want to know more about how you organized the instruction during these two days. The next questions will help us better understand your decisions about what and how to teach heritable variation within species.

1. From your plan, it appears that you chose to organize the class as __________________ (i.e., lecture, experiment, investigation). Talk to me about making that decision.
   - Where did you learn about how to teach this way?
   - Did you consider organizing the classes in a different way? Why/why not?
   - IF NO TO THE LAST QUESTION: Teachers often develop a range of ways to think about organizing their class; why do you think that you just have one way to think about it?
2. I noticed that you used a picture (graph, equation, analogy…) in your plan. Tell me why you used that ____________ at that point in your plan.
   - How do you think this (picture, graph, equation, analogy) helps students learn about heritable variation within species?
   - Did you consider representing that idea another way?

**Knowledge of Curriculum**

*Say to the participant:* These next questions are designed for us to know something about where your ideas for these two days came from.

1. Where did you get your ideas for these two days of class?
• If you had access to other resources, what would you like them to be?

2. Tell me about the materials (handouts, transparencies) you prepared.
   • Where did you get the ideas for these materials?
   • How do you think these materials will help or hinder achieving the purpose your plan?

Knowledge of Assessment

Say to the participant: The last area I want to ask you about is how you will know what students learn from these two days of class.

1. During the 2 days of instruction, describe how you will know if students are “getting it.”
   • In my experience as a teacher, there are inevitably some students who are still confused at the end of each class. How will you know if your students are confused at the end of each day in your class?
   • Are there other ways that you might know what your students learn in class on these two days?

Is there anything else about your plans that you want us to know?

Thank you again for participating in this interview.
Figure Captions

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

Figure 2. PCK representation for Helen

Figure 3. PCK representation for Susie
Beginning Teachers’ PCK in an ACP

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 of Instructional Strategies

which shapes

Knowledge & Beliefs about Assessment of Scientific Literacy
Beginning Teachers’ PCK in an ACP

Subject Matter Knowledge

Context Knowledge

Pedagogical Knowledge

Didactic Science Teaching Orientation

Knowledge of Instructional Strategies

Knowledge of Assessment

Knowledge of Learners

Knowledge of Curriculum

Lesson Planning Task
Beginning Teachers’ PCK in an ACP

Subject Matter Knowledge

Context Knowledge

Pedagogical Knowledge

Didactic Science Teaching Orientation

Knowledge of Instructional Strategies

Knowledge of Learners

Knowledge of Assessment

Knowledge of Curriculum

Lesson Planning Task