THE DEVELOPMENT OF PCK IN A POST-BACCALAUREATE CERTIFICATION PROGRAM: A LONGITUNAL STUDY OF THE DEVELOPMENT OF TEACHER KNOWLEDGE OF STUDENTS AS LEARNERS AND ASSESSMENT

A Dissertation

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

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MAY 2014

The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled:

THE DEVELOPMENT OF PCK IN A POST-BACCALAUREATE CERTIFICATION PROGRAM: A LONGITUNAL STUDY OF THE DEVELOPMENT OF TEACHER KNOWLEDGE OF STUDENTS AS LEARNERS AND ASSESSMENT

presented by Enrique M. Pareja,

candidate for the degree of doctor of philosophy

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor Patricia M. Friedrichsen, Dissertation Supervisor

Professor Mark J. Volkmann

Professor Elizabeth A. Baker

Professor Lloyd H. Barrow

Professor Heidi Appel

DEDICATION

To my mother and father who, despite all evidence to the contrary, always believed that I would accomplish something important in life (ah the delusion of parents!). It is likely you were wrong – but it has been one amazing journey, worth every bit of your faith in me. Thank you for never giving up on me, no matter how badly I messed things up.

ACKNOWLEDGMENTS

It is clear to me that, considering my nature, an endeavor such as this one would have been impossible to do on my own. Thus many people have had, directly or indirectly, a share in the completion of this project – I am grateful to all of them. However, and at the risk of forgetting someone, I would like to acknowledge those who have contributed, in some way or another, to turning this story into a success story.

First and foremost I would like to thank Sandi Abell, my first advisor. She saw in me something worth her time and aggravation (someday I will figure out what). Mentor, friend, counselor and confidante everything one would want in an advisor and more – way more. She showed I did not know as much as I thought I did, that I was not as intelligent as I thought I was – she was always one step ahead of me. I wish we could have shared more of our thoughts as we used to do on our drives back from our observations. I will miss your directness when assessing the quality of my work ('this is [expletive criticism or exalted praise] Enrique'), you never held back in your comments on anything if there is anything good in me today, a good part of it is because of you – I will never, ever forget you and maybe someday I will accomplish something that would validate your faith in me.

I would like to thank Mark Volkmann for his seemingly endless patience with my, at times, odd ways. You always knew how to play me against myself and show me how to address my shortcomings as an instructor and as a student. I think I never truly came to understand teaching *and* learning until I had the opportunity to be in your class and do my internship with you. You set me up in ways that allowed me to figure out many things

on my own – subtle hints and clues pointing at the flaws in my logic made me better and better every day. I hold myself extremely fortunate to have crossed paths with you – let us hope it will happen again!

I was once a man armed with a spreadsheet and statistics. However I have learned to see the world from a deeper, more holistic perspective. If there is *anything* of worth in me as a researcher, it is due to the patience, insight and dedication of Betsy Baker. I would have missed on a great deal of the world around me if I had not had the fortune of being in your classes. Like Sandi and Mark, you found a way to open my mind to a dimension that I would have never even considered on my own – I would still be half blind to life were it not for you.

Someday I hope I will get the opportunity to help someone in the same manner that Heidi Appel helped me. I was a stranger to her and, in an amazing display of kindness and goodwill she accepted a plea for help from me. Hopefully I did not let you down and the time you invested in me was time well spent – and maybe our paths will cross again sometime in the future.

When I first walked into the suite where the Science Education I was a lost international student with no idea what was going on. I still remember that day and the moment in which Lloyd Barrow welcomed me and gave me advice for the first time. I find it fitting that he was the last faculty member I addressed in official business as a student. I am grateful for your insight, always deep and reflective, you were a source of wisdom during my coursework and the final rock in the foundation of this project. If I ever manage to become even *half* the gentleman and scholar that you are I will consider myself an exceptional man.

The mind behind the notion of conceptual change as part of my research was that of Dave Jonassen. The time that our lives overlapped was too short for me to learn all I could possibly have learned from you. Come to think of it, not it what remains of mine could I possibly hope to learn and *understand* all I have learned from you. I regret to never have had the chance to show you my favorite hikes and trails in the Peruvian Andes.

One twisted smile from Jan Weaver was all it took for me to realize I had been outsmarted yet again and shown, without question, some error in my rationale and thinking. Jan brought to my work the notion of joy and excellence in teaching. I hope that, in time, I can follow your example and maybe, someday, fully answer your question: “What makes a *good* teacher?”

I know I am not the easiest person in the world to deal with but Anna Waldron and Debbie Hanuscin took me under their wing, if for a little while, and introduced me into aspects of research and academia I had been oblivious to. Thank you Anna for your time and for showing me about outreach and inter-departmental cooperation, thank you Debbie for guiding me through academic presentations – only at the end can I fully appreciate what you did for me.

I always had the weirdest requests as part of my work in Re-SMART, however Marilyn Estes and Marilyn Soucie both had all the patience in the world when dealing with me. No matter what my problem was or what information I needed they solved it an addressed it expeditiously and efficiently. Were it not for their work it would have been near impossible to organize this dissertation in any way. Thank you so much.

I once had the chance to share an office with an outstanding guy, driven, hard working and always smiling. I recall so many fun conversations and debates over many different topics. Pat Brown there have been many days I have wished to have only a fraction of your drive and dedication – always looked up to you as an example to follow Patrick.

If I have ever seen a kind soul who always has a comforting and encouraging word, regardless of cloudy, cold or rainy the day is it is that of Deanna Lankford. No matter what was going on you *always* had time to give me a small encouragement, a word of advice and always, always a smile. Though I never said it in person D, I would like to share it here – you are one amazing woman with a heart of gold, thank you for all.

Kadir Demir and Meredith Park Rogers were my older brother and sister. I remember Kadir showing me around campus on my very first trip. He shared, being a foreigner himself, all that I needed to know to make my family's transition as easy as possible, thank you so much. Meredith was on her way out when I entered the program but she always had time to spare a thought or two with me. She introduced me to the use of software in qualitative analysis with NVivo 2.0 (yes it has been that long!) and I believe I have made the best of your example, thank you Meredith.

I will always recall each and every class I took with Michele Lee. Your cheerfulness made some of our more demanding tasks *almost* fun (I still keep your list of lessons learned). So many fond memories of things academic and otherwise made this an experience worth living through.

If one is to measure the worth of my interaction with Chia-Yu Wang by her academic brilliance one would miss so much of value that I learned from her. I remember the stories you shared with me as if it was yesterday – and I share them as often as I can with those who need.

Many others I shared time over this whole process and provided me not only with enlightening academic conversations, but also with solid advice regarding my work in research. Jim Concannon, a team player and hard working man who was always willing to lead by example. Cathy Wissehr, the conversations shared, the drives home and the time you invested in making sure I was not deviating to far from my goals seem to have been worth it! Aaron Sickel, you are one of the most thoughtful people I have met in my life. Hard working and intelligent you set an example for me. Our conversations over the topic of PCK were always enlightening, thank you so much. Steve Witzig and Andrew West showed me that it is possible to balance my work academic and my responsibilities as a father and partner. While I have yet to be at least half as successful as you guys are at any of these, I sure hope someday I can come to within 90% of it (well I will settle for 80% ... maybe). I had the fortune of sharing many a class with Mark Gagnon and, while we did not always have the same perspective on issues, I always walked away wiser and from our exchange of ideas. You are an example to me because of your strong will and dedication to what you believe in. Two of the students I met towards the end of my coursework (yet far from the end of this dissertation) showed me a dimension of life that I either shy from or refuse to even allow around me. I will always remember Kristy Halverson and Kristen Hutchins smiling and ever cheerful, regardless of how rainy, cloudy or cold days may be. Your ability to do this will always be a mystery to me and I even now I miss it (and will probably continue to do so).

I do not know where in this litany I should have put Fran Colley as she was a part of every single step in this dissertation. She is the person behind the curtains who rarely gets seen but is present everywhere. From my very first questions regarding registering for the first time, to the very last on reserving a room to defend my dissertation and uploading the final product, Fran was my go-to person. There was *never* a problem she could not solve, *always* and answer or solution, you are the best Fran.

Whatever ideas I manage to put on paper for this project would be as comprehensible as hieroglyphics, were it not for the help of Carla Roberts. Always happy, I imagine you shaking your head and smiling as you read through some of my ideas, you went beyond anything I could have asked and were glad to share your insight and comments on my work. This provided me with an additional, unexpected, layer of analysis, thank you Carla.

Despite her small stature Paola Avalos proved a pillar of support when I decided to take on my doctorate. Against all logic she decided to start this journey with me – sacrificing much of her promising career. No matter what transpired after we split ways, only the good memories remain – and I am happy that your short adventure with me did not hinder your ability to become the amazingly successful person you are today.

However, for all that was done in the process that led to the completion of this dissertation and my development as an academic, the effort of all would have gone to waste were it not for seven people. I save you for the last because. As important as Sandi was in initiating this journey and supporting me while she was around, you were instrumental in picking up her project to make me into a worthy academic (something which is left to be seen) and seeing it through to completion.

I would like to thank by brothers and sisters Francisco, Andrés, Ximena and especially Jose and Wendy. Their unconditional support in all aspects of my life, personal and academic, provided the foundation without which all this work would have never been completed – whenever things seemed to not work, they were always there, regardless, unquestioning and always willing to stretch their hand out to me no matter how many times I failed.

When things were the darkest in my life and nothing seemed to fall in place there was one person who shone above all others – Katie Piacentini. You shared a dream when I had none; she shared hope where I knew no way out. When I was confused you held on to me and gave me the courage to keep on going. I am ever so grateful for all you shared with me and all you have given me. If there is anything human in me it is because you once smiled at me and made me believe in so many things. I wish that someday I could do the same for you.

And last of all, but certainly not least, Pat Friedrichsen. Pat took onto herself the undesirable task of leading me, the most difficult, stubborn, rebellious, distraught and cynical advisee ever. Most would have given up on me within weeks if not days. I believe few people, if any, could have done as good a job as she did, especially considering the sort of person I am. This ship has reached port only because your light shone brighter than all others in the dark … and you had the patience to let me find my way.

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ABSTRACT

This study focused on the development of specific aspect of beginning teacher Pedagogical Content Knowledge (PCK) in an Alternative Certification Program (ACP). Data was collected over a period of over two years and included lesson plans, interviews with the participants and their mentors as well as classroom observations and participant reflections. Four participants were purposefully selected to represent one cohort in the ACP. Individual profiles constructed for each case and the subsequent cross-case analysis revealed that the participants shifted their beliefs about students as learners and assessment based on the influence of the context under which they were developing at each point in time. These shifts, while dependent on their views of the context, were strongly influenced by their initial views as they relate to these aspects of PCK. Participants would resolve any conflict arising with new views presented to them in a subjective manner, prioritizing coherence with their prior knowledge on the specific aspect of PCK and with the other aspects of their PCK. These findings provide an alternative perspective on the nature of the shift in knowledge that occurs during teacher preparation and the initial years of teaching. It allows us to provide a different angle on the dynamics among PCK components based on the interaction among them as they

develop over time. Moreover they allow us to see that this development is neither linear nor unidirectional. Additionally it shows us that teachers constantly revalue their views of students as learners and assessment based on the experiences provided by both their academic and professional context.

CHAPTER 1. INTRODUCTION

Background

Since the late 1950s, the achievement of scientific literacy has been the primary goal of science education (DeBoer, 2000). Achieving scientific literacy means that students have developed a broad understanding of science to the point that they are capable of critically analyzing existing and new scientific knowledge as it relates to their daily lives (Bybee, 1997). Given that the rate of scientific development continues to grow (Larsen & von Ins, 2010) and that science research is shifting to a more interdisciplinary approach (Hicks & Katz, 1996), the impact of science in our lives is even greater today than in the past; thus, the need to achieve scientific literacy is becoming increasingly important.

However, research in the United States as well as international testing by the International Association for the Evaluation of Educational Achievement (IAE) and the Organization for Economic Cooperation and Development (OECD), sponsors of the Trends in International Mathematics and Science Study (TIMMS) and the Programme for International Student Assessment (PISA), indicate that students are not achieving the expected level of scientific literacy. In 2012, average scores in scientific literacy from students in the USA were comparable to the international average for PISA, ranking the USA 28th amongst 65 participating countries. Moreover, as far as top participating global economies are concerned, the USA barely managed to rank better than the Russian Federation and Italy while being clearly outperformed by the likes of Japan, Germany, Korea and Canada (OECD, 2013). This pattern has been consistent throughout PISA testing since 2000 (Kelly, Nord, Jenkins, Chan & Kastberg, 2013; Miller & Warren, 2011).

Research on student learning suggests that not only do students fail to connect science explanations in class to their everyday lives, (Driver, Leach, Millar & Scott, 1996), but they also leave school with a variety of misconceptions regarding nature and natural phenomena (Driver, Squires, Rushworth, Wood-Robinson, 1994).

One of the more influential factors in student learning is the way in which students are taught (Brophy & Good, 1970, 1986; Brophy, 1992). This supports the need for highly qualified teachers to help students achieve the desired levels of scientific literacy. A highly qualified teacher has been described by the U.S. Department of Education (2002) as an individual with a bachelor's degree, teacher certification and a major in the field they teach. Furthermore, in 2012, the National Research Council published their latest document on science teaching and learning: *A Framework for K-12 Science Education: Practice, Crosscutting Concepts and Core Ideas* (NRC, 2012). This document provides guidelines for the development of science education standards. It also gives a vision of how a highly qualified teacher would teach science and a view of how science learning should take place between grades K-12. According to this document, high quality teaching of science and engineering is based on three dimensions: practices, crosscutting concepts and core disciplinary ideas. Science teachers are thus expected to be able to address the "major practices scientists employ as they investigate and build models and theories about the world" (NRC, 2012, p. 30). They should address these practices by touching upon crosscutting concepts, that is, concepts that have "application across all domains of science" (NRC, 2012, p. 30). This notion is not unique to this document and has been addressed in several reform documents preceding it. Crosscutting concepts were referred to as "unifying concepts and processes" in the *National Science Education Standards* (NRC, 1996) and "common themes" in the *Benchmarks for Science Literacy* (AAAS: Project 2061, 1993).

Finally these themes and practices should cover the disciplinary core ideas. Two aspects of these core ideas that hit squarely on the development of quality teachers and on this investigation are that core concepts should relate either to the interests and life experiences of students (or connected to relevant societal concerns) and that they should be teachable and learnable across grades in increasing levels of depths. These criteria imply that quality teachers should be aware that knowledge develops over time as students re-construct their understanding of science based on new experiences and information. Thus teachers should seek to provide students with opportunities for discussion and debate, sharing responsibility with students while developing a supporting classroom community based on cooperation and respect (NRC, 1996)

However, teacher quality is not the only factor to be considered when addressing shortcomings in terms of achieving scientific literacy. Schools in the U.S. currently face a growing shortage of qualified teachers, especially science and mathematics teachers (Abell Foundation, 2001). This is not only due to the need for teachers being greater than the teachers being certified via traditional programs but also due to poor teacher retention (Johnson, Birkeland, & Peske, 2003). Predictions suggest that as many as 2.2 million K-12 teaching positions will need to be filled by 2015 with the greater shortages occurring in urban and rural areas (Feistritzer, Harr, Hobar, & Scullion, 2005; Ingersoll, 1999).

Alternate certification programs (ACPs) have been one of the ways in which this teacher shortage has been addressed. These have been defined as “[t]hose teacher preparation programs that enroll noncertified individuals with at least a bachelor’s degree, offering shortcuts, special assistance, or unique curricula leading to eligibility for a standard teaching credential” (Adelman, 1986, p. 16). These programs allow individuals with a strong science background a faster route to obtaining science teacher certification. Nevertheless this path of teacher preparation lies in the middle of two competing agendas. On one side is an agenda that supports teaching professionalization in order to guarantee full certification in accordance with professional standards (Cochran-Smith & Fries, 2005). On the other side a deregulatory agenda that aims to eliminate the requirement of teacher preparation in teacher education, arguing that strong subject matter knowledge is paramount in becoming a good teacher (Ballou & Podgursky, 2000; Kanstoroom & Finn, 1999).

Although ACPs have been successful at teacher recruitment, in terms of teacher quality – they show mixed results (Wilson, Floden, & Ferrini-Mundy, 2002). This suggests that, if ACPs are one of the pathways to satisfying the need for teachers, we need to better understand how they develop their knowledge for teaching in order to find the best way to develop highly qualified science teachers from these programs. The early 1980s marked a shift in education research, where the calls for understanding how teacher knowledge develops become central to the issue of developing more effective teacher education programs (Cochran-Smith & Fries, 2006; Feiman-Nemser, 1983; Zeichner, 1988). This study seeks to understand the development of teacher knowledge for teaching in the context of an ACP and into their first years as teachers.

Rationale for the Study

The rationale for a longitudinal study within the context of an ACP centers around two objectives. First, it seeks to better understand the way in which students enrolled in education programs develop their knowledge for teaching in an ACP program, an issue that is central to addressing the debate on the best ways to deal with teacher shortages without sacrificing quality. The second objective is to determine how the different factors in the ACP influence the development of the participants' knowledge for teaching. This objective is called the rationale for pedagogical content knowledge.

Teacher knowledge is a complex construct that has been viewed from a variety of perspectives. In order to understand it, researchers must narrow down their scope in order to investigate the issue in a form less complex than the whole (Shulman, 1986). The result of this approach has produced a variety of constructs. In addition to the many specialized subjects that have become part of the education curriculum, researchers must separate the chaff (general knowledge, beliefs, attitudes and values subject to bias) from, disciplined constructs used by researchers to reduce yet understand and communicate the complexity underlying the development of teacher knowledge (Gess-Newsome, 1999). However, many terms have been used inconsistently by researchers (Alexander, Schallert & Hare, 1991). In order to address these issues, this study is guided by an overarching research question and five sub-questions, while being framed within the context of two existing models of knowledge description and development: pedagogical content knowledge and conceptual change.

Overarching Research Question

How does a science teacher's understanding of learners and assessment develop over time from entry into a post-baccalaureate certification program through their first two years of teaching?

Sub-questions

1. What conceptions of students as learners do ACP-track teaching interns have at different points in time, from the beginning of the ACP to the beginning of their second year as full-time teachers?
2. What conceptions of assessment do ACP-track teaching interns have at different times, from the beginning of ACP to the beginning of their second year as full-time teachers?

3. In what ways do the experiences in the ACP and teaching influence teaching interns' conceptions of students as learners over time, from the beginning of the program and into their second year as full-time teachers?
4. In what ways do their experiences in the ACP and teaching influence teaching interns' conceptions of assessment over time from, from the beginning of the program and into their second year as full-time teachers?
5. In what ways do the conceptions of students as learners held by ACP-track teaching interns interact with their conceptions of assessment throughout the ACP and into their second year as full-time teachers?

Conceptual Framework

Selecting a conceptual framework to guide the research allows a researcher not only to determine what theories and models will guide an investigation, but also to connect findings to these theories, helping with the analysis and explanation of results (Maxwell, 2005; Zeichner, 2005). Furthermore, a conceptual framework allows the researcher to determine possible ways of refining theories in the field (Zeichner, 2005). Given that my study was carried out within the context of a larger project – studying the development of Pedagogical Content Knowledge (PCK) – it made sense to use this concept as an organizing framework. Nevertheless initial findings from the program known as "Alternative Science Teacher Education Program" (ASTEP) made us question the value of using this framework alone to analyze the differences between experienced and inexperienced teachers. These results suggest that PCK alone might not provide a framework that would help us understand the mechanisms that mediate the development of teacher knowledge for teaching. The approach taken in this case was to extend the analysis beyond the knowledge components included in PCK and extend it into the knowledge bases that influence the development of PCK (Friedrichsen et al., 2009). Moreover, due to the longitudinal nature of the project and the differing nature of the data collecting tasks, it was not possible to consistently collect data that was topic specific as would be required to rigorously describe PCK in terms of the definition given by Shulman (1986), which is at the core of the model described by Magnusson, Krajcik and Borko (1999). I will therefore extend the definition of PCK as proposed by Veal and MaKinster (1999). In this case they define a hierarchical structure of PCK that can be general, domain specific or content specific (Figure 1).

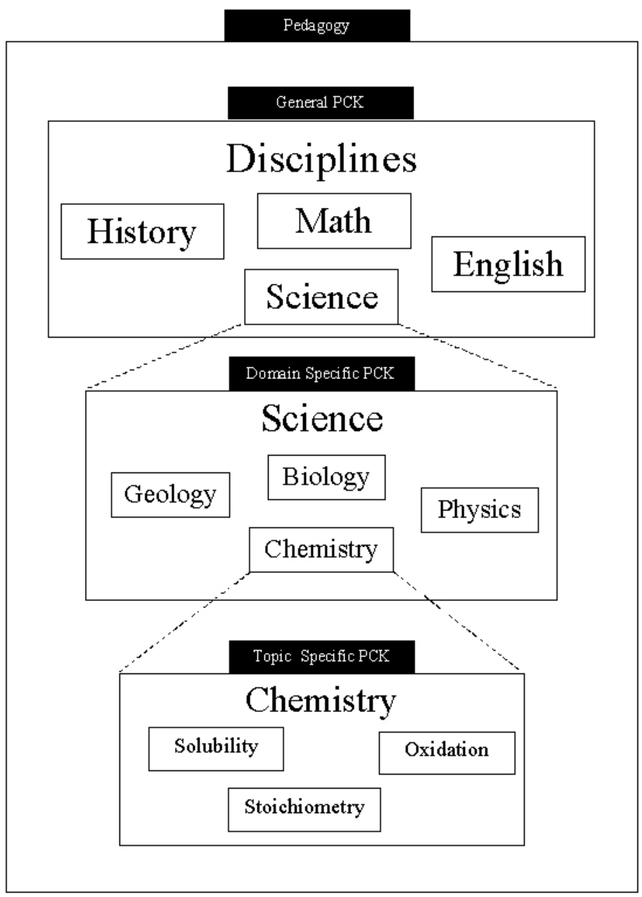

Figure 1. General taxonomy of PCK [1]

[1] Note. From Veal, W. R., & MaKinster, J. (1999). Pedagogical content knowledge taxonomies (p. 9). *Electronic Journal of Science Education* [Online]. Available:www.unr.edu/homepage/crowther/ejse/vealmak.html.

This study focused on domain specific PCK. Because of this focus, the research questions were formulated around the categories of knowledge that, according to Morine-Dershimer and Kent (1999), are influenced the least by subject matter knowledge. These are 1) knowledge of assessment 2) knowledge of learners and learning as far as the components of PCK and pedagogical knowledge are concerned, and 3) knowledge of context as far as the knowledge bases that interact to develop PCK are concerned. See Figure 2.

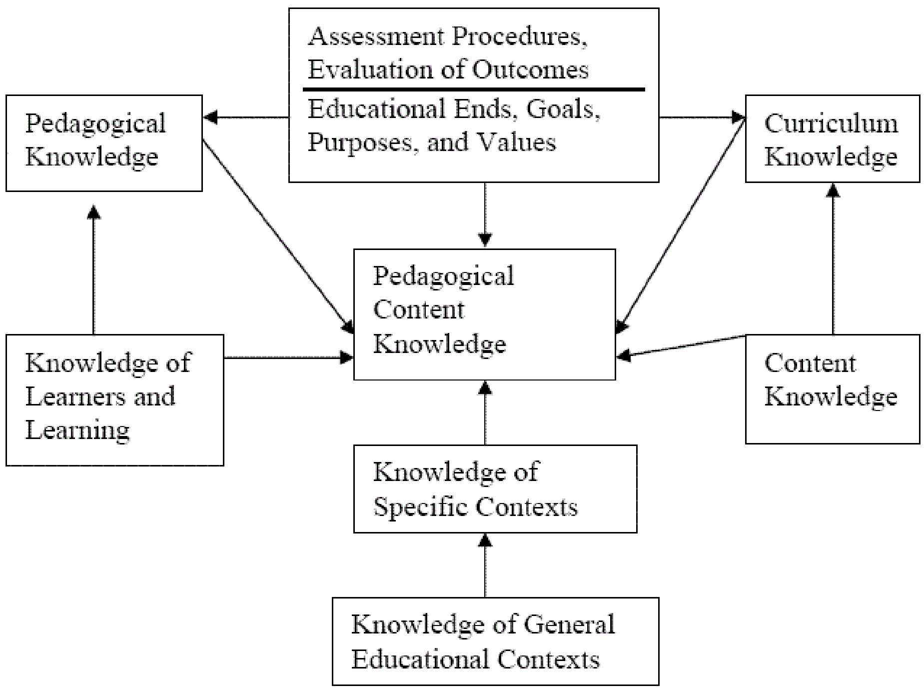

Figure 2. Categories contributing to PCK[2]

Another limitation of the PCK model is that it is a descriptive, static model which allows us to portray only a snapshot of the knowledge a teacher has at a given time. However it provides, on its own, little in the way of connecting two or more snapshots together. The way I intend to address this limitation is by using a conceptual change model (Posner, Strike, Hewson,

[2] Note. From Sources of teachers' pedagogical content knowledge (p.22), by G. Morine-Dershimer and T. Kent, 1999. In J. Gess-Newsome & N. G. Lederman (Eds.) *Examining pedagogical content knowledge: The construct and its implications for science education*. Boston: Kluwer. Copyright 1999 Kluwer Academic Publishers

& Gertzog, 1982; She, 2002; Strike & Posner, 1992; Vosniadu & Brewer, 1997) in conjunction with the PCK model to analyze the data collected. It is not my intention to merge these models into a single unified theory of teacher learning but rather to use them simultaneously in a coherent manner to support this study. The conceptual change model provides a suitable framework to analyze changes in understanding of learners and the learning process that individuals have as they develop into teachers by providing a mechanism to explain the changes that take place.

This approach is not without precedence as far as the use of conceptual frameworks in the field of teacher knowledge development is concerned. Cochran-Smith and Lytle (1999), when reviewing the developments in teacher research during the 1990s, discussed the developing of conceptual frameworks as one of the five major areas of development in this field. They acknowledge that, while as researchers we tend to classify and make distinctions among different frameworks and models for heuristic purposes, these are complexly interrelated and overlap in such a way that lines among them cannot be easily drawn (Cochran-Smith & Lytle, 1999). However, claiming that the interrelation between models and frameworks is complex and that the overlapping makes their distinction difficult is not equivalent to saying that relationships and connections can be clearly established or taken for granted. As a researcher I will thus outline the models that comprise this conceptual framework as well as establish the connections between them that provide support for this investigation. First I will present the PCK model which served primarily an organizational function, providing a framework under which to organize different aspects of an individual's knowledge for teaching. Over the last 25 years, researchers have further refined the PCK model; hence, slightly different views of its components and its nature have been presented. Therefore I will then proceed to make explicit my view as a researcher on this matter. I will then proceed to elaborate on the conceptual change model as proposed by Posner and his colleagues (1982). This model was initially developed as a framework to explain the learning of science. However Pajares (1992) referred to the principles of conceptual change when explaining how teachers' beliefs change. This continuum of change is still viable. This dissertation first defines the different views of conceptual change that have been outlined in the field of science education and then presents the model as it applies to this investigation.

Pedagogical Content Knowledge

The notion of PCK was first proposed by Lee Shulman in his Presidential address at the 1985 American Educational Research Association meeting in Chicago, USA (Shulman, 1986). In this speech, he made the case for what he called the missing paradigm. This missing paradigm, according to Shulman, is the content of the lessons, not just any content, but that which is specifically related to teaching, "[w]hat we are missing is the content of the lessons taught, the questions asked, and the explanations offered" (Shulman, 1986 p. 8). Shulman identified PCK as one of the types of content knowledge that are part of teacher knowledge. Since its introduction in 1986, PCK has been translated, revised and extended by many researchers (Abell, 2007). Shulman initially defined PCK as a "… particular form of content knowledge that embodies the aspects of content most germane to its teachability" (Shulman, 1986, p.9). Within this form of content knowledge, he included knowledge of the most regularly taught topics, the most powerful analogies and representations, examples and explanations, in his words "the ways of formulating the subject that makes it comprehensible to others" (Shulman 1986, p. 9). He further argued that since there is no single most powerful form of representation, teachers must be aware of several forms of representation for a given concept, the sources of which may be research or the wisdom of practice. He narrowed the types of knowledge teachers should have to seven (Shulman, 1987):

- Content knowledge (specifically subject matter knowledge);
- General pedagogical knowledge, including principles and strategies of classroom management and organization;
- Curriculum knowledge, with particular grasp of the materials and programs;
- Pedagogical content knowledge, that special combination of content and pedagogy that is exclusive to teachers;
- Knowledge of learners, their characteristics and how they learn;
- Knowledge of educational contexts, ranging from the workings of the group or classroom to the governance and financing of school districts to the character of communities and cultures; and
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

A student of Shulman's, Pamela Grossman, proposed a model of teacher knowledge based on Shulman's ideas (Grossman, 1990). In this model, Grossman drew from Shulman's definition of PCK and refined it. She claimed that teacher knowledge has four components: (a) subject matter knowledge; (b) general pedagogical knowledge; (c) knowledge of context; and (d) pedagogical content knowledge (see Figure 3). Grossman claimed that a bidirectional relationship exists between PCK and other components of teacher knowledge (Grossman, 1990).

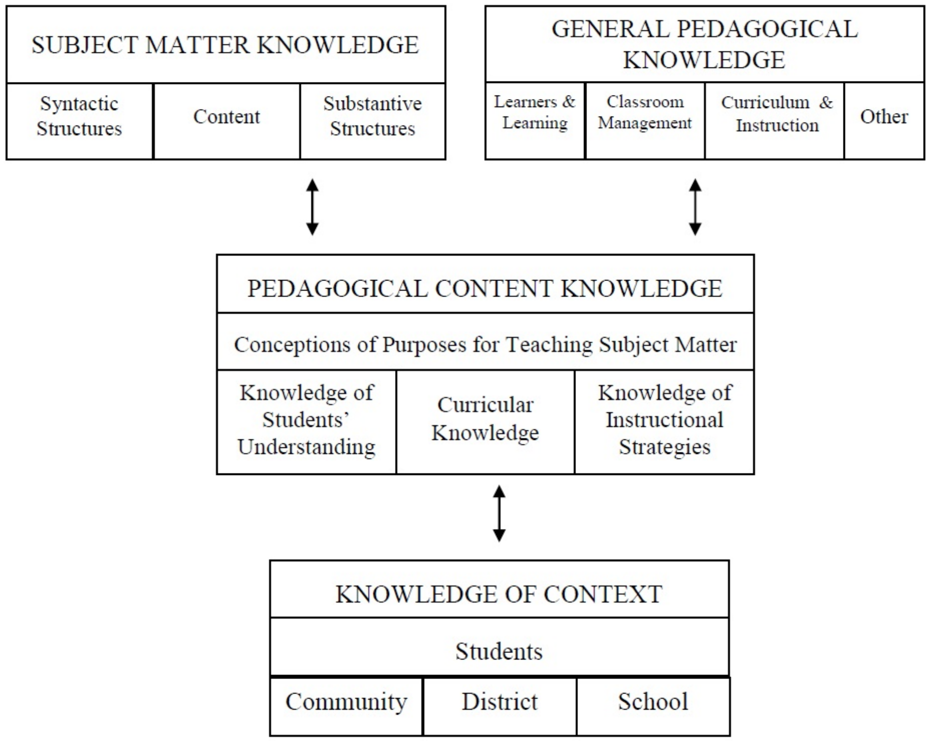

Figure 3. Grossman's Model of teacher knowledge[3]

Shirley Magnusson and her colleagues elaborated on the definitions proposed by Grossman and Shulman (Magnusson, Krajcik, & Borko, 1999). They defined PCK as:

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

Magnusson et al. (1999) proposed an additional component of PCK: knowledge of assessment (see Figure 4). Furthermore, they redefined Grossman's "conceptions of purposes for teaching subject matter" (Grossman, 1990, p. 9) to "[o]rientations toward science teaching and learning" (Magnusson et al., 1999, p. 97). These orientations are defined as "teachers'

[3] From: Grossman, P. L. (1990). *Making of a teacher*: *Teacher knowledge and teacher education* (p. 5). New York: Teachers College Press.

knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (Magnusson et. al., 1999, p. 97). A transition model that provides a scaffold to this redefinition is provided by the modified version of the Grossmann model presented by Magnusson et al. (1999). In this model, all knowledge components are labeled 'knowledge and beliefs' as opposed to only 'knowledge'. The Magnusson model then removes the term 'beliefs' and adds the component 'orientations'. As we can see in Figure 4, Magnusson et al. argued that the knowledge of curriculum, students, assessment and instructional strategies shapes, and are shaped, by a teacher's orientations. Orientations are a part of PCK and in turn guide instructional decisions, resulting in a bidirectional relationship between them. All these components are influenced by a teacher's subject matter knowledge, pedagogical knowledge, and knowledge of context. The five components of PCK for science teaching according to Magnusson et al. (1999) are:

- Knowledge of students' understanding of science. This includes both understanding of students' prior knowledge and learning experiences as well as the difficulties they might experience learning specific content.
- Knowledge of assessment. This includes the understanding of different methods to use in order to assess student learning.
- Knowledge of curriculum. This is comprised of a teacher's understanding of the goals and objectives for students both at a particular grade level and across grade levels as well as their understanding of the use of a variety of curricular resources.
- Knowledge of instructional strategies. This includes knowledge of general teaching strategies for teaching science as well as strategies for teaching specific topics within science.

- Orientations toward teaching science. This component includes teachers' understanding about the purposes and goals for teaching specific science content at a particular grade level.

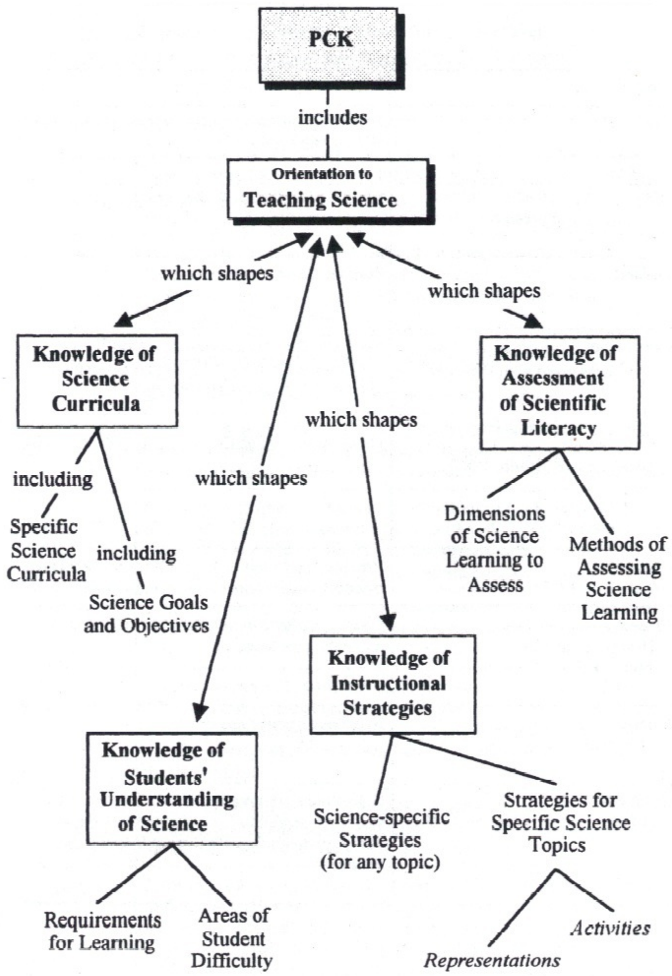

Figure 4. Components of pedagogical content knowledge for science teaching.[4]

Regarding the nature of pedagogical content knowledge, the scenario is not as clear. Shulman's (1986) definition of PCK centers on the need for teachers to present subject matter content knowledge in a way that is comprehensible to students. Teachers must understand the

[4] Note. From Nature, sources and development of PCK (p.99), by S. Magnusson, J. Krajcik and H. Borko, 1999. In J. Gess-Newsome & N. G. Lederman (Eds.) *Examining pedagogical content knowledge: The construct and its implications for science education.* Boston: Kluwer. Copyright 1999 Kluwer Academic Publishers

content knowledge of their discipline, both substantive and syntactic, and be able to “transform the content knowledge he or she possesses into forms that are pedagogically powerful yet adaptive to the variations in ability and background presented by students.” (Shulman, 1987, p.15). It is thus clear that, when first conceived, PCK was assumed to be the result of the transformation of knowledge. This transformational model of PCK is said to be grounded in the work of Dewey, Bruner and Schwab (Deng, 2007), who argue for the transformation of subject matter knowledge into appropriate representations by curriculum specialists. The main change the PCK paradigm provides is the shift of transformation from a source external to the teacher to the teacher itself. However, not all researchers agree that PCK is the result of the transformation of knowledge. In her introduction to PCK, Gess-Newsome (1999) compares both transformative and integrative models of teacher cognition and their implications on teacher preparation and research. Based on her review of the literature, she conservatively argues that what occurs in reality is most likely to be found somewhere in the middle of these two models (Gess-Newsome, 1999). She argues that the knowledge bases (or in the extreme case, PCK) must be “… well structured and easily accessible” (Gess-Newsome, 1999. p 13). This implies that the knowledge components of PCK must be organized in a system. Moreover, she argues that even if exemplars of PCK can be identified, once integration takes place, it is difficult to differentiate one knowledge base from the other and the knowledge components might have to be inferred by researchers. The integration of these knowledge bases is shaped, according to Magnusson et al. (1999) by what they call ‘Orientations to science teaching’, a term used to encompass what Grossman (1990) called “Conceptions and purposes for teaching subject matter’ (Figure 3). The model presented by Magnusson et al. (1999) (Figure 4) suggests a bidirectional relationship between orientations and the other knowledge components of PCK.

This researcher views PCK as type of knowledge unique to teaching that is the result of the transformation of subject matter knowledge, pedagogical knowledge and knowledge of context. This view is consistent with the models proposed by Shulman (1986), Grossman (1990), and Magnusson (1999). Due to the nature of the ASTEP program and the variety in teaching assignments of the participants both during and after the program, it was impossible to observe topic-specific PCK as defined y Veal and MaKinster (1999). I, therefore, chose to focus on the components of PCK least dependent on subject matter knowledge: knowledge of assessment and knowledge of students' understanding of science. In this case, the description of these components by Magnusson et al. (1999) provided the interpretive lens for examining teacher knowledge development in this study. A third component of PCK, the orientations to science teaching, is argued to interact in a bi-directional manner with the knowledge component of PCK, shaping them and in turn being shaped by them. In the case of this study, rather than take a stance that could be mired in a 'Which came first—the chicken or egg?' dilemma I chose to complement the PCK framework with a different model to analyze changes: the conceptual change model.

Conceptual Change

Conceptual change has been defined as the process that occurs as a person changes his or her individual coherent mental structure of the world for another that represents it more appropriately. The conceptual change model has been proposed and investigated extensively with regards to learning science and draws from the philosophical views of Kuhn (1970) and Lakatos (1970) as far as defining its epistemological base (Posner, Strike, Hewson and Gertzog, 1982). The majority of examples supporting this theory are found within the field of science education, specifically the Physical Sciences (Posner et al., 1982; Chi, Slotta and de Leeuw, 1994; Vosniadu and Brewer, 1992; Vosniadu, 1994; Vosniadu & Ioannides, 1998; She, 2002, 2004; Harrison & Treagust, 2001) and the Life Sciences (Chi et al., 1994; Chan, Burtis & Bereiter, 1997). While conceptual change involves a rearrangement in an individual's conceptual framework, pre-existing notions might be replaced entirely (Spada, 1994). However conceptual change is not merely a form of cognitive development; it is influenced by social and affective factors (Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992; Vosniadu, 1994; Vosniadu & Ioannides, 1998). Researchers have taken different stances on what is changed, how this change takes place and the role of prior knowledge (Mayer, 2002) as well as the importance of the nature of the content and the evolutionary or revolutionary nature of change taking place (Tyson, Venville, Harrison, & Treagust, 1997).

What changes? Three perspectives on this can be found in the literature. Some researchers claim that the changes that take place rearrange the ontological categories regarding a specific concept. In this case, change occurs as concepts are reorganized within a given ontological category or across categories (Chi, 1992; Chi, Slotta, & Leeuw, 1994). The examples proposed by Chi and her colleagues are based on both the field of physical sciences and biological sciences. In this case, they define ontological categories in terms of the nature of the physical phenomena being studied. Two examples of ontological categories in the field of physical sciences are matter and processes. They claim that conceptual change is easier for concepts perceived to be within the same category with reorganization across categories being considerably more difficult (Chi et al., 1994).

Others argue that epistemological commitments are changed via the transformation of analogies and beliefs regarding a particular knowledge and its interaction with others. In this case, conceptions ‘compete’ with each other in a form of conceptual ecology based on their potential to reconcile observations which come across as anomalies to the preexisting knowledge framework (Hewson, 1981, 1996; Posner et al., 1982; Strike & Posner, 1992). An example of this is the competition that might occur when a person holds a strong commitment to Newtonian mechanics and is confronted with phenomena that can be explained fully only by the use of special relativity theory like the de-synchronization of watches attributed to relative motion of different reference points (Posner et al., 1982). Finally some researchers claim that conceptual change affects both ontological and epistemological structures with radical conceptual change. In this case the mental models that are constructed to explain reality involve both ontological and epistemological commitments and, under certain circumstances, conceptual change will require more than just a shift in ontological categories (She 2002, 2004; Vosniadu, 1994, 2003 Vosniadu & Brewer 1992, 1994 and Vosniadu & Ioannides 1998). Moreover, Vosniadu (2004) argued that this change results in the alteration of an individual’s mental models and representations of a given phenomenon.

How does change occur? Researchers agree that prior knowledge is the starting point for conceptual change, whether it is ontological categories or “trees” (Chi, 1992), a conceptual ecology that is constituted by both concepts and misconceptions supported by an epistemological base (Posner, Strike, Hewson, & Gertzog, 1982), or a mental model based on an individual’s presuppositions and understanding of a given phenomenon, which forms the basic structure to assimilate or reconcile new information (Vosniadu, 1994). An individual challenges his prior knowledge when it cannot explain incoming experiences (information). This prior knowledge is judged as to its appropriateness by a rational process that determines how suitable the model/framework is in explaining this new information (Strike & Posner, 1992). Conceptual change occurs as understanding is modified to incorporate this new information into pre-existing structures, replacing these structures through competition (Posner et al., 1982) or reorganization and enrichment of pre-existing structures (Chi, 1992; She, 2002; Vosniadu, 1994). Change is triggered by cognitive conflict resulting in dissatisfaction on part of an individual based on the fact that his or her current understanding fails to satisfactorily explain the information that is obtained. New understanding and accommodation occur as an individual is presented with or determines new models based on plausibility and potential for extension. The first condition requires that the new conception or model be capable of explaining not only the new data but also pre-existing information. The latter one requires that the model show potential for extension into other areas (Posner et al., 1982).

While most authors agree that conceptual change is evolutionary or gradual, others suggest that revolutionary and radical changes are possible and sometimes necessary (Chi, 1992; She, 2002; Vosniadu & Brewer, 1997). Chi and colleagues claimed that changes within a given ontological category are easier than those between categories, the former resulting in the addition and transformation of the category while the latter requires radical conceptual change. Moreover, this radical change is more difficult as ontological structures are underpinned in an individuals' understanding of the world, specifically his or her ontological beliefs and the categories in which certain knowledge structures are assigned. Nevertheless, She's (2004) research supports this notion of radical conceptual change in physical science by using a dual situated model. The latter model represents a situation where the individual is exposed to a scenario that creates dissonance with an individual's pre-existing knowledge and challenges their epistemological and ontological beliefs so that an alternative explanation or model is more easily accepted. In this case, the radical conceptual change may be achieved if the situation creating the dissonance targets a mental model known to be limited in some form. For example, in the case of inheritance, one could target the notion of dominance being an intrinsic characteristic of an allele as opposed to a function of the mechanism of gene expression.

Factors influencing conceptual change. From the above discussion it is clear that the primary factor influencing conceptual change is the learners' presuppositions and mental models, specifically regarding ontological categories and epistemological commitments. Building on this, researchers have determined that the nature of the content to be learned is important in the process of conceptual change. Chi (1992) found change that requires students to shift a particular notion between ontological trees was more difficult than notions that are built upon the same ontological category. While Vosniadu argued that Chi's ontological categories were arbitrary, making the model limited (Vosniadu & Brewer, 1994), she agreed that different content relates to different ontological presuppositions and observational information, thereby making some concepts harder to change than others. Moreover, She (2004) added that the hierarchy of a concept within a given ontological category "subsumes more essential underlying concepts, making it difficult for conceptual change to occur" (She, 2004, p 143).

Finally, both Posner et al. (1982) and Vosniadu (1994) argued that metacognition is of significant importance in fostering conceptual change. This is evident as conceptual change takes place at the level of mental models; ontological and epistemological underpinnings that represent reality as perceived by the individual and have a significant affective and societal component. If an individual does not consider his or her understanding as subject to question, it will act as a barrier for conceptual change. Vosniadu (1994) argues that students that lack metaconceptual awareness fail to realize that their presuppositions and beliefs can be questioned and challenged and are thus more likely to retain misconceptions.

While the theory of conceptual change has not been developed to explain the development of teacher knowledge, it has been used as a suitable framework to address the development or change in beliefs by teachers (Pajares, 1992). Concurring with this line of thought, this dissertation defines conceptual change as a change that occurs in the mental models held by an individual based on a revision of his or her existing knowledge framework, which supports those models by assimilation or accommodation to reconcile inconsistent information. This definition is consistent with the models proposed by Posner et al. (1982), Chi (1992) and Vosniadu and her colleagues (Vosniadu & Brewer, 1992; Vosniadu & Ioannides, 1998). This dissertation defines mental models as a dynamic cognitive structure that is created with the purpose of dealing with a specific situation perceived or conceived (Vosniadu & Brewer, 1992; Vosniadu, 1994). These mental models are based on the epistemological commitments and ontological categories held by an individual, which gives him or her a way to deal with problem-solving situations. I view the process of conceptual change as evolutionary occurring mostly by accommodation of new information into existing models until revision of the model is necessary unless a situation of such dissonance is presented that radical revision of the mental model is required (Posner et al., 1982; Chi, 1992; Vosniadu, 1994).

In this study, the conceptual change model served as an interpretive lens under which changes in PCK were analyzed. Given the nature and structure of PCK, we can see that it is comprised of a series of knowledge categories that I take to be analogous to the ontological categories described in conceptual change research. Moreover, the transformational nature of PCK as well as its dependence on contextual knowledge to address reality (based on an underlying epistemological and ontological structure) is analogous to the mental models within which conceptual change is argued to take place. In the case of this study, that transformational learning represents the development of teacher knowledge for teaching over time.

Significance of the Study

Given the rate of retirement and retention of teachers over the past decade, the US education system, which is underperforming in international testing, faces a shortage of highly qualified science teachers (Feistritzer et al., 2005). In order to address this shortage, many states have created alternative certification programs (ACPs) that usually seek to move individuals already holding undergraduate degrees through a shortened teacher preparation program and into classroom teaching (Feistritzer, Harr, Henry, & Ulf, 2006). Current legislation requires teachers to be highly qualified and accountable for student achievement in mandatory state testing. However, despite meeting the requirements to be considered highly qualified relative to content knowledge, many ACP teachers feel their pedagogical knowledge is limited and inadequate and is in need of additional support and mentoring (Roehrig & Luft, 2006). Our understanding of how teacher knowledge develops over time in an ACP is limited and, given the increasing need for highly qualified teachers in the current accountability context, understanding how future teachers' knowledge about science learners develops is important in order to effectively improve science teacher education. The results from this study contribute to what we know about teacher PCK at the beginning of a teacher preparation program and how teacher knowledge develops during an ACP and into the initial teaching experiences. This study seeks to inform the design or redesign of ACPs in order to promote high quality science teaching.

Organization of the Dissertation

This study is divided into five chapters. Chapter 1 is an overview of the study including the rationale, research questions, theoretical framework, and significance. The theoretical framework is based on two models, a model based on teacher knowledge and a model based on the development of knowledge, which serves to organize this dissertation: pedagogical content knowledge and conceptual change.

Chapter 2 elaborates on these concepts by discussing how they are described in the research literature. Chapter 3 outlines the qualitative methodology that was used in this study. This includes a description of the research tradition, research methodology, and the study's design. In order to provide the necessary background information to frame the qualitative methods used, I included details of the context of the study such as the design of the ACP, school demographic data and participant background, including experiences with K-12 age students. Furthermore, at the end of this chapter, I discuss the trustworthiness of the design. Chapter 3 describes the data collection and analysis methods. Chapter 4 describes the findings of the study. In this chapter I initially provide a case profile for each of the participants in the study. At the end of each case narrative I provide tables summarizing the case over time. I then proceed to use the details from the case profiles to carry out a cross-case analysis providing assertions that emerge from the data using the frameworks discussed in Chapter 3. Chapter 5, the final chapter, includes a summary of the findings in relation to the research questions and a discussion of the findings relative to the research literature. The chapter concludes with implications for practice and recommendations for future research.

CHAPTER TWO: CONTEXT AND PRECEDENTS

Review of the Literature

In this chapter, I will discuss the existing literature on the matters addressed in the research questions presented in Chapter 1. To this effect I will review the following areas of research: teacher knowledge of students as learners, teacher knowledge of assessment, development of pre-service and beginning teachers' PCK and factors that influence this development of teacher knowledge and conceptual change as it pertains to the development of teacher knowledge for teaching. Because these topics tend to overlap in many investigations, I will address them in three subsections and show the interrelatedness of each investigation. Two of these topics relate to the research centered on the PCK components of the theoretical framework, and the third refers to the development of teacher knowledge for teaching. When an investigation addresses more than one of the larger subsections, such as knowledge of assessment and development to teacher knowledge, I will refer to the specific findings of that investigation under the most relevant subsection.

Knowledge of Students as Learners

This component of PCK encompasses the understanding that teachers have about students' science learning. This includes prerequisites for learning certain concepts, areas of student difficulty, approaches to learning science and any alternative or erroneous conceptions that they might have (Magnusson et al., 1999). Research in this aspect of teacher knowledge has determined that beginning and prospective teachers will state a preference for both student-centered and teacher-centered approaches when discussing their beliefs on learning. While initial practice has been related to stated beliefs, it has also been determined that beginning and prospective teachers are likely to change their stated beliefs as opposed to their classroom practice over the course of their initial experiences as full time teachers. This change has been found to be gradual suggesting a period in which competing beliefs exist within individual pre-service teachers. An initial analysis of the participants in both tracks of ASTEP provided researchers with an initial view of what the PCK of participants in an ACP might look like. In this study, the authors reported that regardless of the path they intended to follow or their prior experiences with K-12 students, all participants espoused teacher-centered views of learning. Moreover, they showed no evidence of any topic-specific PCK, relying on their knowledge of pedagogy from their experiences as K-16 students (Friedrichsen et al., 2009). These findings were consistent with those of a larger investigation on teacher practice carried out by a consortium of nine universities across the USA by Simmons et al. (1999). This investigation analyzed a sample of 116 beginning students teachers divided into three cohorts over three years. They used a naturalistic paradigm to analyze data obtained with two instruments: the Teacher's Pedagogical Philosophy Interview (TPPI) (Richardson & Simmons, 1994) and the Secondary Teacher Analysis Matrix (STAM) (Gallagher & Parker, 1995) as well as contextual and demographic data provided by their participants. This investigation found that student teachers were likely to describe their classroom practices as student-centered. This study also observed the lessons of the participants and revealed a reality in stark opposition to their self-proclaimed views: Participants' lessons were actually teacher centered. They also observed that this difference was maintained during their second year as teachers, while it began to diminish during their third year; however, none of the student teachers ever exhibited a fully student-centered approach. The case study investigation by Koballa, Glynn and Upson (2005) followed three participants in an ACP seeking to determine their conceptions of teaching and how these conceptions related to their teaching practice. Like Simmons et al. (1999) they found that, while the participants' espoused conceptions of teaching were both teacher and student centered their practice was mostly teacher-centered. Another investigation of an in-service, inquiry-based program by Luft (2001) involving six beginning teachers and eight experienced ones observed faster changes in terms of proclaimed beliefs within induction programs than those reported by Simmons et al. (1999). However, Luft's investigation was consistent with Simmons' in that it found that beginning teachers were likely to change stated beliefs before changes in practice were observed. Luft and her colleagues compared the influence of an induction program on first-, second- and third-year teachers with other types of induction programs. In this case, they used the Teachers' Pedagogical Philosophy Interview (TPPI) from the Science Education Center at the University of Iowa in their interviews to collect data on teacher beliefs (Salish I Research Project, 1997). This investigation, in contrast to the ones discussed previously, used a mixed methods approach that included an analysis of the coded TPPI information using non-parametric statistics; a Kruskal-Wallis test at $p=0.10$ was complemented by a post-hoc one-tailed Mann-Whitney test if significance was found. While the qualitative analysis of the data pertaining to first year teachers corroborated the findings discussed in previous investigations as far as the shift in student-centered views to teacher-centered ones, no statistically significant difference was found (Luft, Roehrig & Patterson, 2003). Roehrig and Luft continued their research on induction programs (2006). This time, they focused on an ACP program, which allowed them to shed light on this particular path of teacher preparation. In this case, they used a case study approach and followed 24 teachers over two years documenting the development of their views on teaching and learning. This study noted some contradiction to the studies presented before in that the initial relationship between beliefs and practice seemed to be more coherent among participants. They determined that participants attempting to use inquiry based, teacher-centered approaches had teacher-centered views; however, only half of the participants in this category carried out activities that would be considered inquiry under the parameters of the National Science Education Standards (NSES) (NRC 2000) (Roehrig & Luft, 2006). Purely qualitative investigations in this area of teacher knowledge have not only echoed the results of these large investigations, but they have also provided more evidence concerning the existing notions of students and learning that prospective teachers hold as they develop. A case study investigation carried out by Bryan (2003) from a constructivist perspective using a single pre-service elementary teacher, identified co-existing beliefs regarding students as learners in a matter consistent with that documented by Simmons et al. (1999). The participant manifested two conflicting views of students as learners: a teacher-centered one, which guided her practice, and a student-centered view, which she used to describe herself as a teacher. She also described an interrelationship between both views which she labeled 'nested' in reference to the intertwined relationship she claimed existed among the different components of her beliefs, suggesting an interdependence between the observed and declared views of students as learners (Bryan, 2003). Crawford (2007) also reported similar findings in an investigation following five pre-service teachers throughout a one-year teaching internship. This process was framed within the context of teaching science as inquiry in a manner consistent with the NSES (NRC 1996, 2000). In this study, Crawford determined that the five participants held complex and, sometimes conflicting beliefs in their views of teaching science (2007). This particular investigation used a theoretical framework that used Gess-Newsome's definitions of knowledge and beliefs (1999). Hence, knowledge was defined as empirically based, non-emotional, rational, gradually developed, and well-structured while beliefs were considered to be highly subjective with an emotional component that included attitudes derived from significant personal experiences. The Gess-Newsome study not only reaffirmed what was identified by others, but also assigned a subjective component to an individual's views on teaching and learning. Essentially, researchers have found that prospective and beginning teachers have been found mostly teacher-centered views on learning, based primarily on their experiences as K-16 students. While it has been found that shift in espoused views may change initially during teacher preparation programs, this is not usually accompanied by a change in practice. Furthermore, some researchers have found that it is possible that beginning teachers struggle with conflicting views on learning and that the mechanism behind any shift resulting from this situation is guided by a subjective component.

In terms of awareness of a student's prior knowledge, researchers have determined that, for the most part, beginning and prospective teachers' rarely, if ever, showed awareness of knowledge that students might hold. Investigations that reported this lack of awareness would usually associate this to teacher-centered views on part of the participants. In a case study investigation involving two pre-service chemistry teachers (Geddis, Onslow, Beynon & Oesch, 1993), not only found that pre-service teachers were inclined to teach in a teacher-centered manner, but they had little awareness of the prior knowledge students might have when planning their lessons. In this particular investigation, the participants were surprised to find out that their students did not have the prerequisite knowledge to address the topics they intended to teach. A later study by Geddis and Roberts (1998) in a Canadian post-baccalaureate certification program further highlighted this. This investigation took place in the Physical Education, Mathematics and Science Teacher Education Program (PEMSTEP). In this case, the findings were drawn primarily from three of the students in the program who, like many of their peers, had done graduate work in science. The findings were mostly reported in the voice of

Kevin, one of the participants interviewed, though relevant references were made to the data from the other participants. The researchers determined that the views of teaching held by these beginning teachers were related to their undergraduate experiences as students. While one of the participants, Leonard, initiated his class by trying to relate to students' personal experiences with electricity, his interview, where he expressed the need to provide college-bound students with what he saw as legitimate physics was interpreted as a commitment to a teacher-centered, algorithm-based approach to teaching. The researchers concluded that this commitment left little room for consideration of students' experiences and prior knowledge.

The investigation of programs seeking to develop pre-service teachers with student-centered views of learning has shed more light on their awareness of student prior knowledge and how it develops. This research has determined that, while pre-service teachers do become aware of the existence of student prior knowledge, it is rarely incorporated into their teaching. Moreover, the importance placed on prior knowledge varied based from one individual to the next, with those individuals holding teacher-centered views hinging on direct instruction showing the least likelihood of changing their views. In the 1990s, Hewson, Tabachnick, Zeichner and their colleagues reported the findings of a complex investigation on a teacher preparation program, which focused on graduating individuals expected to hold student-centered views of teaching based on the notion of conceptual change (Hewson et al, 1999; Marion, Hewson, Tabachnick and Blomker, 1999; Hewson, Tabachnick,, Zeichner and Lemberger, 1999; Tabachnick & Zeichner, 1999; Lemberger, Hewson & Park, 1999; Meyer, Tabachnick, Hewson, Lemberger and Park, 1999). As part of this project, Tabachnick and Zeichner investigated an action research seminar which was part of the teacher preparation program. This investigation was an action research project that collected data from two groups of students consisting totaling 20 participants when combined. The researchers analyzed taped seminar discussions and notes taken from the observation of the participants as they participated in the seminar. They found that, while the seminar made the participants aware of their students' possible prior knowledge, very few were capable of incorporating it into their practice (Tabachnick & Zeichner, 1999). A case study of three of the elementary school teacher participants in this investigation focused on their knowledge of teaching and biology. This study reported that while pre-service teachers were aware of student prior knowledge, the interpretation as to its importance varied from one individual to the next (Meyer, Tabachnick, Hewson, Lemberger, & Park, 1999). Case studies of three of the prospective secondary science teachers in the aforementioned program revealed that the teachers' initial conceptions of students and learning were teacher centered. They believed that students should be provided with correct, factual knowledge of science by essentially direct instruction. The researchers related this belief to the strong positivistic views presented by the teachers during the interviews; they all believed that truth can be discovered by experts, which is described in authoritative sources, such as textbooks, as facts. While the participants showed evidence of incorporating some notions of conceptual change into their schema, their overall views did not change significantly by the end of the program (Lemberger, Hewson & Park, 1999).

Further research on pre-service teacher PCK found that, when it comes to student teachers' awareness of prior knowledge and difficulties, pre-service teachers will consider only facts that relate to what they believe relate to everyday experiences. The predominant conclusion of all pre-service teacher-related research was that pre-service teachers assumed that students would have no difficulty with the content they address. Studies in Europe by de Jong, van Driel and their colleagues focused on understanding topic and domain-specific PCK in chemistry. However, several findings are applicable to subject area or even domain level PCK. One of these investigations, derived from the International Research Project and involving the analysis of lesson plans and interviews of 22 pre-service teachers from England, Finland, Greece and Holland, focused on PCK considered the general topic of combustion. This study determined that, as far as prior knowledge is concerned, pre-service teachers would only consider those facts that students can relate to their everyday experiences. Moreover they also found that prospective teachers did not consider any difficulties students might have when designing their lessons (de Jong, Ahtee, Goodwin, Hatzinikita & Koulaidis, 1999). This latter conclusion is consistent with the observations of Simmons et al. (1999) that beginning teachers assume students will learn in the same unproblematic way they themselves learned. However, in the study by de Jong and his colleagues, contrary to the findings of many of the articles cited at the beginning of this section, almost half the teachers were found to present teacher-centered views of students and the learning process (de Jong et al, 1999). Another investigation, this time by van Driel, de Jong and Verloop (2002), on the development of pre-service teacher chemistry PCK looked at a sample of 12 prospective teachers all of which held M.Sc. degrees. This time they looked at more domain specific PCK, focusing on the interpretations of observable physical phenomena and its interpretation based on its corpuscular nature. In this case the researchers designed a qualitative study based on the multi-method approach described by Baxter and Lederman (1999). They collected data using two questionnaires, interviews of both participants and their mentor teachers as well as the recording of a specific workshop carried out with the participants. They interpreted their data from a phenomenological perspective. Their analyses determined that, initially, the prospective teachers had little awareness of specific difficulties students would have regarding the macro vs. micro dichotomy addressed in the phenomena they intended to teach about. However, this knowledge would develop significantly over the course of the first semester of their teacher preparation program (van Driel, de Jong & Verloop, 2002). Further research de Jong and van Driel (2004) on the development of teacher PCK in chemistry addressed teacher views on student difficulties regarding the teaching of topics that involved where the overarching theme was switching perspectives from micro to macro resolutions, rather than topic specific PCK. This study involved eight prospective teachers from a one-year teacher preparation program. All of the participants held a master's degree in chemistry. The program itself focused on learning by experiencing teaching. While difficulties were hardly mentioned in the interviews preceding the lessons, in the post interviews participants showed an awareness of student difficulties when they tried to switch from a macro to a micro perspective. Moreover they acknowledged that their own approaches could have been confusing. In essence research in this area has found that, for the most part, beginning teachers are unaware of any potential student difficulties and plan their lessons accordingly.

On the issue of misconceptions and their role in student learning, which overlaps both the aspect of prior knowledge and student difficulties, researchers have found that beginning and prospective teachers, for the most part, lack any understanding of the presence or role of these in learning. For example, Halim and Meera (2002) worked with 12 pre-service physics teachers in Malaysia and focused on two aspects of PCK, knowledge of students' conceptions and misconceptions of science topics including solubility, Newtonian dynamics and optics. They found that participants were not only oblivious of students' misconceptions, but they held many misconceptions themselves. Similar results were obtained from studies looking at experienced teachers. For example, Berg and Brower (1991) focused on topic specific knowledge related to rotational motion and gravity. They asked 20 physics teachers to predict the misconceptions of their students. While the teachers were aware of the misconceptions in the literature, each teacher only identified a few of the misconceptions their students might have and consistently overestimated their students' knowledge on the topic. Gomez-Zwip (2008) identified a similar pattern in a sample of 30 elementary school teachers in California. However, even though she found that most of the teachers were aware of misconceptions, that awareness did not necessarily translate into any consideration at the time of planning lessons. Otero and Nathan (2008) studied the interplay between views of assessment and student prior knowledge in 61 pre-service teachers in a science methods course. The main source of data was student coursework focused on developing an understanding of misconceptions and their role in learning. While this does not allow for a comparison to studies seeking to investigate pre-service teacher's initial views regarding the awareness of prior knowledge or misconceptions, it does provide insight as to the development of this understanding. They did find out, like Meyer et al. (1999), that the manner in which each participant viewed and reacted to prior knowledge varied among the group, moreover they found that factors other than the program, such as their own beliefs on teaching and learning were more likely to influence how they incorporated the notion of misconceptions into their teaching.

In essence, research into the development of teachers' understanding of students as learners has found that prospective and beginning teachers tend to have teacher-centered views of learning. While these seem to change very little, at least within the first few years of practice, some shift has been observed. More importantly, some studies have reported that student-centered views will co-exist with teacher-centered ones. As far as student prior knowledge is concerned, beginning teachers show no awareness of either its existence or importance. Even as awareness of students' prior knowledge increases, it does not necessarily translate into practice. This also holds true for common student misconceptions. Teachers become aware of misconceptions but do not try to challenge them during instruction. In addition, beginning teachers foresee no difficulties in students learning the concepts presented in their classes. These beliefs have been connected by some to the existence of teacher-centered views of learning.

Knowledge of Assessment

The majority of studies on the topic of assessment have been conducted to explore the understanding of experienced teachers. However, some research has been done on the views and knowledge of assessment of pre-service and beginning teachers. Studies seeking to explore the PCK of pre-service teachers have found that, for the most part, beginning teachers show little if any awareness of assessment. Qualitative studies using interview approaches have also determined that, when forced to consider assessment in planning, these teachers will resort to informal questioning approaches to assessment. Initial results from the ASTEP program reported by Friedrichsen et al. (2009) found that pre-service teachers did not consider assessment in their lesson planning, but would depend on informal assessment when questioned about the issue of gauging student learning. The study by de Jong at al. (1999) on topic-specific PCK for combustion also touched on pre-service teacher knowledge of assessment. The participants in this investigation showed no inclination to using written forms of assessment and rather opted for informal questioning either at the end of the lesson or at the beginning of the next lesson. The researchers presented no evidence that any of the participants mentioned any specific skills or content to assess and concluded that the participants' views were likely the result of them having only vague ideas regarding methods and instruments of assessment. The investigation by Luft and her colleagues on teacher induction programs also analyzed the use of assessment instruments and approaches on part of the teachers involved. Their analysis revealed that among all the participants (which included first, second and third year teachers), use of assessment was infrequent and any difference among the participants was related not to their experience teaching but rather to the type of induction program that followed (Luft et al., 2003).

Research on the knowledge of assessment of experienced teachers has determined that views of assessment not only align closely with curricular goals, but also relate to teachers' perceptions of learning. Research by Gearhart and Osmundson (2009) focused on the role of assessment portfolios. This investigation involved 23 science teachers in a program designed to develop their understanding of assessment. They analyzed portfolios, self-reports, surveys and focus groups. As the program progressed, they noted an increased interrelation between their curricular goals and assessment. This alignment of goals for teaching and assessment had also been identified by Duffee and Aikenhead (1992) who studied the assessment strategies of six urban science teachers addressing a Science, Technology and Society (SMS) curriculum. They found that while the teachers showed a variety of approaches to assessment, their choice of assessment was clearly aligned to their goals for instruction. For example, teachers with stronger positivistic, student-centered approaches chose to use objective questions seeking correct answers.

Further research that sought to establish relationships between teachers' views of learning and their understanding and use of assessment has determined that while teachers will espouse assessment goals aimed at high order thinking skills associated to their student-centered teaching approaches, their preferred method of assessment was rote memorization. This apparent disconnect between views of learning and assessment was found to extend even into aspects such as students' prior knowledge. In this regard researchers have found that, even when teachers show awareness of prior knowledge, teachers will rarely, if ever, plan on assessing it. Research by Bol and Strage (1996) looked at the assessment practice of 10 biology teachers and found that, while teachers advocated for application and elaboration skills, they primarily assessed rote memorization. These findings were echoed by an investigation on the assessment practices of four experienced teachers by Morrison and Lederman (2003), which sought to understand the use of assessment tools to determine students' prior knowledge. They used a qualitative approach with pre- and post-observation interviews as the main data sources. They found that while experienced teachers were aware of the existence and importance of prior knowledge, they did not plan for or use any tools to assess it. Another investigation by Otero and Nathan (2008) on pre-service teachers focused on how pre-service teachers' awareness of student prior knowledge interplayed with their formative assessment practices. In this respect they found that the views of formative assessment were influenced by the participants' perception of the usefulness and types of prior knowledge. Moreover they concluded that hybrid stances on the issue where different views overlapped provided a starting point to growth in understanding, thereby contributing to teacher knowledge within teacher preparation programs.

In summary, pre-service teachers lack structured views of assessment when starting their programs. However, these views are reported to have changed in a shorter time span, sometimes within a course. It has also been found that the development of knowledge of assessment can be related to a teacher's views on learning and understanding of students as learners. Nevertheless, to the best of this investigator's knowledge, a conclusive study has not yet determined the manner in which each of these forms of teacher knowledge influences the other, or if any priority exists in the manner in which they develop.

Development of Knowledge for Teaching

The development of teacher knowledge for teaching has been addressed in many of the investigations cited previously. In this section, I will summarize their findings as they pertain to this specific aspect of my research questions. One aspect of the development of teacher knowledge for teaching that is found in the PCK model that is conspicuously absent from this section, at least as a stand-alone topic, is the Orientations to Teaching component, suggested initially by Magnusson (1990) and incorporated explicitly into the Magnusson et al. (1999) model. The Magnusson model does indeed present the role of different factors on the development of teacher knowledge or teaching in the "[o]rientations toward science teaching and learning" construct (Magnusson et al., 1999, p. 97); however, a number of difficulties preclude it from being an independent all-inclusive source as defined by this review, let alone a central theme in the development of teacher knowledge for teaching. These difficulties have been discussed extensively by Friedrichsen, van Driel and Abell (2011). They present their case from the first inclusion of Orientations to Science Teaching as a component of the PCK model presented by Magnusson et al (1999). They posit that the definition provided by Magnusson et al. (1999) is based partly on an initial suggestion made by Grossman (1990), who draws attention to the conceptions of what it means to teach and the goals for teaching. Grossman also defined the term 'orientations' used by Anderson and Smith (1987) to mean "general patterns of thought and behavior related to science teaching and learning" (p. 99). This mixed definition as well as the hodge-podge classification provided by Magnusson of different types of orientations, based loosely on research across the field without a supporting framework, led to a construct that has been interpreted in different ways by investigators (Friedrichsen et al., 2011). For these reasons, I chose to not only avoid the use of orientations in the research questions guiding this research, but also sought to include in this section investigations that referred to the development of relevant components of PCK, that is, whether or not they used the PCK model or included Orientations to Science Teaching.

When investigating the development of teacher knowledge for teaching, researchers have found that a teacher's initial views on the process of learning is the one important factor influencing the way in which pre-service teachers develop their understanding of learning and assessment.. The findings of Geddis and Roberts (1998) in the Canadian PEMSTEP found that commitment to certain educational beliefs would influence prospective teachers' views on students. In this particular case, the development of a need to have an awareness of student prior knowledge was hindered by strong commitment to teacher-centered views on teaching and learning.

Another aspect that has been found to influence the manner in which teachers, especially beginning teachers, develop their understanding of learning and assessment are the teaching experiences they go through at the beginning of their careers. The investigation by Simmons and her colleagues, discussed previously, identified the fact that their participants changed over time reducing the conflict between self proclaimed student-centered views and teacher-centered actions by showing some shift toward student-centered actions. They concluded that the teachers' experience in the classroom was a factor influencing these shifts. However, Simmons et al. (1999) did not define what aspects of the experience or the factors related to this experience influenced the shift or how the shift occurred. Nevertheless, if these results are viewed in the light of Crawford (2007), who added a subjective component to this change, it is possible to entertain the thought that such shifts are guided by said subjective aspect at the beginning of teachers' schema; this also resonates with the findings of Geddis and Roberts (1998) discussed previously. Concerning the development of prospective teachers' knowledge of assessment, an investigation involving 25 pre-service teachers by Morrison, McDuffie and Akerson (2005) sought to determine the nature of the development of assessment knowledge. Comparison of pre- and post-intervention data showed that, while participants had no structured initial knowledge of assessment, they developed an understanding of assessment through their coursework. However, the analysis of end data in the form of reflections led the researchers to determine that the most significant influence in this development was the opportunity to interact with students. While the researchers concluded that it was the reflection on part of the participants that facilitated this change in views, the mechanisms underlying the change were not discussed.

A third aspect that influences the development of teacher knowledge for teaching focuses on the academic experiences in their preparation programs. Research in this area has highlighted the importance of contact – not only in coursework, but also in mentorship programs. In the latter case, it has been found that reflection on the part of prospective teachers in the light of situations in which their pre-existing beliefs are challenged can initiate change in their views on teaching. Moreover, it has been found that more restrictive environments are less likely to foster the development of student-centered views on learning. The work in 1999 by Hewson, Tabachnick, Zeichner and their colleagues at the Wisconsin Center for Education Research at the University of Wisconsin-Madison (Hewson et al., 1999; Marion, Hewson, Tabachnick and Blomker, 1999; Hewson, Tabachick, Zeichner and Lemberger, 1999; Tabachnick & Zeichner, 1999; Lemberger, Hewson & Park, 1999; Meyer, Tabachnick, Hewson, Lemberger and Park, 1999) argued that many of academic and non-academic components of the teacher preparation program were influential in the changes they observed in their participants. They highlighted the methods courses, the action research seminar, and field experiences, as well as their personal interactions with instructors, supervisors, cooperating teachers and project personnel as playing a role in this change. Among these factors, the coursework and the cooperating teachers, a form of mentorship for the participants during their teaching practice, seemed to be the most influential. They also ascertained that, while the role of the cooperating teacher was influential, the school context in which the prospective teacher was placed served as an additional layer of influence. They argued that a context that was driven by strict curricular objectives with non-negotiable assessment mechanisms, such as that experienced by most of their prospective secondary teachers, was less likely to facilitate the development of student-centered, conceptual-change-based views on learning. The opposite was the case for scenarios in which the prospective teacher had more freedom to introduce both curricular and instructional changes, which held true for most of the prospective elementary school participants. However, the mechanisms as to how these influences helped shape the prospective teachers' views on learning were not described (Hewson et al, 1999). The work of Geddis and Roberts (1998) and Duran McArthur and Van Hook (2004) shed further light on the issue of teacher preparation programs and the apparent dissonance between student views and those introduced by reform efforts highlighting personal conflicts, providing further evidence of the subjective nature of the mechanisms in action as beginning teachers develop their knowledge for teaching. The investigation by Simmons et al. (1999) on beginning teacher experiences and the study by van Driel, de Jong and Verloop (2002) that addressed the development of PCK regarding the macro vs. micro dichotomy in observable physical phenomena, determined that change in the prospective teachers occurred as they took part in the activities of their teacher preparation program. They found that not only did the participants and investigators acknowledge the teaching experience and their workshops as significant factors in this change, but many also referred to their mentor teachers as being influential. Yet like previous investigations, this study did not determine the manner in which PCK changes occurred based on the role of the teaching experience, the coursework or the mentor-teacher relationship (van Driel et al., 2002; de Jong & van Driel, 2001).

Pre-service teachers' experiences as students also provide an important factor in the development of their knowledge for teaching. Researchers have found that pre-existing, teacher-centered notions on learning, based on experiences as students are an obstacle to the development of views perceived as opposite. This was highlighted in the findings of Duran, et al. (2004). This qualitative investigation involved focus groups with 25 students taking part in a Physics for Middle School Science Education course. The investigators coded and analyzed focus group interviews and student evaluations to determine the perceptions of undergraduate students who took part in an inquiry-based curriculum designed to help them develop an inquiry-based approach with an emphasis on the 5E model. They found that while students developed an appreciation of the views presented in the course, especially regarding the 5E model, they found their own beliefs, based on prior experiences as students, to be antagonistic to those that were presented to them. This cognitive antagonism led to a personal conflict that, according to the researchers, could have hindered the development of the goals of the course. The work of Luft and her colleagues on Teacher Induction Programs specifically aimed at participants in an ACP also identified factors that influenced changes in both views of learning and on use of assessment. In this case, while the views on teaching and learning were influenced mostly by experience, as far as assessment was concerned, the differences among the groups of participants were determined to be related to the approaches used in each of the different induction programs. Hence, less established schemas, such as assessment, were considered more likely to change as a result of coursework. The difference in the nature of the programs was presented: One presentation discussed a science-focused induction program whereas the other did not. However, save for the relationship between science being an inquiry-based discipline that likely resonated more with the inquiry teaching approach and speculation on the effect of the varying teaching schedules allocated to each program, the way in which this approach served to facilitate assessment change was not discussed. Nevertheless, the researchers noted that participants who held transitional beliefs leaned toward more teacher-centered views when not engaged in any type of professional activity that provided support for student-centered approaches (Roehrig & Luft, 2006).

While the factors influencing the development of beginning and prospective teacher views of learning and assessment have been studied to some extent, the mechanisms underlying these changes (or lack thereof) have not. However meta-analysis of the research on PCK has suggested that it is possible that assessment development can be mapped using the notion of Learning Progressions, wherein increasingly sophisticated ways of thinking about a particular idea follow one another over a broad span of time (NRC, 2007). The analysis of Schneider and Plasman (2011) on this line of research also attempted to identify the factors that influenced said development. In their findings, they proposed progressions for the major components of PCK based on research that covers the spectrum from prospective teachers to experienced ones. In some areas they argued that progressions could follow alternate, albeit similar paths, based on the experiences teachers had, for example secondary vs. primary school teachers. They also identified several factors influencing these progressions: formal coursework, concurrent science instruction (especially regarding the Nature of Science). As with the findings of Luft et al. (2003), they found that science courses designed for science teachers were more influential than traditional science coursework when the focus was to develop teacher-centered views on inquiry. For other aspects, including assessment, they concluded that thoughtful teaching experiences provided a positive influence on the development of PCK progressions. However, the mechanisms by which these factors influence the development of the components of PCK were not addressed.

Overall, research into the development of teacher knowledge and understanding has determined that experience, mentoring and coursework are likely the most important factors shaping PCK. Moreover, the meta-analysis by Schneider and Plasman (2011) suggested that not only is this development unlikely to be random, but it is also not necessarily linear. This suggests a more complex interplay between the factors influencing the development of teacher knowledge for teaching and an individual's views of teaching; hence the external/internal interplay has always been hinted at and proposed in the PCK models presented over time. However, the mechanisms that explain how these changes occur, which could allow a better understanding of how individuals develop their understanding have not been largely discussed. This is quite likely because many of the *how* questions in research end up focusing on *describing* the changes as opposed to *explaining* them. Teacher preparation programs would benefit from a better understanding of these questions and their answers.

Conceptual change. The research in conceptual change in science teaching, as far as I have been able to find, has focused primarily on the incorporation of teaching perspectives by teachers based on the principles of conceptual change. While significant research has been done in conceptual change as a teaching approach, there seems to have been no attempt to use this framework to explain the mechanisms of teacher learning. However, Davis (2004) attempted to use a socio-cognitive framework to analyze the development of teacher knowledge – Knowledge Integration. This framework is based on the ideas proposed by Bransford, Brown and Cocking (1999) in *How People Learn*. Prior to this investigation, the framework had been used primarily to understand the development of student knowledge. In this investigation, Davis used it to analyze the development of teacher knowledge. The Knowledge Integration framework essentially posits that learners have initial ideas in which they identify weaknesses. They link some and distinguish between others in order to reconcile ideas that appear contradictory (Linn & Hsi, 2000). The framework is foundationally very similar to the Conceptual Change framework. This investigation looked at a four-semester teacher preparation program in the USA. Approximately a dozen students from the course participated in the study, and four were interviewed. The findings suggest that the approach used could provide a clearer view of the thought processes, especially the reconciliation of nuances, which might have not been discerned using other approaches to measure teacher knowledge. In addition to this, Davis claimed that inquiring as to the specific connections between different knowledge types could help shed light on the relationships that occurred between them to the point of contradicting some pre-existing assumptions made by other researchers. In this investigation, she found that one of the participants, Val, who had highly integrated subject matter knowledge, failed to develop effective PCK despite having multiple links to real-world experiences. However, even then, Davis' report deals almost exclusively with the development of integrated, topic-specific PCK. However, it does provide insight as to the usefulness of a socio-cognitive framework to interpret the development of beginning and pre-service teachers' PCK.

CHAPTER THREE: THE RESEARCH PROCESS

Research Questions and Tradition

The purpose of this study was to investigate the development of teacher knowledge for teaching as it develops during an ACP and into the first year of teaching. Specifically, the study focused on: (a) how teacher knowledge of students as learners and how their knowledge of assessment develops, (b) which aspects of the experience as a student within an ACP and as a beginning teacher help or hinder the development of teacher knowledge and (c) how these experiences lead to the development of beginning teacher knowledge for teaching. The overarching question guiding this study was: How does science teacher understanding of learners and assessment develop over time from entry into a post-baccalaureate alternative certification program through their first two years of teaching? This overarching question was answered by addressing the following sub-questions:

Sub-questions

1. What conceptions of students as learners do ACP-track teaching interns have at different points in time, from the beginning of the ACP to the beginning of their second year as full-time teachers?
2. What conceptions of assessment do ACP-track teaching interns have at different times, from the beginning of ACP to the beginning of their second year as full-time teachers?
3. In what ways do the experiences in the ACP and teaching influence teaching interns' conceptions of students as learners over time, from the beginning of the program and into their second year as full-time teachers?

4. In what ways do their experiences in the ACP and teaching influence teaching interns' conceptions of assessment over time from, from the beginning of the program and into their second year as full-time teachers?
5. In what ways do the conceptions of students as learners held by ACP-track teaching interns interact with their conceptions of assessment throughout the ACP and into their second year as full-time teachers?

These research questions focus on the knowledge teachers have regarding teaching and how their personal experiences both within an ACP and as teachers shape this knowledge over time. Moreover their views and experiences are interpreted through theoretical lenses that focus on their personal constructs and interpretations of said experiences. Given the nature of this research and its questions, it is placed within a constructivist research tradition (Patton, 2002) or paradigm (Hatch, 2002; Dezin and Lincoln, 2005).

Constructivism

Constructivism distinguishes between the human, social world and the natural, physical world in that the former is not real in an absolute sense but is shaped by our cultural constructs. In essence, the world seen through human eyes is laden with our interpretations. Our view of the world is not based on how physical objects are but are shaped by our cultural and linguistic constructs (Patton, 2002). As such, from a constructivist perspective, knowledge and understanding is co-constructed between research participants and researchers. The aim of constructivism is to understand and reconstruct knowledge (Guba & Lincoln, 1994, Denzin & Lincoln, 2005). The nature of knowledge is that it is constructed individually or collectively (Denzin and Lincoln, 2005). As such constructivist studies are appropriate for studies that aim to understand beliefs (Ferguson, 2007).

Constructivism assumes that knowledge is context dependent and thus relative rather than absolute. Individuals construct knowledge about reality, not reality itself; thus, each construct is considered a 'meaningful reality' (Patton, 2002). An individual's interpretation of reality will be guided by his or her experiences and the context within which they develop, given this premise individuals with different past experiences will construct different realities (Patton, 2002). Constructivists assume reality or "truth" is relative to the individual and do not seek out truth but rather set out to describe knowledge and find patterns. By adopting a constructivist tradition, I recognize that meaning is constructed by individuals based on their experiences and setting, and thus multiple realties exist (Denzin & Lincoln, 2005; Patton, 2002). This provides the foundation for understanding how people construct reality by incorporating new knowledge into their existing knowledge.

By selecting a constructivist tradition to frame the case study I assume specific philosophical principles as well as epistemological and ontological assumptions (Denzin & Lincoln, 2005):

The existence of multiple realities (ontological relativity)

Knower and respondent construct personal understanding (subjectivist epistemology)

Naturalistic methodological procedures.

Ontological assumptions. Ontology has been defined as the branch of philosophy that "studies the most pervasive features of reality, such as real existence, change, time, causation, chance, life, mind, and society" (Bunge, 2003, p. 242). As such, ontology deals with the nature of reality and the structure of the world we live in. A constructivist paradigm assumes ontological relativity. This means that statements about existence depend on a worldview, and no worldview is determined by sensory data alone but rather by local and specific co-

constructed realities (Patton, 2002; Denzin & Lincoln, 2005). In the context of this study, it is assumed that multiple realities exist for what constitutes knowledge. Individuals construct knowledge based on their personal experiences, which are dependent not only on the context within which these experiences take place, but also on their individual previous experiences (Patton, 2002). As such, two individuals are not likely to construct the same knowledge based on similar experiences, but are more likely to shape their own knowledge based on their prior experiences and understanding of events as they take place. As a constructivist researcher I assume all realities are meaningful.

Given the variety in backgrounds and experiences that the participants have at the beginning of the investigation as well as the different experiences they are subject to throughout the research process, by making these assumptions I allow myself to make sense of each of the individuals' experiences within the unique context in which they develop, not to generalize to unique contexts but rather to provide a basis for comparison and analogy (Lincoln & Guba, 1985).

Epistemological Assumptions. Epistemology is the branch of philosophy that deals with the nature of knowledge and how knowledge is generated (Bunge, 2003). As discussed previously, I focus on the assumption that individuals construct their own reality, rather than reality itself, and this reality hold true for the individual regardless as to whether or not it is true to the researcher. This understanding of reality, this knowledge of reality, is unique to the individual and is constructed and filtered by past experiences and personal beliefs (Denzin & Lincoln, 2005).

Given that this investigation intends to develop an understanding of how specialized forms of knowledge are developed within the context of the scope of a larger research project, it presents a tiered structure of knowledge development that needs to be made explicit. First, there is the knowledge about my participants that I develop over the course of the investigation. Second, as a researcher, I purposefully co-construct reality with my participants through my interpretation of their experiences as I observe them and later through the exchange of ideas during a series of interviews with them. This co-construction is further achieved by the use of multiple sources over an extended period of time. Third, as they take part in their training process and later apply it to their teaching, my participants develop knowledge and understanding of student learning and assessment by co-constructing their own realities. This was accomplished through their interaction and negotiation with a variety of situations and actors that constituted the context within which their learning took place, including those activities conducted with the research team and me. I understand that, by sharing and exchanging ideas with the participants during the interviews, in order to develop our understanding of participant knowledge, the research team added an additional layer of reflection upon which the participants constructed their own knowledge of students and assessment. In a way, the investigators, myself included, played a role in the co-construction of our participants' realities through our interaction with them. Finally, being part of a larger project involving several investigators, my own interpretations of the observations were shared with a team of researchers which shaped my understanding of reality based around a collective reconstruction that, at times, would coalesce around consensus among the team members. As a constructivist researcher, I accept this multi-tiered epistemological relativity and thus present my interpretations based on the understanding that they are co-constructed, at times in a bi-directional manner, with the participants and other researchers and thus have specific meaning within this context.

Context of the Study

The study took place within a post-baccalaureate science teacher education program designed to recruit and retain science and mathematics teachers known as ASTEP. It was part of a larger investigation funded by the National Science Foundation (NSF) that sought to understand how teacher knowledge develops as teachers take part in an alternative certification program: the ASTEP research program (ASTEP-RP). The project had two alternative tracks; the track depends on whether students enrolled as interns or as full-time teachers. The former were placed in local school classrooms under the supervision of a mentor teacher where they observed and taught for 20 hours a week, fulfilling their program requirements in 15 months. The latter, being full-time classroom teachers, took part in a two-year independent internship fulfilling the program requirements in 24 months. In addition to understanding teacher development, the larger research program agenda included an effort to define the factors that facilitate or constrain teacher learning.

The larger research project focuses on three cohorts of students, the first of which started ASTEP in June of 2006. Researchers initially collected data at seven different points in participants' development as teachers. Entry data was collected when participants began the program and at the end of the first eight weeks of class using a Lesson Planning Task (see Appendix A) with a follow up interview (See Appendix B) and a Video Analysis task with a follow up focus group (see Appendix C). At the end of the first summer an additional interview was conducted to allow participants to reflect on their original plans based on their summer experiences (see Appendix D). As participants began their internship and moved into teaching, classroom observations of two consecutive lessons of the same class were scheduled for each of the next four semesters of teaching. Finally, two years later, participants were invited back for a final round of data collection using the same tasks used initially with a modified interview protocol. After data collection for the first cohort was completed and partially analyzed, the research team believed that an additional two years of data collection was necessary to better understand the development of teachers. Thus, each participant provided us with sets of data at 11 different points in time. The full data set, for each of the participants, consists of 23 interviews, six 2-day lesson plans, four 1-day lesson plans, eight written reflections and 12 lesson observations. In addition, we conducted interviews from the mentor teachers for participants in the 15-month program.

As one of the Graduate Research Assistants (GRAs) who has been part of the project since the beginning, I took part in all the aspects of the research design and execution. I was involved in the design and revision of interview and field observation protocols and collected classroom observations and interview data. By the end of the project, I had followed seven different participants over a period of four years. Overall, I observed over 30 lessons and conducted over 60 interviews throughout all stages in the research process.

The research team divided itself into smaller teams that specialized in data analysis of different components of the PCK model. Throughout the process, I have been part of the group focusing on analysis related to teacher knowledge of learners and teacher knowledge of assessment. As part of this group I worked on developing the coding scheme for our team as well as coding and analyzing the data obtained.

Role of the Researcher

The ASTEP-RP program sought to investigate the development of beginning teacher PCK within the context of an alternative certification program. In order to achieve this, students entering ASTEP were invited to participate in the investigation and remain a part of it for two years after completion. The ASTEP-RP research team was divided into six teams of researchers equally divided according to the number of math and science specialists. As far as data collection was concerned, each team was responsible for following a specific group of participants over time. Regarding data analysis, paired interdisciplinary teams were responsible for specialized initial data analysis based on the different components of PCK. I was part of one of the science teams and my interdisciplinary group focused on the analysis of PCK components related to knowledge of students as learners and assessment.

My interest as a researcher arises from my work as a science teacher, teacher educator and program evaluator in public schools. I was interested in determining how knowledge of students as learners and assessment was shaped as student teachers took part in a post-baccalaureate certification program and moved into their beginning years of teaching. More specifically, our focus was to find out how their initial knowledge and experiences interplayed to develop these components of their knowledge for teaching. My research interest stems from my belief that we need to understand how to provide prospective and beginning teachers the best possible tools and knowledge to have successful and productive teaching careers.

As a researcher I had a variety of roles. I carried out initial data collection when participants entered the program; specifically, I conducted focus groups for the video analysis task. While participants took part in fall and spring classes, I was responsible for conducting class observations and follow up interviews, including interviews with mentor teachers and collecting written participant reflections. Given that other members of my institution were either instructors for A- STEP or intern supervisors, all member of the ASTEP-RP team, including myself, were very careful to act as mere observers and not to provide any type of feedback on teaching to the participants. This was made explicit to the participants at the beginning of the process, and they did not expect or ask for any during the data collection for ASTEP-RP. Finally, I was responsible for data analysis following both specific and general themes that arose from the guiding questions of the ASTEP-RP. This process was initially carried out within the different ASTEP-RP interdisciplinary teams. Each of these teams was composed of a member of the Mathematics and the Science Education groups, including at least one faculty member and one graduate student. Initial analysis was carried out separately by pairs consisting of members of each group, who then exchanged ideas until arriving at a consensus. The resulting ideas were then shared and debated with the rest of the interdisciplinary group in order to arrive at overarching themes that were applicable across both disciplines within the PCK framework.

Context of ASTEP

When participants entered ASTEP they selected whether they would take part in the Accelerated Post-Baccalaureate track (APB) or the Alternative Certified Program (ALT) as can be seen in Figure 5.

The program requires students to hold degrees in a science discipline or a science related field such as engineering. The selection process for ASTEP was designed to ensure that high quality graduates were accepted into the program. This process included data such as their undergraduate GPA, Graduate Record Examination (GRE) scores, letters of recommendation and a written statement. In order to be admitted into the program, students needed either a minimum 2.75 overall GPA or a 2.5 GPA in science courses and a minimum combined GRE of 1000. In order to qualify for certification, students had to pass the Praxis II for Biology with a minimum score of 150. Upon completion, participants earned teaching certification and a

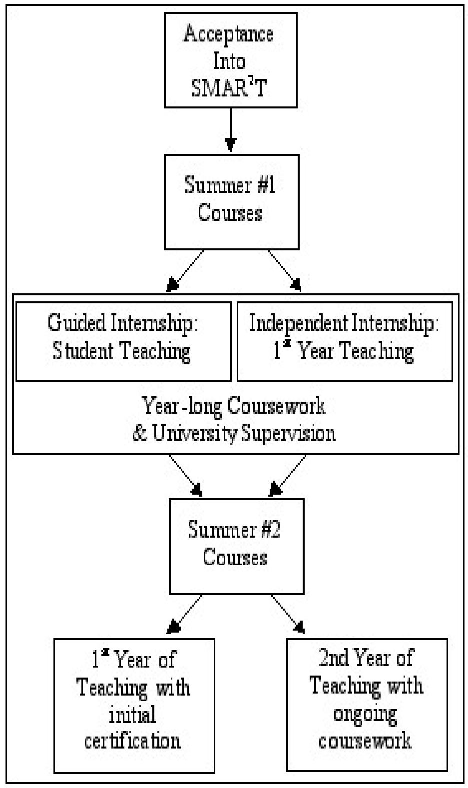

Figure 5. Alternative Certification program (ALT) and Accelerated Post Baccalaureate program (APB) tracks of ASTEP

master's degree in education. The students in the APB track were those who had a one-year internship at a local school and completed the program in 15 months. Full time teachers who took the ALT track program completed it in 24 months (Table 2). The ALT program was designed to allow teachers working full time with a temporary authorization certificate to obtain teaching certification while spending two years as full time teachers.

Both tracks required 35 hours of coursework. Participants completed three science teaching methods courses in the first nine months of the program. Participants completed three science teaching methods courses in the first nine months of the program. In this dissertation study, all participants were enrolled in the APB track or guided internships (Table 1).

In addition to selecting one of the aforementioned tracks, students could also choose to obtain middle, secondary or middle and secondary (dual) certification, in biology, chemistry, physics or earth sciences. In the case of APB students, who choose to obtain dual certification, their internship was split between a middle school (first 10 weeks) and a secondary school (22

Table 1

Timeline of APB program

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

weeks), which required two mentor teachers (one for each level) during their internships. Participants seeking secondary or middle school only certifications completed their entire internship over 32 weeks with the same mentor. The program leads to a master's degree in education (M.Ed.) and qualified graduates for state teaching certification. In this dissertation study, all the participants were seeking secondary biology certification.

During their coursework, participants were expected to understand and learn, primarily by experiencing and discussing, a modified learning-cycle-based teaching approach (Karplus & Their, 1967) referred to as the Five-E (5E) instructional model (Bybee, 1997). This instructional approach is based on the natural learning process and advocates constant,

Table 2

Timeline of ALT program

Summer Year 1	Fall Year 1	Spring Year 1	Summer Year 2	Fall Year 2	Spring Year 2
Advanced Educational Foundation of Teacher Preparation (8 credits)	Teaching, Learning and Research in Secondary School Science II (3 credits)	Teaching, Learning and Research in Secondary School Science II (3 credits)	Integrating Mathematics and Science Instruction (2 credits)	Reading in the Content Areas (2 credits)	Complete Portfolio and Action Research
Teaching, Learning and Research in Secondary School Science I (3 credits)					
	2 School-year internships for fall and spring semesters (11 credits)				

formative assessment throughout its various stages. The first stage of the 5E model, Engage, allowed the instructor to draw the students' interests and attention to relevant science topics while providing her with an opportunity to assess prior knowledge, including common misconceptions students might have associated with the topic (Bybee, 2002). This stage required the teacher to understand not only the content and any relationship it had with other topics but also to be familiar with the most common misconceptions. In addition, the teacher was expected to have a well structured assessment dynamic that allowed her to use not only student products but also observation and questioning to identify both prior knowledge and student learning progression as it took place. The second stage, Explore, involved the instructor based on her assessment of progress in the initial stage, allowing students to explore additional material that would either challenge their existing misconceptions or make them re-think their prior knowledge and modify their current conceptual model to a more sophisticated one in order to accommodate the new data. This stage required the teacher to have an understanding of the mental models that make up her students' explanations of the phenomenon, gauged by her assessment during the first stage, as well as a working knowledge of the most appropriate additional information to provide a suitable challenge to foster reflection in her students. The third stage, Explain, was the time in the sequence when the teacher determined when it was appropriate to introduce new terminology, redefine pre-existing content or provide alternative explanations to the students based on her assessment of students' learning progress through the first two stages and her knowledge and understanding of the substantive and syntactic knowledge of the content being addressed while providing the students with an opportunity to express their conceptual understanding or process skills (Bybee, 1997). The fourth stage, Elaborate, allowed the students to explore the recently addressed conceptual framework in alternative situations to verify its validity and thus superior explanatory value when contrasted with their prior knowledge. This stage also required the instructor to be familiar with appropriate data, models and/or analogies pertaining to the content that could effectively reinforce the conceptual framework that was developing in the students, while assessing student learning as it took place. The final stage in the process, Evaluate, allowed two levels of evaluation; from the teacher's perspective and from the students' perspective. From the teacher perspective, it was the moment in the instructional sequence that allowed the teacher to evaluate, most often in a summative manner, the learning process of the students. From the students' perspective, it was designed to add a metacognitive component, allowing them not only to reflect on their new conceptions but also on the process that lead to their development. As can be seen, the 5E instructional model that permeated and defined the courses in the ACP, hit strongly on the participants' understanding of students as learners as well as their view and use of assessment providing a referential level of understanding that is expected in high quality teachers.

The intention of the ACP courses was to develop in the participants a constructivist view of learning based on conceptual change and the 5E model. It sought to develop an awareness of prior knowledge and an understanding of the interplay between this prior knowledge and new concepts to be presented to the students. It also highlighted the existence of misconceptions and their resistance to change. These views were supported by a framework of assessment that put emphasis on embedding assessment into teaching (Abell & Volkmann, 2006). This assessment framework was comprised of both formal and informal assessment tools used in a formative manner in each step of the 5E model. This approach presented a strong connection with the views of learning that the program sought to develop. It focused initially on pre-existing knowledge, including misconceptions and, in latter stages, sought to gauge the development of new conceptions on part of the students. The summary of the goals and objectives for the Methods courses in ASTEP that are relevant to this study is presented in Table 3.

Furthermore, in order to assist my cross-case analysis, I developed a guideline, based on the course goals and the 5E model, that summarized the different dimensions of the knowledge of student learning and knowledge of assessment as it pertained to PCK components expected to be developed by the participants during their coursework and internships (see Table 4).

Table 3

ASTEP Secondary Science Methods Course Goals

Course	Goals
Course: Secondary Science Methods I	- Develop a deeper understanding of students' conceptions and explanations about a variety of scientific phenomena - Reflect on how science teachers can model and support school science inquiry - Develop an awareness of instructional models that focus on conceptual change
Secondary Science Methods II	- Further develop an understanding of the learning process through review/reflection on the first course experiences and additional readings - Develop a working understanding of the design and rationale of the 5E Instructional Model. - Design science lessons using a variety of teaching strategies, with a focus on discrepant events, inquiry labs, and interactive lectures.
Secondary Science Methods III	- Design and use pre-instructional, formative and summative assessments to inform teaching practice at each step of an instructional sequence. - Design an instructional sequence informed by current learning theory

Context post-ACP

Interns and teachers from ASTEP who initially agreed to participate in ASTEP-RP consented to be part of the research project for two years. After receiving their certification, APB students were expected to move into full-time teaching positions. The continuity into the second year was subject to participants holding such teaching positions in schools that were accessible to the researchers; namely schools within the continental U.S. that granted us access.

Table 4

ASTEP expected understanding of domain level PCK components

PCK Component	ASTEP - Expected understanding
Students as learners	- New knowledge is developed as students reconsider their prior knowledge (including misconceptions) and re-arranged it, based on evidence/experience, to provide a more accurate explanatory model
Pre-requisites for learning	- Inconsistencies in the students' existing knowledge framework has to be challenged - Students are provided with an opportunity to develop new explanatory frameworks via investigations and explanations
Difficulties in learning	- Difficulty in learning occurs because of incomplete or inaccurate explanatory (misconceptions) that are strongly held
Views of Assessment	- Assessment connected with instruction and informs instruction as learning takes place - Considers both formal and informal assessment for either summative/accountability or formative purposes
Methods of assessment	- Integrates assessment into teaching (embedded assessment)
Dimensions to assess	- Learning as it takes place, including prior knowledge/misconceptions, development of ideas and final learning outcomes

Data collection during this time followed the same format as during the previous year. As stated previously the post-ACP data collection was extended for an additional two years. Participation in years three and four was subject to the same conditions as in year two.

Design of the Study

I used a case study approach to guide the collection and analysis of data. A case study approach constitutes a specific form of data collection, organization and analysis (Patton, 2002; Stake, 2005). A case study is an investigation of a bounded system over time with data obtained using a variety of sources (Stake, 2005). It can be used to study individuals, groups, cultures or organizations. Furthermore, a case study deals with questions that seek to make sense of the operational connections made by individuals rather than a single incident (Yin, 2003). A case study can be considered intrinsic, when the aim of the investigation is to better understand the case in itself, or instrumental, when the goal is to provide insight into an issue to re-address a generalization (Stake, 2005). In the latter form of a case study, one can have a 'collective case study' or 'multiple case study' if a number of cases are selected as units for analysis (Stake, 2005).

Case studies can be holistic or nested. These two types can be differentiated when the unit of analysis can be broken down into smaller cases contained within the larger 'case'. Examples of nested investigations occur when dealing with institutions or collective organizational structures as each 'case' (Patton, 2002; Yin, 2003). Whatever the type of case study, researchers seek out both what is common and what is particular about the 'case', using multiple data sources to construct a meaningful representation of the case (Stake, 2005) while being careful to identify cases that might be deviant or extreme (Creswell, 1998; Miles & Huberman, 1994; Patton, 2002). In order to construct this representation researchers often use purposeful sampling and selected cases they identify as 'information-rich', which allowed them to learn '… a great deal about issues of central importance to the purpose of the research …" (Patton, 2002, p. 46).

This investigation was guided by a constructivist paradigm that focused on reality being the result of how participants made sense of the events that took place within the context in which they developed as science teachers. Due to the nature of the process, each context was unique to each participant. Furthermore, the overarching research question guiding this investigation sought to understand the operational links that individuals made throughout the experiences that made up the context in which they developed. Therefore, I considered each participant to be a single case, making this an instrumental, multiple-case study (Stake, 2005).

I purposefully selected participants who would allow me to construct rich descriptions of their experiences. These descriptions were constructed using data obtained through the use of open-ended interviews and observations as primary data sources and using mentor teacher interviews, instructor interviews and written reflections as secondary sources. The use of multiple sources allowed me not only to determine the relevant experiences from each participant (Stake, 2005), but also to address issues of trustworthiness and credibility (Denzin & Lincoln, 2005; Lincoln & Guba, 1985; Patton, 2002). Data reduction by coding of the various sources was viewed comparatively to determine the major themes and then used to construe a rich description of each case (Miles & Huberman, 1994). Constant revision of the data isolated using NVivo 8.0/9.0 and the documents themselves allowed me to carry out constant analysis and provide holistic, meaningful representations of the process (Patton, 2002; Yin, 2003). These findings were reported within cases (within case analyses) and across cases (cross-case analyses) (Denzin & Lincoln, 2005).

The use of a case study methodology allowed me to identify and describe meaningful instances in the development of teacher knowledge (Denzin & Lincoln, 2005; Yin, 1994). I achieved this by using multiple sources to describe, in detail, changes in teacher knowledge over a prolonged period of time (Denzin & Lincoln, 2005) while attempting to describe these changes within each case and relate them to each participant’s experiences (Patton, 2002).

Methodological Assumptions

By using a case study in a qualitative paradigm this investigation took a hermeneutical approach in which it was assumed that the researcher was the primary instrument for data collection and analysis (Guba & Lincoln, 1981; Denzin & Lincoln, 2005). As such, it is likewise assumed that I was an observer in the data collection process and could not in any way control the actions of the participants as each case unfolded over time (Stake, 1995). By the very nature of qualitative analysis, every interpretation is dependent both on the context in which it is created and the one under which it is interpreted (Merriam, 1988; Patton, 2002). Therefore, the interpretations by the participants within the context of their own experiences were interpreted by me and thus constrained by my own biases and understanding of the phenomenon. This analysis is inductive, seeking to build abstractions and theories from multiple data sources, as opposed to testing them (Merriam, 1988). Finally, the very nature of a case study approach is holistic and context bound (Patton, 2002).

Methodological Limitations

As a researcher, it is important for me to acknowledge the limitations of my methodology of choice. First of all, case studies require large amounts of data in order to create rich descriptions via triangulation (Patton, 2002; Yin, 1994). This, coupled with the recommendation to use several cases to address trustworthiness and credibility, results in a possible limitation in the depth of analysis (Yin, 1994). For this reason many researchers select no more than four cases to work with (Creswell, 1998). For this investigation, despite having data available for over a dozen individuals, I selected four in order to focus on an in-depth analysis of their experiences. Secondly, Yin (1994) argues that it is possible that researcher bias influences the criteria for sampling, based on his or her interests, choice of theoretical framework(s), etc. This leads to the belief that case studies lack rigor (Yin, 1994). In the case of this investigation, I acknowledge the existence of this bias rather than reject it. However, while my background in biology indeed biased my selection of participants, it provided a stronger foundation from which to analyze the aspects of PCK that are not content-based. I was familiar with all the content addressed by the participants, and my biology teaching experience also allowed me to give my analysis a deeper analysis of PCK components by isolating them from the topic itself. Furthermore, initial coding within teams in the ASTEP-RP project helped address my bias in analysis by allowing me to contrast ideas with non-biology education specialists.

Institutional review board and data storage

The ASTEP-RP project gained approval by MU's Institutional Review Board (IRB) to conduct research. All the faculty and graduate students involved in the investigation were certified by the IRB and cleared to participate in all stages of the project. All individuals involved in the process provided written consent to the investigators. In the case of participants, they were invited to participate in the investigation at the beginning of the program (see Appendix E). Given that the initial investigation was expected to cover only the first year as teachers additional consent was obtained in order to extend their participation in the investigation past the second summer interview (See Appendix F). All principals from the participants' school district also provided written consent at the beginning of the ASTEP program (see Appendix G). At the beginning of the MU 2006 Fall Semester, experienced teachers, who had been assigned to be the mentors of the participants, provided written consent (see Appendix H). Finally, the parents of the students in the participants' classroom were asked to give their consent to record their child on video during the lessons observed, clarifying that the investigation would focus on the participant and his or her interaction with the students (see Appendix I). The students who either did not return the consent forms or whose parents refused to give consent to record them on video were positioned so as to have them out of the camera's field of view. Furthermore seating plans were drawn in which the students without consent were marked to ensure that, if for some reason they ended up in the video because of classroom dynamics, their participation was not used in a manner contravening the guidelines of the IRB in terms of participant well-being and privacy. All signed consent forms, video and audio recordings and their backups were kept in a locked cabinet for a minimum of three years after the final ASTEP-RP data collection.

Participant selection

Given that I will be using a case study methodology (Denzin & Lincoln, 2005; Stake, 1995, 2005; Yin, 2003), I selected reflective participants who had extensive data sets that would yield the rich descriptions necessary to properly present a holistic view of each case. For this purpose, I have determined the following criteria for case selection:

- Participants were part of the APB track of the ASTEP program.
- Participants had to take part in the program for at least three years without interruption participating in full observation cycles and tasks at all data points.
- Participants had to teach the same subject (biology) throughout the process.
- Participants were reflective individuals who gave elaborated interview responses.

Participants

I selected four participants for this study, Alice, Beatrice, Catherine and Danielle. All four participants were female in their twenties of non-Hispanic, white ethnicity. While all participants had earned degrees in biology, there were differences in their self reported prior experiences regarding middle and high school aged children. Alice was a Pre-Med undergrad who was employed as a permanent substitute teacher for K-12. She had also worked as an assistant soccer coach and a camp counselor for AmericaCorps' VISTA. For her internship, Alice was assigned to Avery, a public high school in a small Midwest town; relevant demographics are shown in Table 6. During her internship, she taught Honors Biology under the supervision of her mentor. She would eventually be hired by Avery upon the completion of ASTEP. As a full-time teacher she had a normal workload and taught a variety of students. The first class observed was designed to be a 'class-within-a-class' (CWC), which meant that students with special learning needs were assigned to it. The classes observed in the second and third semester were mainstream classes focused on neither honors work nor special needs students. Beatrice had earned her BS in biology and worked as a camp counselor as well as a church youth group leader. She interned at two schools during her first year in ASTEP. She first interned at Bellamy middle school, to satisfy the requirements for the middle school component of her dual certification. Bellamy is located in a small town in the US Midwest and its student body composition is summarized in Table 6. Beatrice then interned at Carson high school located in a small rural town in the US Midwest. Upon completing her work in ASTEP, she worked for a year at Bellamy middle school and was then hired by Denisson middle school, a private Catholic school in the same Midwestern town as Avery high school (see Table 6 for student demographics). Catherine had worked as camp counselor as well as mentor in the Stand by Me Program and carried out her internship teaching anatomy and physiology at Avery high school throughout her first year in ASTEP. During her first and second year as a teacher she taught biology at Ellis high school, which is located in another small Midwestern US town. The demographic information for this school is summarized in Table 6. Danielle had worked as an after-school tutor and as a mentor for both the Big Brothers and Big Sisters program and the Women of Worth program. She interned at Bellamy High School during her time as an ASTEP student and was hired as a full time biology teacher by Fairview high school, a private school in the suburban areas of a large city in the US Midwest. Alice, Beatrice and Catherine initially intended to obtain dual certification in both Middle School and High School teaching; however, only Beatrice completed the necessary internship requirements. Participant background information is summarized in Table 5. At the time of this dissertation's completion, all the participants except Catherine continued to work as teachers, Alice and Danielle continued to work at the same schools that hired them while Beatrice still worked at Denisson middle school. Catherine left teaching to work in the private industry biology research. Table 7 summarizes participants' teaching placement at different times throughout the investigation.

Table 5

Participant Summary

Participant	Gender and Ethnicity	Degree	Field	Relevant Prior Experiences
Alice	Female, non-Hispanic white	BSc.	Biology (Pre-Med)	Camp counselor – AmericaCorps VISTA Coaching
Beatrice	Female, non-Hispanic white	BSc.	Biology	Camp counselor Church Youth Group Leader
Catherine	Female, non-Hispanic white	BSc.	Biology	Camp counselor Mentor in Stand by Me
Danielle	Female, non-Hispanic white	BSc.	Biology	Mentor in Big Brother, Big Sister Mentor in Women of Worth After school tutor

Table 6

School Demographics

School	Total Enrollment	Asian	Black	Hispanic	Indian	White	Free/Reduced Lunch (FTE)
Avery HS	1,717	4.9%	11.1%	2.6%	0.3%	81.1%	12%
Bellamy HS	803	1.1%	9.5%	2.0%	0.2%	87.2%	31%
Bellamy JHS	576	0.4%	12.3%	1.7%	0.0%	85.6%	50%
Carson HS	242	0.0%	2.9%	0.0%	0.0%	97.1%	33%
Denisson MS	592	0.2%	1.0%	0.8%	0.1%	97.9%	NA
Ellis HS	1,289	0.6%	6.0%	6.2%	0.2%	87.0%	40%
Fairview HS	400	←	25%		→	75%	NA

Table 7

Participant school location

Participant	Internship		Teaching		
	Semester 1	Semester 2	Semester 3	Semester 4	Semester 5
Alice	Avery HS	Avery HS	Avery HS	Avery HS	Avery HS
Beatrice	Bellamy MS	Carson HS	Bellamy MS	Bellamy MS	Denisson
Catherine	Avery HS	Avery HS	Ellis HS	Ellis HS	Ellis HS
Danielle	Bellamy HS	Bellamy HS	Fairview HS	Fairview HS	Fairview HS

Data Collection

Data for this study was collected at seven different instances over a three-year period. Each data collection point represented a specific semester of the academic year. Two distinct data collection processes can be identified: (a) school in session data collection semesters (Fall/Spring); and (b) school not in session data collection semesters (summer). This sequence of data collection allowed me to determine how teacher understanding of assessment and student learning developed over time throughout their work as interns into their first two years of teaching as summarized in Table 8.

Table 8

Data collection timeline

Data collection	Summer Year 1	Fall Year 1	Spring Year 1	Summer Year 2	Fall Year 2	Spring Year 2	Summer Year 3	Fall Year 3	Spring Year 3
Lesson design	x						x		
Video Analysis Task	x						x		
End of Summer Interview	x								
Class Observations		x	x		x	x		x	x
Stimulated Recall		x	x		x	x		x	x
Written Reflection		x	x		x	x		x	x
Mentor teacher Interview		x	x						

Summer Data Collection

Upon entry to the ASTEP program all students were invited to participate in the first data collection session before starting their coursework. This data collection had two components to it: (1) a lesson planning task and interview; and (2) a video analysis task and focus group (See Appendixes A, B and C). These tasks were used to elicit participant PCK before any activity related to the ACP program. At the end of this first summer, after completing their first sequence of courses, students participated in an additional semi-structured interview in which they were asked to reflect upon their original lesson plan. During this interview, they were asked to suggest what changes, if any, they would make to their original lesson plans and to provide explanations as to the reasons for these changes (See Appendix D).

Two years after starting the ASTEP program, participants were invited to take part in another summer data collection process. This process was similar to the initial process in that it included both the lesson planning task and the video analysis task (see Appendixes A, B and C), but was different in that during the final interview participants were asked to compare and reflect on the differences between their first lesson plan and the last one they prepared.

Lesson planning task. For this portion of the data collection, students were asked to develop a lesson plan following the guidelines of the Lesson Preparation Method described by Valk and Broekman (1999).

In this process, participants were asked to design two 50-minute lesson plans for consecutive days (Tuesday and Wednesday) including learning objectives, expected student behavior and any necessary transparencies and handouts. The grade level expectation (GLE) statement to be addressed was: ‘There is heritable variation within every species of organism’ (see Appendix A). While participants were not allowed to use textbooks, they were told to assume they had a well supplied classroom with appropriate resources for teaching the topic (Valk & Broekman, 1999). Participants were given one hour to complete this task which was follow up with an interview (see Appendix B).

Video analysis task. This process involved students watching a video of a physics teacher presenting the topic of optics by studying the human eye. Participants were asked required to reflect, first individually and then as a group, on the teaching observed throughout the clip (see Appendix C).

Fall/spring data collection

Data was collected over a period of three years in observation cycles that took place during the fall and spring semesters. These observation cycles were carried out in three parts: (a) lesson planning and pre-observation interview (see Appendix J); (b) field observations with post-observation interviews (see Appendix L); and (c) written reflection. During the first two years of observations, these cycles focused on two consecutive days of instruction. Starting on the third year, only one day of instruction was observed. In addition to this their mentor teacher was interviewed at the end of the observation during the first fall and spring semesters (Table 8) with a different interview protocol that sought to gain an additional perspective not only on the development of the interns, but also on the mentors' views on their role in the shaping of the participants' PCK (See Appendix L).

(a) Lesson planning and pre-observation interview. Participants were required to submit lesson plans describing their goals, procedures and overall teaching intentions for two days (one day during year 3). This was then followed up by an interview by one of the researchers. The interview was semi-structured (Seidman, 1998); the researcher would focus on the participants intentions for the lessons to be observed. Questions were asked addressing the major themes in the PCK framework (see Appendix J).

(b) Observations and stimulated recalls. The second stage of the observation cycle involved the alternation between lesson observations and stimulated recall interviews as follow-up. Lessons were videotaped and selected parts were played for the participant in order for them to reflect upon the events. This stimulated recall interview was conducted as a semi-structured interview. The video clips used were selected paying particular attention to instructional decision making events that were identified by the researchers as relevant in illustrating the participant's PCK (See Appendix K). At the end of the observation cycle additional questions were asked in an attempt to identify the sources upon which the participant drew upon to make instructional decisions. A final reflection on their instructional decision-making and development as teachers was requested. Initially this reflection was in written form, but the team eventually decided to incorporate them, when possible, at the end of the observation cycle.

(c) Written reflections. Participants were sent an email after the second day of observations. This email asked them to reflect on their learning about teaching over the observation process as well as on the strategies they used during this process.

Data Analysis

As part of the project, initial coding began concomitant with data collected in order to help improve our observation protocols and interviews (Creswell, 1998; Hatch, 2002; Lincoln & Guba, 1985). The coding process involved allowing categories to emerge from the data (Patton, 2002; Strauss & Corbin, 1998), while being strongly influenced by the PCK framework that guided the design of our data collection instruments. I was part of the team that developed the initial coding scheme for knowledge of students and knowledge of assessment. For this study I further refined the coding on these two strands using the conceptual frameworks described.

The units of analysis for this study were the individual participants. For each of these I developed a narrative that described their understanding of learners and assessment at different points in time. Initial coding was carried out using the overarching categories of PCK relevant to the study: Knowledge of Students as Learners and Knowledge of Assessment. However no subcategories were used during the initial coding. Themes emerging from the analysis of each allowed me to construct subcategories that reflected the relevant experiences as perceived by the participants. For example, initial coding of all cases showed an emphasis on student group work, especially after the first courses in summer, thus a ‘group work’ subcategory was used to compile this information. Different perspectives on the importance and dynamics of group work were coded under this theme within cases and over time. Notes were taken when a particular theme became less relevant, disappeared completely, or maybe even reappeared from the data sources over time. An example of the latter was the issues associated with the notion of misconceptions, which were initially discussed by all participants and became conspicuously absent from their planning during the first year of teaching, only to resurface again during the Exit Task.

In addition to the two overarching categories directly related to PCK, a third overarching category, factors influencing knowledge, was used to code the rationale, experiences and explanations provided by the participants to support their plans, actions or beliefs as they pertained to the PCK categories. Further analysis of the information coded to this category allowed me to determine sub-themes of the major relevant factors, experiences and personal considerations that shaped the participants’ understanding of students as learners and assessment over time. The categories in this theme included prior experiences as K-16 students, coursework in ASTEP, mentor teachers, and school policies among others. When participants discussed what they perceived as conflicting views in this category, note was taken about their rationale for their personal solution to the conflict. The categories related to these issues ranged from personal factors to experiences as students or teachers and views about the process of learning to external factors and influences, such as coursework, ASTEP instructors, and mentor teachers as well as school and district policies.

After the analysis of each individual case I carried out a cross-case analysis to make tentative claims that allowed me to address my research questions (Stake, 1995, 2005). In order to facilitate the comparison across cases, I expanded in the initial PCK categories using the sub-categories used by Magnusson et al (1999). In the case of Knowledge of Students as Learners, the subcategories employed were knowledge of prerequisites for learning and difficulties in learning. The former category included views on the process of learning and how this can be facilitated; the latter included difficulties that ranged from behavioral to cognitive. In the case of Knowledge of Assessment the subcategories used were Knowledge of Methods of Assessment and Knowledge of Dimensions to Assess. The first category included formal and informal assessment as well as formative and summative assessment which, in a way addressed assessment goals. The second category included not only the content and/or skills to assess but also the rationale behind the assessment of these. Themes that were found across cases that did not clearly fall in any of the subcategories were considered under the original category.

Trustworthiness

Naturalistic research must deal with what positivistic and post-positivistic researchers have labeled as 'sloppy research' or 'merely subjective' observations. Qualitative researchers must persuade their audiences that their research findings are worth paying attention to. In order to do this, the researcher must establish trustworthiness. In order to achieve this, the researcher must address four criteria during the investigation: credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). The aspects of the investigation that allowed be to address these issues are summarized in tables 9 and 10.

The first step to establish trustworthiness was to ensure data collection from multiple sources over time (Lincoln & Guba, 1985; Yin, 2003), which was used for triangulation purposes as stated by Stake (2004). Moreover, while not constantly exposed to the participants, the fact that we engaged them over a prolonged period of time allowed us to build trust with them in a manner similar to the ‘prolonged engagement’ approach suggested by Lincoln and Guba (1985). Another aspect addressing the credibility of the study was the team structure that existed within the larger project that served, in a way, as a peer debriefing technique. Being part of a multidisciplinary team allowed me, at times, to share my research findings with other researchers who, while not vested in my own investigation goals, were knowledgeable on the subject and provided me with a chance to remain focused and reminded me of my role as a researcher within the context of the frameworks that guided both the larger project and my own. This peer debriefing allowed me, as an independent researcher for this investigation, to reflect on the themes that arose from the analysis of the data within the larger scope of the PCK conceptual framework. This helped me not only define codes within cases but to also refine my codes as similar themes arose between cases. Finally, all our observations of the classes were recorded on video and used, when necessary, to confirm any notes that were made by observers and interviewers, allowing us to go back to observations if clarification was needed regarding the conclusions or hypothesis derived from what we had seen in class. The conjunction of these approaches helped to strengthen the credibility of both the larger investigation as well as my own.

Table 9

Addressing trustworthiness: Credibility

Criteria	Definition	Addressed by
Credibility	Confidence in the 'truth' of the findings	- Triangulation: Data was collected from several sources including: - Lesson plans - Lesson observations - Multiple interviews with participants under different circumstances - Written reflections - Mentor interviews - Prolonged observation - More difficult to achieve in this context. - During the duration of the data collection I was constantly immersed in the context of ASTEP interns, collecting data not only the majority of the data for this dissertation but also following participants in two other cohorts simultaneously as well as being an inter-instructor for ASTEP. - I interacted not only with the participants in their teaching and learning settings, but also during summer data collection - Given that many o the instructors of ASTEP were also investigators in ASTEP-RP I had the opportunity to discuss the project under different circumstances and from a variety of angles. - Persistent observation: As an investigator in ASTEP-RP, I was constantly observing and analyzing the context of ASTEP in different time frames, with different cohorts at different internship sites. - Peer debriefing - As a part of a larger research project that extended over a longer period of time, initial findings that included aspects of this investigation were presented at different research conferences - My advisor, also a part of the ASTEP-RP and therefore familiar with the data, also read the findings and provided feedback - The doctoral committee set to review the investigation provided an additional level of peer debriefing, albeit at the end of the process. - Negative case analysis: Findings within and across cases were compared to determine if evidence that contradicted initial assertions could be found. If such data was found, assertions would be revised in order to account for this. The process was repeated throughout the investigation in order to arrive to the final assertions. - Referential adequacy: Data was not set aside for later revision, however the analysis of the data from other cohorts provided the opportunity to review my findings in a manner similar to that required by this criterion - Member checking: This step was carried out only during initial stages of the investigation, as time passed this became increasingly more difficult and was not always addressed. \

Table 10

Addressing trustworthiness: Transferability, dependability and confirmability

Transferability	Showing that the findings have applicablity in other contexts	- Thick descriptions in the form of the case narratives provide insight that would allow to determine the extent to which the conclusions of the study are transferrable
Dependability	Showing that the findings are consistent and could be repeated	- While the constructivist paradigm that supported the investigation might lead to confusion regarding this component, two aspect of the process addressed, to a certain extent, the issue of dependability: - Initial findings of ASTEP, some of which are part of this study, were presented at national conferences and submitted for publication, this allowed for them to pass through peer reviewed processes. - Three out of five members of the committee reviewing this dissertation were not involved in any aspect of ASTEP and as such evaluated the extent to which the findings and conclusions of this investigation were supported by the data.
Confirmability	A degree of neutrality or the extent to which the findings of a study are shaped by the respondents and not researcher bias, motivation, or interest.	- Triangulation - All steps in the process were kept in an NVivo file providing an audit trail. This included: - Raw data - Data reduction and analysis products - Synthesis products - Process notes - Instruments and their development

It is agued by Lincoln and Guba (1985) that establishing credibility is sufficient to establish dependability. However, I would like to add that the team structure that was the foundation for the larger research team allowed us to analyze data in pairs and groups of four. This functioned, in a way, like a ‘stepwise replication’ as suggested by Lincoln and Guba (1985) both for the larger project and my dissertation study, allowing us to compare and contrast ideas, and reach consensus as well as analyze negative cases in order to test our individual and group-derived hypotheses.

In order to address the issue of transferability, the participant selection process allowed me to construct rich descriptions of the experiences of the participants in narratives and tables that summarized not only these findings over time, but also as much relevant background information of each case as possible, including characteristics of the individuals, locations and interactions that would help provide readers with the possibility to transfer the findings to similar situations (Lincoln & Guba 1985; Patton, 2002).

Confirmability was not only addressed by the use of triangulation of multiple data sources (Lincoln & Guba, 1985) but also by the use of a reflective journal. The NVivo software allowed us as a team (and as individual researchers) to keep a journal of our work, observations, reflections, coding and recoding. It also allowed us to bring out different queries and analyses of data that shaped our thought processes and refined our hypotheses during the data analysis process. Moreover, the unmodified backups of the NVivo files served as a timeline of the thought process that each of the researchers, me included, went through as part of our investigations.

CHAPTER 4. CASE STUDIES AND ASSERTIONS

The purpose of this chapter is to present the assertions that address the research questions that guided this investigation. These assertions will be preceded by narratives that represent profiles of each of the participants at different points in time. These profiles will provide insight and evidence to support the assertions that will be compiled at the end of the chapter. In order to provide support for the claims made throughout the narratives, I will provide specific pieces of data from the various sources used in the investigation. This data was selected because I deem it to be representative of the ideas, perceptions and reflections that each of the participants had at the particular point in time when they were collected.

Alice's Case

Background Information

Alice was a white, non-Hispanic, female. She had a bachelor's degree in biology and, at one point in her academic career, considered applying for medical school. She met all the academic requirements for A-STEP and initially signed up for dual certification in middle school and high school science. However, after completing her coursework, she was hired by the high school (Avery) where she had interned during her time in A-STEP. Hence, she elected not to complete the middle school internship required for middle school certification. Her prior experience with K-12 students included coaching sports and volunteering as camp counselor for AmeriCorps VISTA program.

Beginning the ACP

At the beginning of the ACP, Alice carried out a three-step process designed to collect data of her views and understanding of science teaching. In step one, she designed a lesson sequence to teach heritable variation to 8th grade students. In step two, she was interviewed using the information from the lesson plan to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. At this point in the program, Alice believed that students' knowledge is comprised of life experiences and observations with no understating or relating of these observations to scientific knowledge and terminology. She stated, "I think that the variation, the heritable variation, is probably going to be a new term to them, but they see it every single day, and it is surrounding them" (Entry Task Interview). She recognized the importance of connecting this everyday knowledge to the content she intended to teach. When specifically asked to elaborate on this she stated:

> I don't think that they'll know exactly that their traits are heritable variation until maybe we start looking at it and then maybe they'll be able to associate the different traits within their family – that they are inherited and there is variation between their family, and there is variation between the student sitting next to them. (Entry Task Interview)

At this point Alice believed that students were primarily passive learners and that it was her responsibility, as instructor, to point out the connections between their daily observations and scientific knowledge. However, she did believe that, in order for her to help them make these connections, she must elicit curiosity in her students. In order to get her students to think about variation, Alice intended to ask them to observe different traits among their family members and come up with explanations about how inheritance worked. She stated, "I was getting them to (pauses to rephrase) [to] ask them questions to kind of get them to really think about [why]: okay, I don't just have brown hair because I was born with it; I have it because my family has it or somebody in my family has it, that somebody else had it." (Entry Task

Interview). Furthermore she believed that, to a certain extent, discomfort might not necessarily be a bad thing as it might cause students to reflect “They might flip out. Which is not necessarily bad. It gets them to think.” (Focus Group).

Knowledge of requirements for learning. As far as prerequisites to learning are concerned, Alice highlights the importance of connecting a student’s existing knowledge and experiences to the content being taught. However, her primary use of this prior knowledge was to prime her students for teacher-centered discussions by making them curious about observations: “So I was just hoping it would get them thinking more along the lines of: ‘if there is this much variation just within my family, I wonder how much is really …’” Alice continued her attempt to imagine the questions her students might ask by phrasing the question: “Variations – are (they) in their (my) family or in just the world around me”? (Entry Task Interview). Alice wanted students to ask questions, to be curious about the topics she would later elaborate on. As she said, “Ask them questions to get them thinking about their own heredity traits and the possible variations within their own family” (Entry Task Lesson Plan)”.

Knowledge of student difficulties. Alice believed that students’ difficulties would lie in the more abstract notions of inheritance. For example, students would find it hard to comprehend concepts related to the molecular or cellular details that could not be visualized. She stated, “I think probably more of like the actual, if we got into the terms and stuff. The different actual DNA terms or chromosomes and … visualizing how everything came together.” (Entry Task Interview). Another area of difficulty for students would be when generalizations would extend beyond the students’ personal experiences. Regarding this point Alice shared:

> But I think it'll be harder definitely when you look at a bigger picture, because there are so many different species out there … think that'll maybe be the kind of harder part, is thinking about things they can't actually visualize or see. (Entry Task Interview)

Knowledge of assessment. In her initial lesson planning, Alice included no formal instances of assessment. Nevertheless questioning students was a common part of her teaching. She believed that the specific questions she came up with would allow her to tailor and adapt her discussions to student interests. When asked to elaborate about her use of questions she replied:

> And I think that's where I got the questions. I thought, if I ask these then I can kind of understand how much they actually know, or what their interests are, or what they're thinking, and then be able to change my discussion around based on that. (Entry Task Interview)

Knowledge of the dimensions of science to assess. Alice's focus on assessment gravitated primarily around gauging students' prior knowledge and students' overall ability. However, she did not focus on specific skills or content related to the topic. She was mainly interested in being able to accommodate her discussions to her students' interests and abilities. When prompted as to how she would figure out how much detail she would go into, Alice answered:

> And they'll be definitely some students that are going to move along faster than others, so I think you have to assess the class and find a nice medium pace that everybody can move along with fairly well and learn. (Entry Task Interview)

Knowledge of methods of assessment. Alice's goal for assessment was basically to gauge student learning ability and interests. Neither in her plan nor during the interview did she mention assessment as a component of her planning. However, when questioned about how she intended to determine how in depth the topic should go, she loosely referred to the need for assessment. Alice said, “so I think you have to assess the class … I don’t know how I would do the first day, … I would kind of think, okay if this takes a little bit longer to do . . .” (Entry Task Interview). Upon reflection during the interview, she further suggested that she could gain knowledge of her students from the discussions and conversations that were part of her planning.

Factors influencing Alice’s knowledge of students and assessment. Lacking significant teaching experience, Alice drew primarily on her experiences as a student to guide her planning of a lesson. It was also these experiences that provided her with insight as to how students would tackle and work through the tasks she had designed for them. Her belief that student learning is improved by arousing their curiosity stemmed from her own learning experiences as a student. She recalls, “I don’t think I would have known quite as much or been quite as interested in doing [the experiment] if I had not heard about genetic variation before” (Entry Task Interview). Furthermore, it was her own difficulties that she recalled when asked to elaborate on her expectations of her students’ difficulties, “I just remembered it being really hard – the meiosis and mitosis and visualizing how everything came together” (Entry Task Interview).

End of Summer

At the end of the first summer in the ACP, Alice had completed courses in Educational Psychology and Secondary Science Methods 1. She was then asked to reflect on the initial lesson plan she prepared for the Entry Task.

Knowledge of learners. By the end of the first summer in the ACP, Alice had a more structured view of students' knowledge and was aware of pre-existing knowledge that could help or hinder their learning. Alice also became aware that students learn in different ways. She stated, "I mean I think that, you know, obviously kids learn in so many different ways. I mean, even just some kids can pick things up so easily just from reading it and other kids need to write it or hands on, you know, that kind of stuff …" (End of Summer Interview). In addition to this, she highlighted the importance of group work as part of her teaching strategies, as Alice stated: "I really didn't realize how important that is for kids in the classroom just to learn to work with one another, but also that helps them learn, having somebody else to discuss their thoughts with." (End of Summer Interview)

Knowledge of requirements for learning. Alice highlighted the importance of using a variety of strategies to present in order to keep students engaged, as she explained in her interview:

> Because I think that this all might be kind of boring for them, for things that they're going to be (they're eighth graders), so I'm not sure they're going to be too engaged in this, but you could actually discuss that a little bit but then go on to, you know, maybe a different activity, something a bit more, you know, engaging and fun. (End of Summer Interview)

Nevertheless, these various approaches still retained the original intent of the discussions within her original lesson plan: to relate the content to be taught to student personal experience. When asked to elaborate, Alice explained; "… even pick different flowers or something and see and learn about the genetic variation within them and, so I was trying, I guess, just to get it to relate to them, their selves…" (End of Summer Interview). Furthermore, Alice viewed engagement as a way to further foster curiosity and thus improve student learning, as she stated:

> …because if you have them actively kind of engaged and having some sort of interest in what they're doing, I think that they're going to want to learn more about it and they're going [to] be more interested in going and grabbing a book on it and trying to figure out what it is and apply it to what they're doing. (End of Summer Interview)

Knowledge of student difficulties. Alice acknowledged the existence of misconceptions the students may have and related these mainly to scientific terminology. She further expanded on her notion of students having difficulties with abstract notions as opposed to concrete ones, especially considering the age level. As she stated, "They're not going to grasp these really abstract, you know, they all need to be kind of fairly concrete, you know, at least at this eighth grade level" (End of Summer Interview). Upon completing her plans, Alice viewed misconceptions as notions students have that need to be addressed. As Alice explained:

> They can look back and go, oh, I remember, you know, learning about the difference in trees, you know, and so just to kind of give them more of a solid background and to be able to address those misconceptions that they had before they move on and try to add information to it. (End of Summer Interview).

Knowledge of assessment. At the end of her summer courses, Alice considered a wider variety of assessment tools when reflecting on her lesson plan. These tools ranged from formal tests, including standardized tests, to informal questioning of students as they carried out tasks in the classroom. She believed in the strength of informal assessment. She compared both formal and informal learning as follows:

> Lots of teachers will do tests and stuff, but I think that by watching them (the students) and asking them these questions kind of probing on what they know and their information and then having the big discussions at the end or presentations on what they've learned, I could understand, or say, 'okay, this group definitely understands how genetics play in the variation.' (End of Summer Interview)

Knowledge of the dimensions of science to assess. Alice's first change to her original plans was to include an initial diagnostic assessment of students in order to determine the misconceptions they might have regarding the topic of heritable variation. She focused on scientific terminology for this exercise based on her own experience with misconceptions. As she stated when elaborating on this change in the lesson plan: "… like, gene, genome, DNA, RNA, single strand helix, double strand helix, just various other, heredity or genetic terms … I was just thinking of maybe my own misconceptions on genetic variation within humans …" (End of summer interview).

Knowledge of methods of assessment. Alice also focused on the importance of gauging student learning by informal assessment strategies, such as observation and questioning of students, in a formative manner. Alice highlighted the importance of using student products such as projects, presentations or models to assess their learning. She even equated formal testing as assessing memorization. She claimed, "… doing things like the project and the group presentations or even [building] a model of the genes. If they actually are doing that kind of stuff, that gives me a better idea if [the students] understand it as opposed to just testing their knowledge on terms that they memorized" (End of Summer Interview).

Factors influencing Alice's knowledge of students and assessment. Alice's summer courses exposed her to different theories of learning as well as inquiry-based approaches to teaching. Moreover, she discussed different approaches to student assessment including formal and informal tools as well as the strengths and weaknesses of them. She showed willingness to consider both of these as part of her plan while maintaining the same sequence of events.

First Semester Internship

During her first fall semester in the program, Alice took her second Secondary Science Methods course while teaching Honors Biology at Avery. Her class had 10 male and 7 female students. The topics covered during the observation were cloning and stem cells. The interpretations include data from lesson plans, a pre-observation interview, two stimulated recall interviews, field notes from observers and an interview with her mentor teacher.

Knowledge of learners. For this lesson Alice showed a more elaborate understanding of her students' prior knowledge on the topic. Given the controversial nature of the topic and the fact that the state elections included amendments that focused on stems cells Alice had a good idea of the what knowledge her students might have regarding the topic, "They probably have an idea of what cloning is and they probably have an idea of stem cell research just by watching the news and listening to the recent debates on for the new amendments being passed" (Pre-observation Interview).

Nevertheless she believed that students would have had little if any knowledge of other applications of cloning in medicine because they "had not taken much biology" (Pre-observation interview). She also viewed learning as taking place when the teacher provided new information that students could connect to prior knowledge, "once we start giving them information, they pick it up really quickly and they're able to apply new knowledge to the old knowledge" (Pre-observation Interview).

Knowledge of requirements for learning. Given her experience in teaching a sequence of topics, Alice had a clearer idea of prerequisite knowledge for cloning, in this case DNA. As Alice recalls:

> …we did a lot with just DNA and the function of DNA; they learned quite a bit in depth about the different bases and all that kind of stuff. So I think that's a huge part of what cloning is and so I think that will be able to relate back. (Pre-observation Interview)

When attempting to address abstract content, Alice learned that modeling can provide a useful tool for student learning, as she discussed her approach to teaching protein synthesis:

> When we did proteins, we lined them up in the hallway: Each one was a different space and each person a different amino acid and we moved them in and out of the holes, like physically move the kids … I knew it was the only way that they were going to understand. (Pre-observation interview)

Alice also believed that student learning would improve if "at least each student has a chance to listen to another student and say what they think" (Second Stimulated Recall)

Knowledge of student difficulties. While Alice did acknowledge that her students had quite a bit of knowledge regarding the topic to be taught because of media exposure, she still separated this knowledge from formal scientific knowledge. When asked to elaborate on her students' knowledge, Alice stated:

> … because most of this biology stuff is kind of new to them … I feel like we have to kind of start from the beginning; this is what DNA is, these are the names of it – that kind of stuff – because they don't have any previous knowledge on that, but once we start giving them information they pick it up really quickly. (Pre-observation Interview)

Moreover, Alice still believed students will have difficulties with more abstract concepts that they cannot visualize. When asked to elaborate on what aspects she believed students might find difficult she addressed the size of the structures being studied. “I think maybe visualizing because they know how small a cell is and being able to understand how they … actually remove the DNA … might be difficult for them to understand” (Pre-observation Interview).

In addition to this, Alice made a point of looking up common misconceptions so that “I can clarify it [with] the correct, right answer” (First Stimulated Recall)

Knowledge of assessment. Alice began her lesson plan by referring to the use of a test on content covered in the previous topic. This is departmental policy at Avery and thus built into her lesson plan. However the topic that we observed was not to be included in the unit test. When questioned on the need for assessment, Alice focused on the use of an informal approach to gauge student learning and thus accommodate her instructional approach

Knowledge of the dimensions of science to assess. Alice focused primarily on assessing student understanding of content by observing their ability to explain it either to her or to others. She did this informally by interacting with individuals or groups as they worked through the tasks she had prepared for them. While aware of possible student misconceptions, assessing to determine these was conspicuously absent from her planning and execution of the lesson.

Knowledge of methods of assessment. While Alice’s work with her mentor involved the use of tests at the end of each topic, the particular topic at hand was not included in the unit test because “[students] are doing a lot, like genetic screening, and they are doing an actual interview” (Pre-observation interview). This observation resulted in her deciding to use an informal approach to gauge student learning as they worked in class by asking them to explain thing to the class. When asked to elaborate on how this would be accomplished, Alice stated:

> I'm constantly going back to what we learned and making them tell me it in a different way and I think by them having to read these articles and, you know, present the information and actually explain it to the group. (Pre-observation Interview)

However despite there not being any formal assessment planned, she decided to make one up for them "I made up a quiz for them …but in paper form, not quiz form" (Second Stimulated Recall) and proceeded to elaborate on how this would lead them to "explain the process of cloning and what you would use it [for]" (Second Stimulated Recall).

Factors influencing Alice's knowledge of students and assessment. Alice worked very closely with her mentor; she tailored her classes to be near exact replicas of her mentor's in order to ensure that they "have to kind of do it exactly … try to do it exactly the same for the other honors biology …" (Pre-observation Interview). This close working with her mentor provided Alice with a more developed knowledge of her students' learning needs. Her understanding of learning, involving both lectures and student interaction among themselves, was based on this close interaction with her mentor especially regarding a step she called 'share with your neighbor.' "This is something Ms. Phillips uses a lot" (Second Stimulated Recall). In fact she viewed most of her teaching experience as related to this point as "I am watching [Ms. Phillips] teach and just her … I am just kind of mimicking what I am learning" (Second Stimulated Recall).

Second Semester Internship

During her first spring semester in the program, Alice took her second Secondary Science Methods course while continuing to teach Honors Biology at Avery under Ms. Phillips, but by then, she was responsible for a whole section rather than co-teaching. The topic covered during the observation was photosynthesis and it was part of a unit comprised mostly of practical work. The interpretations include data from lesson plans, a pre-observation interview, two stimulated recall interviews and field notes from observers.

Knowledge of learners. Alice continued to highlight the importance of the role of students interacting among themselves to help learning. Her pre-test included a moment for peer feedback and lab work based on group interaction. She elaborated on this methodology when discussing the differences between working alone and in groups:

> I think their friends are going to have somebody to bring up different ideas or say 'what do you think happens?' When they are answering questions, say 'what do you think is the independent variable? What is the dependent variable?' (Pre-observation Interview)

However she acknowledged the possibility that this might not be as effective in other groups of students lacking the motivation to work that her honors group had, "I have honors biology kids that don't really goof off much, so I think it might be different in another class" (Pre-observation Interview). Moreover she believed that students have different levels of ability that allow them to understand more abstract content that would otherwise be difficult, "… because it is honors biology we go a little bit more in depth that they'll be able to grasp" (Pre-observation Interview). However, she believed that core content can be learned if the instructor states it repetitively, even highlighting the point after a test to drive it home one more time. "I spend a little bit more time going over the test, but in this case, I just quickly went over it, and gave the main components we had drilled into their heads." (First Stimulated Recall)

Knowledge of requirements for learning. Alice highlighted the importance of students having prerequisite knowledge from the previous unit covered. After determining students' capabilities via a pre-test, she would “determine what they know and that they don’t know; things we need to focus on more” (Pre-observation interview). In the case of the class topic, photosynthesis, she argued the need for them to be able to connect to ecology, specifically to the carbon and nitrogen cycles, and respiration. In addition to this, Alice highlighted the importance of hands-on experience in students learning:

> They are pretty good about retaining information and remembering. I think it has a lot to do with the nature of our class, because we do a lot of hands-on stuff to where they have physical hands-on things to remember these by instead of just notes on a paper. (Pre-observation Interview)

However she did believe that students in her class were not “… developmentally mature enough to learn for the sake of learning.” (Pre-observation interview)

Knowledge of student difficulties. Alice was aware of several misconceptions students might have concerning this topic and of the persistent nature of these misconceptions. She acknowledged that some misconceptions might be addressed by providing students with activities that will result in data that will contradict their existing beliefs. Regarding the notion that all steps of photosynthesis take place only in the presence of light, she states that her ‘bubble lab’ would address this misconception because students would have to “address that plants do some photosynthesis without light at all” (Pre-observation Interview). However she also acknowledged that some misconceptions might not be addressed; in this case, she commented on the notion that autotrophic cells carry out cellular respiration: “That’s something they aren’t going to grasp, and we’re going to have to beat it into their heads” (Pre-observation Interview). Alice also argued that some prerequisite knowledge, while covered at the beginning of the year, might not be remembered by students, mostly because “I don’t think they have ever written out the question for it or really understood it and how cellular respiration and photosynthesis work together" (Pre-observation interview). As far as experimental work goes, Alice understood that students will have difficulty working with equipment because "some of them have never worked with the fancier equipment" (Pre-observation Interview).

Knowledge of assessment. Formal assessment using a pre-test provided Alice with the necessary knowledge regarding her students understanding of the content covered in the previous unit. She commented on her goals for this test:

> So after we do the objectives, we are going to handout a pretest, and it's just a photosynthesis pretest to see what they picked up on from the ecology unit and what they are able to apply to this new unit. (Pre-observation Interview)

Alice related her goals for student learners to her assessment and worked it into her formal testing. She asserted that written tests can gauge more than just memorizing of definitions or facts. When prompted to elaborate on this she stated:

> They know they can memorize definitions and write it down, and some of them are really good at [being verbose about] the answers. I'm reading these and knowing 'you obviously learned the definition, but you have no idea what you are talking about', so I just mark it wrong. You just have to know the information well enough to know that they're not babbling. (Pre-observation Interview)

Alice still believed in the importance of assessment to determine the depth of content as well as the pace of student learning. When referring to the usefulness of her pretests, she stated "So it's just kind of a gauge for how in depth and how much time we need to spend on stuff." (First Stimulated Recall).

Knowledge of the dimensions of science to assess. Alice stated the need for prerequisite content from previous units, which are necessary to understand the content of the new topic. Given the experimental nature of the class work, she looked to evaluate primary lab skills, especially data analysis and representation.

Knowledge of methods of assessment. In this instance Alice used a formal test as a pre-test; however, this test was structured so as to include peer feedback, which was designed to serve as a leading point into the topic itself. Alice stated in her plans "They will then discuss their answers with a partner, which will lead us into the photosynthesis unit" (Lesson Plan); hence the test became an instance where learning or recalling knowledge could take place. In addition to the pre-test, Alice used student lab reports and quizzes to gauge learning. She elaborated on this by saying:

> I read through them, grade them, and then we go back over them to make sure that they do understand. Whenever they come in, they always know they are going to have lab questions to answer. They're like a little quiz over the lab, and those questions are generally what I want to make sure they got out of it. (Pre-observation Interview)

When it came to reaching conclusions regarding student learning, she summarized her testing results numerically, and she addressed the important points directly as she reviewed the tests.

> We usually go greater detail if they missed a lot more, but all of them did well. The test was out of thirty-six points and most of them got twenty-eight or higher. So they understood it. (Second Stimulated Recall)

Factors influencing Alice's knowledge of students and assessment. Alice's mentor teacher was the major influence in shaping her understanding of how students learn and the approaches that are most effective in teaching. Her experiences in class with Ms. Phillips provided a sounding board against which she compared the concepts provided to her by her instructors in the ACP. She compared both, to determine what approach best fit the reality she was presented with in the classroom. When asked to compare her learning in the ACP to her learning under Ms. Phillips, Alice claimed:

> But with Ms. Phillips and me, it just doesn't work. It maybe could work, but it's just more efficient to even not do all five of the steps [in the 5 E model]. Here, let's do the explore where they do this lab, but we are going to leave the engage out; we are going to leave the lab write-up out, and we are going to explain it and then we are going to take the test on it. Or just modify it a little bit. At Avery we have ninety-minute classes, so we are more apt to be able to do more of the 5-E model, because we have more time. It's kind of time consuming in a sense. (Pre-Observation Interview)

Furthermore her work with Ms. Phillips reinforced her belief about the importance of hands-on experiences in helping students learn. When asked how she believes students learn science best, Alice states:

> I think definitely the hands-on. My idea is coming from a mentor teacher, Ms. Phillips, who has this down like the back of her hand. The nature of her class is very hands-on, and she doesn't let them get away with just sitting and listening and doodling on paper. (Pre-observation Interview)

Alice also used the content provided in her coursework to frame and explain the understanding she was developing at Avery under Ms. Phillips, including explaining Ms. Phillips's teaching style. When Alice was asked about inquiry, she exemplified by describing her mentor's teaching style as it compared to the 5E model addressed in class:

> The 5-E model, we use it, but it's not as clean cut; as today, we are doing the engage phase, and now we are doing explore. She mixes all of that in, and I have never seen her stand up and lecture longer than twenty minutes, and we have ninety minute class periods. So its lots of 'Okay I'm telling you this', now 'talk with your neighbors', let's do this activity, let's go outside and look for different stages of succession. Let's go do this. Its lots of movement; its lots of hands-on. (Pre-observation Interview)

First Semester as Full Time Teacher

During her second fall semester in the study, Alice continued to teach at Avery. In this case she was no longer co-teaching with Ms. Phillips and was responsible for her own classes. She now taught different levels of biology. The class observed for this study was a Class Within a Class (CWC) based on students requiring individualized education programs (IEPs). This meant that certain students in the class required a personalized program within the course.

Knowledge of learners. Alice believed that different student abilities or motivation could also be accompanied by additional levels of difficulty when learning. She believed that learning could be accomplished in a variety of ways even by direct instruction or taking notes and memorizing. Alice provided her students with notes because they requested them. Her explanation was: "[Students] need something physical they can look at" (Pre-observation interview). She viewed students as passive learners; hence, she focused on giving them notes or reviewing content to ensure learning.

Knowledge of requirements for learning. Alice puts emphasis on knowledge required to address the content she intended to teach. She still advocated hands-on experience as being the best way to link existing knowledge to new knowledge, and despite the significant use of notes and repetition, she added "Instead of doing the DNA model activity, I[was] going to do a

“Biology with Junk” activity. They will build a model from different objects and share with the class their models and explain what each part is.” (Post-observation reflection)

Knowledge of student difficulties. Clase1 believed that students will have difficulties with scientific terminology or, as she put it: “[Students should] understand just the basics of this process and [they need] to really understand that – not get them confused by all of these big huge words and things, especially when dealing with protein synthesis and DNA and RNA” (Pre-observation Interview). She also believed that students had difficulty generalizing content to be applied outside of their own experience. In the case of DNA she stated:

> ... because when they think of DNA, I think they just think of our DNA. They don’t really think much outside of it. And they always forget about plants. They leave plants [out]; plants are just there and they don’t have DNA. (Pre-observation Interview)

Moreover Alice was aware of the difficulties students might have visualizing smaller molecules and argued that they tend to focus on larger, less abstract structures; in the case of DNA she stated:

> So the kids, when they think, they’ll hear, my DNA, my DNA, they always hear DNA, but do they think of it as your actual chromosomes, or do they think of it as the smallest, or one of the small parts. (Pre-observation Interview)

Knowledge of assessment. Alice viewed assessment from different perspectives at this point. She still held firm to the formative aspect of assessment while preparing them for a summative test. She included frequent quizzes to prepare her students before big tests “so that they don’t cram so much at the end” and to make sure that they were learning the content she intended them to learn or if she had to “ ... try something else before we get to the test or before we get to next section” (Pre-observation Interview).

Knowledge of the dimensions of science to assess. Alice believed in the importance of initial diagnostic assessment in order to determine whether or not students have prerequisite prior knowledge in order to tackle the content she intended to teach. In this particular case, rather than opt for a pre-test she opted for reviewing and deconstructing the unit objectives, especially vocabulary in order to determine "if they had seen [the word], heard it or might know its meaning." (Pre-observation interview).

Knowledge of methods of assessment. Alice's assortment of assessment tools included formal and informal approaches; she incorporated both into her lessons. While most of her assessment was formative, she now factors in summative assessment as it relates to accountability of student learning. This provides feedback to other stakeholders. In her words, "it is a solid way, because [administrators and parents] are not in there every day when [students] are doing all these little activities that I am assessing what they are doing" (Pre-observation Interview).

Factors influencing Alice's knowledge of students and assessment. The change from honors biology to a CWC setting is one of the main factors influencing Alice's views on student learning. Her views on student learning were based on the belief that students would be highly motivated to carry out the tasks and assignment in the manner that her mentor, Ms. Phillips, had presented to her. In the presence of the conflicting results from these approaches, she returned to the more familiar methods, trying to reach an intermediate position. When asked about where she learned about the more teacher-centered approaches she was using, she replied, "it was just the way I had been taught or the way other teachers do things …" (Pre-observation Interview). Some of the techniques Alice provided her students she used as a K-16 student.

Alice recalls: “In college, I used note cards constantly for things that I actually needed to memorize.”(Pre-observation Interview).

Another important factor was her newly acquired independence from mentorship. This exposed her to departmental and school as well as inter-school cooperation. As far as departmental policies go, the departmental Planning Learning Team (PLT) worked on the department objectives, including objectives that were followed and assessed throughout the year, such as research and experimental skills. Not only did the school policies result in Alice giving a revamped, albeit unwilling, importance to summative tests, but it also fostered team unit planning within departments. When asked why she did them she stated: “Because I am told by my administrators.” (Pre-observation interview). She further elaborates on how these tests are part of the school culture:

> I never liked tests, it’s just the way [of] the parents, the administration, the school; they want to see that the kids are doing homework and taking tests … [Parents] want to know how their kid is doing in class. (Pre-observation Interview)

Other external sources also influence Alice’s views on assessment. At this point in time the PLT group was taking a course called Assessment for Learning (ASL), and they were working on introducing notions from this course into their assessment. Simultaneously they were using software called Mastery Manager to track the development of criteria they found common to all their units.

Second Semester as Full Time Teacher

During her second spring semester in the study Alice continued to teach at Avery. She was responsible for her own classes; this particular class presented no special needs. She now taught different levels of biology. The class being observed focused on genetic technology.

Knowledge of learners. Alice believed that students usually begin a new, unrelated topic in biology with little, if any, understanding of the science involved. However, given the media exposure of genetic engineering, she believed her students would have more extensive ideas relating to this topic. Referring to her students' prior knowledge, she stated:

> They might, from previous biology classes, have heard a few things. Generally they are completely like 'what are you talking about? Protein synthesis? Oh no. Mitochondria? How do you even say that word?' You know, things like that. They're completely clueless, whereas with [Genetic Engineering] they come in, and they have an idea. (Pre-observation Interview)

She also attempted a new way to get students involved in sharing ideas in order to learn: peer-evaluation. Students evaluated each other's projects using the grading rubric provided by Alice. She stated that she hoped that they would "get a better understanding of all the topics through their peers' research". (Pre-observation Interview)

Knowledge of requirements for learning. Alice identified two separate types of knowledge required for learning: 1) formal scientific knowledge, including terminology and knowledge acquired by being exposed to media and 2) informal knowledge stemming from debates over the issues surrounding genetic engineering. She believed students would be more familiar with the argumentation surrounding the issues moreso than the science behind them. When referring to genetically modified foods Alice states: " … so they kind of got the pros and the cons of genetically modified foods, and this kind of stuff is really interesting to the kids … " (Pre-observation interview)

Knowledge of student difficulties. Alice acknowledged both the existence of misconceptions regarding genetic engineering as well as the persistent nature of these misconceptions. She explained this persistent nature based on the moral rather than scientific component of their study as well as the repetitive exposure many students have to one sided arguments on the issue; as she elaborated:

> When you're dealing with things like cloning and stem cells, when you're dealing with ethical and moral type stuff, it's always hard to really address those misconceptions, but to actually change their mind on it, I would think that we're still working on that … then it's really difficult to change a kid's mind when they've been hearing no, no, no for so long. (Pre-observation Interview)

Knowledge of assessment. This particular topic was not part of the state Grade Level Expectations (GLEs), assessment. Because of this, Alice planned her lesson sequence without an end-of-unit test or written quizzes. Her assessment was based on both formal assessment of student work and informal tools. The formal aspect of the assessment was linked to a short research project they worked on and then assessed themselves using the rubric she provided. The informal aspect was primarily her observation and questioning of students as they gave each other feedback.

Knowledge of the dimensions of science to assess. Given the controversial nature of the topic, Alice decided to focus more on student ability to compare arguments and applied this comparison to existing public documentation such as legislation.

Knowledge of methods of assessment. In this case formal assessment of the topic was, for this group of students, a summative one. She did not use it to inform further instruction for them, however the information gained would be used by Alice to "at the end ... figure out what I can do differently to make it possibly better for next year" (Pre-observation Interview); hence, she did consider using it to improve her teaching on the topic.

Factors influencing Alice's knowledge of students and assessment. The primary factor influencing Alice's views on assessment was the departmental policy on not testing content that was not directly addressed in the state Grade Level Expectations (GLEs) and the co-development of a grading rubric with her fellow instructors.

End of Program Exit Task

At the end of the ACP, Alice carried out the same three-step process designed to collect data over her views and understanding of science teaching that she did in the beginning. In one step, she designed a lesson sequence to teach the topic of heritable variation to 8th grade students. In the following step, she was interviewed, using the information from the lesson plan, in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. Alice believed that learners have quite likely been exposed to everyday use of scientific terminology and are probably familiar with the meanings. In addition to this she believed sharing ideas with their peers gives students a chance to reflect on their understanding and helps them learn; as she states: "And I'd, in my mind, ideally, they would be sharing their interviews, some interesting things that they found out …" (Exit Task Interview). Alice also viewed learning as taking place through exposure to the correct information and if it is not she would "need to spend 20 minutes the next day going over it" (Exit Task Interview). Alice highlights that relating content to student experience facilitates learning; "I think this stuff, they'll be fine with. It's kind of all relevant to themselves." (Exit Task Interview)

Knowledge of requirements for learning. Alice translated her experience with older students to the 8th grade setting and operated on the principle that prerequisite knowledge is needed to understand heritable variation. She stated: "In order for them to understand heritable variation, they have to understand what a gene is, what DNA is, where those variations on the base sequence is and come from." (Exit Task Interview).

Knowledge of student difficulties. When it comes to heritable variation, she believed most of the difficulties for students would arise from the mathematical component of the exercise "And actually dealing with ratios and that kind of stuff – I think they might have a little more difficulty …" (Exit Task Interview).

Knowledge of assessment. At this point in the investigation, Alice shows a more complex view of assessment than what she demonstrated in the Entry task. Her views included not only the use of student products at different stages in her plans, but also using informal questioning and observation to gauge student learning. However, she still associated formal assessment, especially tests, to summative or diagnostic purposes, while informal assessment was considered exclusively in a formative manner. For Alice, assessment was primarily a formative tool, and she frequently highlighted informal assessment of her students as she interacted with them; "I'm constantly kind of reassessing and going okay, they aren't getting this at all, so we need to slow down a little bit, go back, re-practice, work this out a little bit more." (Exit Task Interview)

Knowledge of the dimensions of science to assess. In the case of heritable variation, specifically relating to the use of Punnett squares, Alice intended to evaluate students' ability to use them properly, that is, to use them to determine ratios and probability.

Knowledge of methods of assessment. Alice wove both formal and informal strategies for assessment into her lesson plans. In both cases, she used them (formal and informal strategies) to guide her instruction. When it comes to informal assessment Alice stated: "… and I'd walk around and kind of listen and hear some things and then use the things that they learned about their family to lead us in, kind of to the next day, or into the actual lesson" (Exit Task Interview).

Factors influencing Alice's knowledge of students and assessment. The most significant influence in the development of Alice's knowledge for teaching was her internship, as she herself admitted: "I think my internships helped more so that any of my classes." (Exit Task Interview). However a variety of factors within this internship played a significant role in this: She worked with honors students in her first year as an intern, she had a very experienced mentor teacher, and she continued to work at the same school throughout her second year in the program.

Entry vs. exit tasks

Alice's views about students as learners showed remarkable consistency with a few modifications: She continued to believe that students learn as their teachers provide them with correct knowledge. Alice also believed that prior knowledge, when it existed, was important insofar as the teacher provided the student with the correct connections to construct new knowledge. However, for the most part, she believed that prerequisite prior knowledge was provided to students in previous courses and that existing knowledge was unlikely to be scientific or accurate. From the beginning to the end of the project, Alice believed the major obstacle in learning is derived from the complexity of the issue based on either its terminology, abstract nature or complexity of mathematical concepts that might be involved. While at a point, she showed awareness of misconceptions and their role in learning, these had become an afterthought as she believed they could easily be addressed by providing students with correct information.

As far as her knowledge of assessment was concerned, she ended the program with a more structured view of assessment, where informal and formal assessments have roles based on the nature of the information. She determined that formal assessments are primarily used in a summative manner, especially when related to overarching school goals, specifically state testing. However, she was willing to use alternate products by students as long as the topic was not related to the standards. Informal assessment, be it questioning or observing, was used primarily in a summative manner but focused on the achievement of learning goals, with intent to re-teach if not achieved. The emphasis then was not as much on her ability to use assessment after the fact but was based more on the learning process as it took place during her class activities.

Third Semester as Full Time Teacher

Alice continues to work at Avery as a full time teacher very much in the same role as she had had the previous year. This topic of concern in this section is active and passive transport.

Knowledge of learners. While she tried to maintain students' roles as active learners in the classroom setting, at times Alice still viewed students as passive learners; hence, she considered herself to be "…making make sense for the kids that, you know, has, this is the objective of what we are going to do today…" (Pre-observation Interview). Moreover Alice believed that exchanging views about the explanation she provided allowed students to better comprehend it and allowed them to come up with answers on their own:

> I'll have them try to fill in the chart by themselves first, [by telling them] 'Work with you neighbor, try to figure it out.' Then I'll have them actually look at it, [asking them]

'What it's supposed to look like?' and let them change their answers. Then, I'll show more active transport simulations. (Pre-observation Interview)

Knowledge of requirements for learning. No clear data was available to determine her views on prerequisite knowledge for this particular topic.

Knowledge of student difficulties. At this point in the investigation, Alice showed topic-specific PCK by stating the exact content she expected students to have difficulty with rather than just generic aspects. When working with her students on the notion of passive transport, Alice identified the notion of net movement as an area students were having difficulty with. When asked about that instance in class, she said: "She [the student] just didn't know how to use net movement and random molecular collisions in that process." (Stimulated recall interview). However, it is still primarily focused on abstract/microscopic components of the content.

Knowledge of assessment. Alice used informal assessment to gauge student comprehension in class. Formal assessment of the lab work was part of the common assessment as defined by the school program, which she described as a choice – not a directive: "We decided as a PLT what we're going to do this year" (Pre-observation interview). Thus her views of assessment are guided by both her need to gauge student learning and institutional guidelines for accountability.

Knowledge of the dimensions of science to assess. Given the experimental nature of the class, formal assessment focused on experimental skills that were the focus of the assessment and a common link to all sections:

> … experimental design [is] our common assessment; they are all experimental design, and [in] the ACT everything is experimental design, so this, this idea of, you know,

> moving them [individual students] up based on their abilities [was accepted] instead of moving the whole class up. (Pre-observation interview)

Knowledge of methods of assessment. Alice used informal assessment of student conversations and interaction as well as questioning in a formative manner. She says: "… just walking around making sure they know what they are doing". In addition to this, given the experimental nature of the lesson, she used a common assessment too; the Mastery Tool, to assess experimental skills that the students were developing.

The Development of Alice's Knowledge of Learners

Alice showed an initial profile regarding students as learners that was based on the following notions (assumed to be true by Alice):

Students as passive learners: Students are passive learners and knowledge is provided by the instructor who tries to make connections to students' personal experiences. Both curiosity and the opportunity to relate content to the students' own experiences improves student learning.

Students may have observations but not explanations of natural phenomena: Alice believed that students are blank slates when it comes to scientific knowledge.

Relating content to student reality improves student learning. Most student difficulties arise from dealing with abstract notions that cannot be visualized easily because: of either the microscopic nature of the content or the generalization beyond their experiences.

As Alice one moved through the program she adapted (or changed) these views of students based on the knowledge she acquired from her experiences both in class and as an intern. These changes are summarized in Tables 11 and 12. These initial concepts (referred to above as notions) changed as follows:

Students as passive learners: At the end of the first summer in the program, when reflecting on her plan, she realized that it was quite teacher-centered; however, the modifications she suggested still made her students passive participants in the learning process. Throughout her first year and her experience in the internship as well as exposure to methods and courses, she struggled with the notion of keeping students active in class and in their learning. She compared the 5E model which tends to be highly student-centered to the approach she and her mentor teacher used arguing that there were some differences, and that these came from the lack of time needed to carry out a complete 5E cycle; hence, her context provided information that, she argued, conflicted with the ideas proposed in ASTEP. In her first year as a teacher, being responsible for her own class, which was a CWC rather than an honors class, she had to work with students as passive learners. Her views of students as passive learners as well as her lecturing and providing notes with in-class repetition to achieve her educational goals were evident at this stage. However, her views of students being active in class did resurface both in the exit task and in the observation of her first class as a teacher after completing the program. This suggests that, while her methods courses might have successfully exposed her to a variety of pedagogical views that included a student-centered approach and inquiry, the reality of her class as a teacher presented her with a situation in which she believed the principles were inapplicable, and she resorted to the only experience she had known to 'work'; her experience as a student. This suggests that both notions (students as active learners and students as passive learners) co-existed in her schema on students as learners, however, the preference that we observed was dependent on the situation she was working with.

Students have observations but not explanations of natural phenomena and no scientific knowledge. This notion relates to prerequisite knowledge and misconceptions. As she moved through the program, Alice brought in the notion of misconceptions as part of her understanding of student prior knowledge, incorporating it as ‘wrong knowledge’ that needs to be corrected by her as a teacher. As she experienced teaching a sequence of courses throughout the first two years, she made more connections that allowed her to be aware of prerequisite knowledge for the topics to be taught, but she did not necessarily transpose that prerequisite knowledge to the grade she was teaching. . Nevertheless even at that end of the investigation she still believed students came in with little prior scientific knowledge unless it was a topic like genetic engineering that had significant media coverage. Moreover the assessment of misconceptions become conspicuously absent in the later stages of the investigation, even in the Exit task interview suggesting the role of prior knowledge in learning was not coherent and was thus excluded from her knowledge of learning.

Relating content to student reality improves student learning: This is a view that Alice held throughout the whole process, and it seemed to facilitate incorporating the notion of hands-on experience as another way students learn better. This resonated with her mentor teacher’s approach to teaching and was further reinforced by the activity-based components of her coursework. This also resonated with group-work (in lab groups or in pairs). This made the ‘talk to your neighbor’ approach one of the easiest for her to incorporate into her teaching as it allowed students to share points of view that might be closer to their reality and not necessarily exactly what the teacher had told them.

Table 11

Development of Alice's knowledge of students as learners prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Students as learners	Students learn by lecturing. Teacher provides knowledge/connections. Connections to real-life experiences lead to learning. Curiosity enhances learning.	Learning is improved by providing information in different ways (repetition). Students learn in different ways. Group work allows students to share ideas and see things differently. Curiosity enhances learning – Engaging.	Learning takes place when teacher provides correct knowledge and a connection to prior knowledge.	Students learn by lecturing and repetition. Group work important for sharing ideas, allows students to view content from another perspective. Lab work for focus/motivation/confirmation Motivation is important for learning Students learn better if they can relate it to their own experiences.
Prerequisites for learning	Students might have experiences but these are not related to science content.	Awareness of prior knowledge may help or hinder learning: Knowledge is built upon prior knowledge	Prior knowledge pre-requisite to learning: Students have little to no prior knowledge. Media/entertainment is a major source of misconceptions	Prior knowledge is a prerequisite to learning: Students have little to no prior knowledge. Misconceptions can hinder learning.
Difficulties in learning	Submicroscopical concepts that cannot be visualized will be difficult to teach because they represent concepts that extend beyond their every-day experiences.	Developmental difficulties - abstract and sub-microscopical Teacher simplifies processes. Misconceptions can hinder learning and must be addressed at the beginning by providing correct information.	Submicroscopical/abstract concepts that cannot be visualized will be difficult. Media-created misconceptions can be addressed by lecturing at the beginning.	Submicroscopical/abstract concepts that cannot be visualized might be difficult depending on motivation. Misconceptions exist and can be addressed by providing conflicting observations/information.

Table 12

Development of Alice's knowledge of student as learners post-ASTEP

	3rd Observation	4th Observation	Exit Task	5th Observation
Students as learners	Students learn by lecturing and repetition. Group work is important for sharing ideas; it allows students to view content from another perspective. Motivation is important for learning.	Students learn by lecturing and repetition. Group work is important for sharing ideas and allows students to view content from another perspective Motivation is important for learning.	Students learn by lecturing and repetition/practice. Connections to real-life experiences lead to learning. Teacher provides connections. Group work important for sharing ideas, allows students to view content from another perspective. Motivation is important for learning.	Students learn by lecturing and repetition/practice. Connections to real-life experiences lead to learning. Teacher provides connections. Group work important for sharing ideas, allows students to view content from another perspective.
Prerequisites for learning	Prior knowledge as a prerequisite to learning: Students have little to no prior knowledge. Misconceptions not considered.	Prior knowledge as a prerequisite to learning: Students have little to no prior knowledge though some prior knowledge comes from exposure to media	Prior knowledge as a pre-requisite to learning: New learning built upon prior knowledge. Students have little to no prior knowledge.	No clear view, seems to be similar to prior views
Difficulties in learning	Complex terminology and abstract words: Submicroscopical concepts that cannot be visualized will be difficult to teach because they are concepts that extend beyond their every day experiences.	She addresses misconceptions but explains their persistent nature to moral rather than cognitive reasons	Mathematical components & calculations	Complex terminology and abstract words: Submicroscopical concepts that cannot be visualized will be difficult to teach because they are concepts that extend beyond their every-day experiences

The Development of Alice's Knowledge of Assessment

The data collected during the initial collection phase indicated that Alice possessed no structured view on assessment. Moreover she included no explicit form of assessment in her lesson plan. Her knowledge of assessment at this stage was elicited through questioning during the Entry Task Interview where she considered using informal questioning of students albeit with no specific purpose in mind other than to figure out if 'they were getting it'. Her initial views of assessment, with regards to the components in Knowledge of Assessment in the PCK model are summarized as follows:

No structured view of assessment: Alice does not consider formal or informal approaches as part of lesson planning.

Methods of assessment: Given that she plans no assessment, her initial knowledge of assessment methods could not be determined except for her consideration of informal questioning of students to gauge their understanding.

Dimensions to assess. As no plans for assessment were made, it was not possible to determine what dimensions Alice would have considered if she had included assessing in the initial data collection task.

Throughout the process Alice's knowledge of assessment was influenced by both her experiences as an intern/teacher and her coursework. These changes are summarized in Tables 13 and 14. At the end of her summer courses, Alice showed a structured view of assessment that clearly distinguished formal and informal assessment, and this aspect became more and more consistent throughout the process. She considered using both methods to assess student learning. She considered using student products as part of her assessment strategies and, upon being questioned; she considered the use of informal assessment. However her views of assessment showed a clear distinction in terms of the goals of assessment. Alice's use of formal methods focused primarily on summative assessment or diagnostic assessment (focusing on prior knowledge) while she considered using informal assessment for formative purposes.

As far as dimensions to assess are concerned, after her first methods courses, Alice showed an initial focus on prior knowledge, including misconceptions. This focus disappeared as soon as she started her internship reappearing only briefly during her second semester as an intern at the time she was taking her third methods course. This suggests that the assessment of this aspect of student knowledge was inconsistent with her views of what must be assessed. On the other hand, she became increasingly aware of the need to assess learning goals that were consistent with institutional objectives, especially those related to state testing. This focus on external testing seemed to be driven by the school's expectations where she worked. The specific aspects she sought to address were related to state level expectations related to repetitive tasks and specific content/vocabulary.

Beatrice's Case

Background Information

Beatrice was also a white, non-Hispanic, female. Her bachelor's degree was in biology. She met all the academic requirements for A-STEP and signed up for dual certification in middle school and high school science and was, of the cases selected, the only one to complete the internship requirements for said certifications. For her prior experience with K-12 student, she highlighted her experience as a counselor as well as church youth group leader. During the first internship of her coursework she interned at in Bellamy Middle School, moving to Carson

Table 13

Development of Alice's knowledge of assessment prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Views of Assessment	No structured view of assessment Uses questioning as a way to gauge student progress and "find a nice, medium pace"	Distinguishes between formal (test/quizzes) and informal (observation/questioning) Most assessment is summative and provides feedback at the end of the learning process. Considers informal assessment for formative purposes	Formal summative assessment (tests) Informal assessment to gauge student learning and inform instruction	Formal summative assessment (tests) Informal assessment to gauge student learning and inform instruction
Dimensions to Assess	Learning of content as it takes place	Prior knowledge including misconceptions (related to terminology)	Learning process goals (summative) Conspicuous absence of prior knowledge assessment including misconceptions	Learning goals (summative) Prerequisite prior knowledge Laboratory skills
Methods of Assessment	Informal questioning is part of teaching approach but not considered assessment; uses it to 'engage' students	Formal assessment via test/quizzes Informal assessment via observation/questioning	Formal assessment via test/quizzes Informal assessment via observation/questioning	Formal assessment via tests/quizzes Considers using lab reports Informal assessment via observation/questioning

Table 14

Development of Alice's knowledge of assessment post-ASTEP

	3rd Observation	4th Observation	Exit Task	5th Observation
Views of Assessment	Formal summative assessment (tests) Informal assessment to gauge student learning and inform instruction Assessment as a form of review Assessment informs re-teaching Assessment for accountability	Formal summative assessments would also provide feedback to inform her future teaching. Student peer-assessment as a form of reviewing	Informal, formative assessment used to inform instruction as learning takes place	Informal, formative assessment used to inform of students' existing lab skills in order to address shortcomings
Dimensions to Assess	Learning goals (summative) Prerequisite prior knowledge	Analytical skills using science content	Ability to carry out calculations to find numerical answers	Lab skills
Methods of Assessment	Formal assessment via test Tests for accountability Informal assessment via observation/questioning	Formal, alternative assessment, used summatively (no test) Informal assessment via observation and questioning	Formal, alternate, assessment (student work) used formatively Informal assessment used formatively	Informal assessment (observations of students) Formal assessment used summatively

High School in the second semester to complete the requirements for her dual certification. Upon completing her ASTEP coursework she worked for a year at Bellamy Middle School before being hired by a private Catholic school, Denisson.

Beginning the ACP

At the beginning of the ACP, Beatrice carried out a three-step process designed to collect data over her views and understanding of science teaching. In step one, she designed a lesson sequence to teach the topic of heritable variation to eighth grade students. In step 2, she was interviewed, using the information from the lesson plan to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. At the beginning of her program Beatrice believes that students have no knowledge of the content to be taught by her. She relates the topic to her recent experiences as a college student and states:

> Like the stuff I thought was really interesting and being that I have worked in the genetics lab for the last three years was really kind of hard for me to try to dumb it down a little bit, to remember that these kids don’t know this stuff and you really have to start from the beginning. (Entry Task Interview)

Beatrice believed student motivation to be important in student learning. She planned to use analogies to help illustrate scientific processes. In the case of mutations as a source of variation, her analogies illustrated how the meaning of a sentence, which could be of common use by students, can change as words are changed. Her example was as follows:

> I thought it would be really a lot easier for the kids to understand this if you looked at it in terms of a sentence; so, I made this little simple sentence that just says: “I like milk

> chocolate" and that's our original DNA. And then, when part of it is deleted, it says "I milk chocolate" so you can see how if something is deleted, it doesn't code the same, it doesn't read the same, it doesn't make sense. (Entry Task Interview)

For Beatrice, motivation was necessary because she believed that "… sometimes science can get bogged down in facts and we forget to make it fun, because science is fun." (Entry Task Interview). Moreover she believed that students would learn by being told the facts that are represented in the analogies she provided.

Knowledge of requirements for learning. Beatrice showed awareness of foundational topics necessary to teach the content to be delivered. In the specific case of heritable variation, she would have expected the students to know about cell biology, including cell cycle, before addressing heritable variation. She elaborates:

> Well, I think you'd first have to learn about cells, and types of cells and the components of cells, and then I think it might be good to go into mitosis and meiosis and then build on that with something like that. (Entry Task Interview)

However, she believed that learning is also facilitated by making students interact among themselves in groups and by challenging them to think critically about an issue. When she was discussing with her peers a scene presented in the video analysis task, she highlighted her point by stating: "I thought it was great how the students were working in small groups - that allowed them to bounce ideas off of one another and really critically attack the problem." (Video Analysis Task)

Knowledge of student difficulties. Beatrice believed that, as long as she made the topic fun, student difficulties in learning the topic would be minimal. She foresaw few, if any, difficulties with teaching the content of the lesson. However, after elaborating on the importance of ‘making science fun’ she dismissed the possibility of her students hving significant problems when addressing with the concepts she intended to teach. As Beatrice explained when asked if she expected her students to have any difficulties:

> Some of them [student] (you know there are always those one or two that will kind of surprise you) . . ., 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. (Entry Task Interview)

Knowledge of assessment. Beatrice’s assigned 2-day lesson plan did not address assessment of student learning. However when asked about gauging student learning she took an informal, formative approach, which emphasized interacting with students through conversation or even questioning. She states: “... maybe midway through the class ... , it might be nice to ask [the students] questions and make sure it’s not the same person always raising their hand” (Entry Task Interview).

Knowledge of the dimensions of science to assess. Rather than aim at specific content or skill areas that students might have or might be learning, Beatrice argues for a more general interaction with students that seeks to get students involved while gauging their learning. When asked how she would know students are learning, Beatrice states that if she asks questions to the group as a whole “making sure that lots of students are raising their hands, there is lots of feedback that they are comprehending.”(Entry task interview).

Knowledge of methods of assessment. While acknowledging the possibility of using a formal written method of assessment, such as a quiz, Beatrice said she prefers to engage students informally as a group with questions. When asked what methods of assessment she would employ she states: “I think it wouldn’t necessarily have to be something like a quiz or anything little, just like asking questions to the class as whole …” (Entry Task Interview).

Factors influencing Beatrice’s knowledge of students and assessment. As far as the sources she used to guide students, Beatrice acknowledged that her experience in the genetics lab she worked in was a primary source. However she also acknowledged that this experience, given the advanced nature of the content, sometimes hindered her ability to apply it to the content of the eighth grade class.

> I’ve done a lot of, like, teaching in our lab I was in charge of all the student workers so I’d teach them how to genetically modify things, but I mean, that’s still really different from this. So, and that was college undergraduate and not middle school. So I think my experience has been at a higher level and sometimes it’s hard to take those couple steps back. (Entry Task Interview)

However her view on students’ interactions among themselves and the need to keep them engaged drew upon her experience as a college student and as a camp counselor. In the first case, regarding the prevalence of lectures in experiences she states: “I would say probably especially in college where they just lecture the whole time and people are falling asleep around you.” (Entry Task Interview). In regard to her experience as camp counselor, she claimed: “… I’ve worked a lot with middle schoolers at my church and they generally don’t do well when they’re just sitting” (Entry Task Interview).

End of Summer

At the end of the first summer in the ACP, Beatrice had completed courses in Educational Psychology and Secondary Science Methods. She was then asked to reflect her initial lesson plan.

Knowledge of learners. Beatrice highlighted the importance of students making connections themselves as an important part of their learning. She sees this as the foundation of inquiry, which she equates to discovery learning. When asked to elaborate on science as inquiry she asserted:

> It's mostly like the kids discovering things for themselves. So, like, when they make these discoveries themselves, and when they make these connections, they're more likely to stick, to stick with them and it's more likely that they'll replace their previous thoughts as to how and why things work. (End of Summer Interview)

However such a view of the importance of inquiry is not universal, as she has difficulty applying this concept to more concrete content, such as Mendelian genetics and inheritance patterns. The specific case of the use of Punnett squares is addressed by her during the interview as she describes her approach to the second day of teaching. Her response suggests that concrete content might be harder to teach with her view of inquiry. Her response to questions on teaching Mendelian genetics was: "… I don't really know how you could do that through inquiry." (End of Summer Interview). She does, however, acknowledge that it might be possible that students might have no prior knowledge of the topic and, should she determine that this is the case, then she would have to "Start from scratch" (End of Summer Interview).

Knowledge of requirements for learning. As far as the topic is concerned, Beatrice believes that students should understand mutation in order to be able to work on the notion of inheritance and thereby develop an understanding of heritable variation as a mechanism that illustrates how these mutations are inherited. She made the connection explicit when asked to reflect on the overall structure of her plan. She asserted: "So then on the second day, I thought we could move on beyond mutations to how they are passed on … like recombination of genes and then I thought we could go on to Mendel's pea plants" (End of Summer Interview). However, she also acknowledged that it was possible that students might have no understanding of this content given its more complex and abstract nature.

When discussing student learning, Beatrice builds on her personal belief about the importance of group work based on her experience in summer courses, highlighting the importance of this in student learning. She presents a clearer view of her beliefs regarding the advantages of group work, allowing her to get more engagement on the part of students as well as make her assessment of student progress easier. When elaborating on her use of group work in her plan she states:

> … when they are in smaller groups they can kind of brainstorm off each other … I don't have to be talking to the whole group and sometimes it is easier for me to move between groups than addressing the larger group. More people get like, a chance to talk and like, make [the assessment], that can be a little bit easier to go between groups and you have them working on other stuff as well. (End of Summer Interview)

Knowledge of student difficulties. The clearest notion related to student difficulties in learning that Beatrice discusses is the fact that students might have misconceptions. She refers to these misconceptions as a possible issue at the beginning of the topic that needs to be addressed so that students can learn the content that she intends to teach, as she states when discussing the use of informal questioning of students in the initial stages of her lesson plan; "… like, finding out what they know … hidden misconceptions they might have and, yeah, it's just kind of making sure everyone is on the same page" (End of Summer interview). However, her strategy on dealing with misconceptions shows she believes them to be easily changed. When asked about her choice of action regarding the misconceptions that might exist after her first lesson, Beatrice suggests she would "Probably write them down, like on the board so we could go back and reference them …" (End of Summer interview). Furthermore she suggests leaving the misconceptions on the board throughout the second lesson so she could "… go back and reference those answers and be like, 'who still thinks this?'" (End of Summer Interview).

Knowledge of assessment. The first modification that Beatrice brings forth when asked about changes in her lesson plan brings together parts of her summer courses with her inclination to use informal, formative assessments in class. She seeks to expand on the initial questioning session of her plan in order to determine, in depth, the understanding students have of the topic. She states: "I think I would probably keep that, maybe expand on those questions a little bit, because I thought that may be a good way to kind of do, like a group interview to see where all the kids are at."(End of Summer Interview). Furthermore, Beatrice refers to the use of questioning as a way to get students involved in the topic at hand, as she says "I might try to think of more probing questions … I think it, you know, puts kids in the mood to think about what we're doing and gets them involved in the lesson …" (End of Summer Interview). However she also considers the use of students' work as a way to gauge their progress

Knowledge of the dimensions of science to assess. Beatrice's beliefs concerning the dimensions that need to be assessed focus on two main themes: misconceptions and prerequisite knowledge. Beatrice addressed the assessment of misconceptions via informal methods such as questioning or interviewing students. When discussing the use of informal assessment of students she states: "It's just basically, like, finding out, like, what they know and . . . hidden misconceptions they might have …" (End of Summer Interview). She determined that it was effective to use "…more opening questions, like, to see what the kids already know or how they think things work." (End of Summer Interview). However, her statement regarding the content to be assessed was generic and explicitly linked to prerequisite knowledge.

Knowledge of methods of assessment. While still showing an inclination toward informal, formative assessments, Beatrice considered utilizing student work as formal assessment instruments. The clearest indication of this was her statement regarding the worksheet she intended to use in her initial planning which was an exercise designed to illustrate mutation using common language. She spontaneously states, reflecting on her initial design: "… instead of, like, having them do [the worksheet], maybe use something like this more as an assessment" (End of Summer Interview).

Factors influencing Beatrice's knowledge of students and assessment. When reflecting on her ideas on students, their learning and her assessment of learning, Beatrice focused on two factors that were the most influential in shaping her views at that point in time: her experiences as a student and her class work over the summer. When referring to her experiences as a student, Beatrice recalled highlights of what she defined as a 'boring' teacher: "… and he was just the most monotone person, like Ben Stein in *Ferris Bueller* (1986, movie, i.e., *Ferris Bueller's Day Off*). And he would just talk and talk and everybody would be falling asleep …" (End of Summer Interview). She also established a connection between her coursework, which addressed the use of group work in teaching, and her beliefs about student learning, reinforcing her belief about the importance of group work. She makes this connection explicit when reflecting about the changes she would consider in her original lesson plan:

> Well, the first class, we learned, like I've always been a big fan of group learning, but I guess we kind of learned about why that works and how, like, cooperative learning and

> stuff can place. So I'd like to have some more group work in there, which is a really good way. (End of Summer Interview)

Beatrice also referred to the influence of her summer coursework and how it affected her views of assessment. She not only discussed the use of informal approaches to assessing student learning and misconceptions but she also referred to the use of student products, via projects or presentations, as a way to gauge student learning. She used as an example a written task, which was part of a class project, as a way to formally gauge student learning. When asked to elaborate on this view of formal assessment, Beatrice recalled the experience from her summer course:

> … we did this whole parachute experiment to study, like, physics and stuff, so we did, we designed experiments in our groups to test for different ways, like different things that could affect the parachute, like the size of the chute or the weight of the payload, and the length of the strings and, you know, all sorts of stuff. And then at the end, we had to present to the class our findings and then she provided us with a letter from the toy company that was like, oh, this toy isn't working and we don't know why and we had to use everything that we'd learn to like, write back to the president of the company and be like, well, we're going to test this and this and see how this works. So it was a way of, it wasn't a test, but I mean, it was a way of like, applying our learning in a more formal way. (End of Summer Interview)

First Semester Internship

During her first fall semester in the program, Beatrice took the Secondary Science Methods II course while teaching sixth grade science in Bellamy Middle School. Beatrice's lessons were based on the National Science Standards, content Standard D. The focus was on water and the water cycle. She related this to State Grade Level Expectations in the topic of the water cycle and weather. The plan started with demonstrations of evaporation and condensation and concluded with a group activity that led to the production of a poster of the water cycle. It was her intention to use the principles of cycling water as it related to weather as an introduction to the carbon cycle.

Knowledge of learners. Beatrice showed a concern about the need to keep students engaged in order for them to focus on the task at hand. However, her belief about how this engagement works did not focus on the content being taught as much as on keeping the students active in some form or another. When discussing her lesson plan, as well as possible alternatives to it, Beatrice recalled: “Because if they are falling asleep, I make them get up and run in place so they will wake up” (First Stimulated Recall Interview). Moreover, when considering the engagement activities provided in the text book she stated: “Their textbook will have little engage things to do but usually they’re kind of dumb. They’re not really hands-on …:” (Pre-observation interview).

Regarding the ability level of her students, Beatrice stated that her class she had showed a mix of skills, and she claimed that most of her students were particularly good. She highlighted not only their inquisitiveness but also their ability to work hands-on. When asked to describe them, she elaborated: “They are really, really bright class, … so they’re really inquisitive and they remember a lot, and they generally ask really good questions and they like doing hands-on stuff” (Pre-observation Interview). Her use of quizzes and emphasis on reviewing content at the beginning of class is evidence of her belief that students will learn certain content by repetition. When asked, after the first observation, to reflect on her plan for the next lesson, Beatrice stated: “Fourth hour will start probably review, just do like a verbal review of what run-off is, what ground water is, transpiration, and the different parts of the cycle" (First Stimulated Recall). Moreover, when asked to elaborate on her approach to "just keep coming back to [ecosystems]" (Second Stimulated Recall Interview), she replied "If we don't do that, they are not going to learn it" (Second Stimulated Recall Interview). However, Beatrice also claimed that establishing connections to their lives was also important: "[if you] provide examples that are really relevant to their lives, that makes it easier for them to remember" (First Stimulated Recall Interview).

Knowledge of requirements for learning. Beatrice believed in the importance of presenting the appropriate terminology to students, after the introductory activities, so that they could then address the group work part of her plans. However, when it came to specific prerequisite knowledge, she made no explicit connection, but rather established a vague connection to the previous topic addressed in class, which was ecology, specifically populations, ecosystems and food webs. When asked to establish related knowledge she stated: "We've just finished populations and ecosystems and stuff so it could kind of tie into that – like pollution can hurt one tiny part of the ecosystem, which in turn can affect lots of other, like it affects your food web" (Pre-observation Interview). As far as group work is concerned, Beatrice believes that, while important, it is probably not suited for all students. When asked to elaborate on her thoughts on the topic, Beatrice explained: "Every time you try to get them to work together or work in groups, it just falls apart, so there's a lot of individualized reading" (Pre-observation Interview). At this point, the school context provides her with an experience that challenges her beliefs on the role and importance of group work, while she still believed that motivation was important and that group work was a means of achieving motivation, her lack of success in accomplishing this makes her question the usefulness of group work as an approach to motivate students.

Knowledge of student difficulties. Abstract content knowledge that is removed from student reality is the first difficulty Beatrice focused on. She believed students would have difficulties with the processes related to plant physiology, specifically photosynthesis and transpiration. Regarding photosynthesis, as it relates to the carbon cycle, Beatrice elaborated "I'm really comfortable with the photosynthesis part and I plan on hitting that really hard because they are kind of confused when it comes to how plants make food and stuff" (Pre-observation Interview). She explains this perception based on education focused mostly around animal examples: "They know a lot about animals; that's a very biased system. They don't know how plants work" (Pre-observation Interview). During the lessons itself, Beatrice addressed the misconception that students thought rain water is created as new water, a notion that, while not a part of her initial planning, became apparent in her informal assessment of her previous classes; hence, she chose to address the issue directly during the lesson observed. When presented with a video clip that showed her asking students if water was created, Beatrice reflected:

> Well, a lot of them said yes and I think it was [because] they were thinking like when it rains, I don't know. That's new water and that's why I said created, because I think if I did that, then they would think, 'oh, no it's not being created because it just evaporated and everything. (First Stimulated Recall)

When asked to elaborate on her reasons for this approach, she replied:

> Second hour actually was like, 'but, when I drink water, how does it, it doesn't leave me.' And I was like, 'Oh when you drink, nothing comes out?' And they were all like,

> ‘Oh gross!’ And then I think they probably figured out that other people peed out their water before but … That was actually in second hour. But that was probably what they were thinking when they were really grossed out by the ocean and not by like other people drinking their water as much. (First Stimulated Recall)

Nevertheless, despite her awareness of these difficulties and misconceptions, Beatrice believed her students will have little difficulty in addressing the tasks in her plan. When asked to state any difficulties she expected her students to have, she stated:

> Not really, I think that they’re pretty much all on the level. I don’t know if they’ll like, look at the water in the bowl and be able to answer all the questions right away. But I think they’ll be able to be pretty close, like sometimes they just forget words or ideas and so. (Pre-observation Interview)

Knowledge of assessment. Formal external assessment, specifically external testing by the state, was a new factor in the thoughts that guided the planning of Beatrice’s lessons. She brought this thought forth as a concern of hers while she discussed the goals that guided her planning and as a result of her informal assessment of students’ prior knowledge; “I know from talking to the kids that they did start talking about the water cycle last year, so hopefully it will refresh their memories because it is on their (state test) test this year” (Pre-Observation Interview). In addition to this, when asked about how she would determine if students had learned what she set out as learning objectives, she highlights her frequent use of short quizzes. However, her view on the usefulness of this assessment is summative and oriented more toward student learning than formative assessment. When asked about why she would use short quizzes, Beatrice states:

> Because they forget stuff; they don't have very good attention spans. And, I mean, even if you do frequent review, they forget a lot of stuff. Especially like over the weekend, they seem to lose stuff so I like to quiz them a lot when they have it. (Pre-observation Interview)

However she still relied on informal, formative assessment to guide her instructional decisions in class. When asked to share her thoughts on a video clip that showed her recurrently approaching a small group of students working, Beatrice stated: "I just wanted to make sure. I kept coming back to them to make sure that they got it" (Second Stimulated Recall Interview).

Knowledge of the dimensions of science to assess. As before, Beatrice's views on the dimensions of science to assess centered around two ideas: misconceptions and prerequisites. Her informal assessment of students throughout the observation allowed her not only to determine misconceptions she knew might exist, like the case of photosynthesis, but also to determine other misconceptions she might have not been aware of. However, her formal assessment focused not only on the misconceptions but also on specific content of the topic at hand, with a specific focus on the content she knew was likely to be difficult or misunderstood. When asked to address the details of what she intended to assess at the end of the topic, Beatrice stated:

> It will probably be like is new water created? How old is the water? Tell me what precipitation is. You know, like how does this fit together? I'll probably make them draw a water cycle but not the whole thing that we learned because I don't know if they'll get transpiration. (Second Stimulated Recall Interview)

Knowledge of methods of assessment. When it came to assessment methods, Beatrice primarily used informal methods to assess students' pre-existing knowledge and progress. Aside from using informal questioning to assess student knowledge during the two days of the observation, Beatrice stated her intention was to not only use informal assessment by questioning students, but also to assess the products made by students during the activity. When talking about gauging student learning during the observation period she stated: “Well if we’re in the right place, hopefully their posters will reflect that with the different information.” (Pre-observation Interview). She further clarified this connection when reflecting on the events that transpired during the first observation, connecting her teaching strategy to her assessment of student learning. When asked whether or not she managed to achieve her goals, Beatrice replied: “I don’t really know, but it’ll be reinforced tomorrow with our group projects so hopefully then it’ll be a little bit more connected, but yeah” (First Stimulated Recall).

Factors influencing Beatrice’s knowledge of students and assessment. When it comes to her knowledge about students, Beatrice recalls the influence of her coursework, specifically the video series *A Private Universe* in developing her understanding of student misconceptions. She makes this connection explicit when she reflects on her intention to take students outside. She recalls:

> And then, you know that video series that (Professor Harris) shows us, that private universe? So I wanted them to like, look at the tree and realize that this came from the air, this is where all the carbon comes from. (Pre-observation Interview)

Moreover, when it came to her students’ learning Beatrice’s experience with these students led her to believe that her students learned more effectively by actively addressing the vocabulary presented to them by acting it out or through hands-on activities. When addressing her students’ learning Beatrice claimed: “I found that when they act out their vocabulary, that works really well … they tend to like the more hands-on things like making collages. This organism thing that we did today, they're usually pretty good about that." (Pre-observation Interview). In addition to this, Beatrice argued that her experience with students led her to believe that, as much as she liked group work, it was an approach that might not always work and that some students are likely to work better on their own. When asked to clarify her views on this, she elaborated: "I have always been a big fan of group work. I love group work. But there are some people who can't handle; they get really distracted or can't focus. They're better by themselves" (Pre-observation Interview). Furthermore, her interaction with students led Beatrice to believe that she must first get students engaged before introducing new terminology. When asked about her idea to start with a demonstration as opposed to vocabulary, Beatrice explained:

> Well, once they start doing vocabulary, they kind of tune out, so that's when we have to take our brain breaks so if you get them thinking first, it's a little bit easier to make connections from the vocabulary bank. And I think that's why acting out the vocabulary or doing little skits for it works better because they get to talk more and move around more. (Pre-observation Interview)

At this point in time, Beatrice's views on assessment are based off her experience as a student rather than her coursework or teaching. When asked about the source of her assessment strategies, Beatrice replied: "I haven't really learned about quizzes and hopefully the ones I make are ok. I don't really know, maybe next semester I'll learn about assessment" (Pre-observation Interview).

Second Semester Internship

During her spring semester in the program, Beatrice enrolled in the Secondary Science Methods III course while teaching 10th grade general biology at Carson High School. This school is part of a state-based program designed to improve teaching and learning using technology and network-based resources. Each student is assigned a laptop and Beatrice's plans included a supplemental one-sheet document given to each student by the school to help with the network-based instruction. This sheet not only included the instructions but also links to web-based resources. The plans did not relate to specific content from either National or State standards as they were according to Beatrice: "finished with the curriculum and so we're doing this bacterial unit" (Pre-observation Interview).

Knowledge of learners. Beatrice established clear differences between high school students as opposed to middle school students in terms of the best teaching approaches. She claimed that hands-on activities work better with middle school students, whereas high school students are more capable of focusing on note taking. When discussing the difference between both groups, Beatrice based her analysis on her experience as a middle school teacher:

> In middle school it was based on my learning and much more shallow. You could focus on an idea, but it's not like you could give them notes multiple days in a row … They would definitely lose their notes or they wouldn't take their notes. You had to be much more (project oriented) and hands on. (Pre-observation Interview)

Beatrice believed that students would learn better if engaged in class, she suggested that the use of computers in class could help this, given that "… kids love to use computers" (First Stimulated Recall Interview). However, Beatrice was also aware they can easily become a source of distraction and hinder progress as she continued to explain: "… they have a tendency to get distracted by E-Bay and Google searching things that they shouldn't be and finding distractions" (First Stimulated Recall Interview).

Knowledge of requirements for learning. Beatrice showed an awareness of prerequisite knowledge related to topics addressed previously by the class. While discussing the lesson plans, Beatrice emphasized the importance of students having an understanding of the basics of cell Biology when discussing her surprise at their lack of basic knowledge regarding cells: "I really thought as sophomores in high school that they would have encountered this before, especially since they studied cells in the beginning of the year" (Pre-observation Interview).

Knowledge of student difficulties. When questioned directly, Beatrice foresaw no major difficulty with the content itself and was more concerned with the possibility of problems arising from technological issues than from students themselves having trouble with the topic at hand.

> I think that finding the information for the harmful and helpful won't be so much of a problem as long as I guide them and make sure that I clearly define what I want. The next day when they compile their information, I sense there will be some melt downs. First of all, our computers are Macs and this is the first year that the kids have had to use the Macs. (Pre-observation Interview)

However, Beatrice also made the case for the aspects related to genetics as something abstract that the students would have difficulty addressing; hence, she expressed her intention to address the topic superficially and further elaborated upon being asked about her approach to this subject:

> I tried to stay away from the genetics and stuff. We talked about how they have a round chromosome and they have plasmids, but then I tried to stay away from that. I tried to keep it a little bit more surfaced when it comes to the genetics of it. Maybe we can touch

into that a little bit deeper when we talk about the antibiotic resistance. I didn't want them to get bogged down in terms quite yet. (Pre-observation Interview)

Knowledge of assessment. Beatrice's knowledge of assessment focused on three aspects:

- Formal and informal assessment for pre-existing knowledge, which guided her lesson planning.
- Formal and informal assessment of learning in class, which further guided her instructional decision making.
- Awareness of state tests content, which both guided instructional decision making and set her expectations for student knowledge.

Beatrice makes constant use of both formal and informal assessment in a formative manner. She bases both her planning and instructional decision making on the results of this assessment. She consistently reflects on this throughout the observation process and even adapts her teaching planning as she goes. When reflecting on her plans, Beatrice shared: "I was actually planning on it being more individual until the end and then based on their questions yesterday; I could tell that they weren't all getting it" (Pre-observation Interview).

Her planning and expectations of students were influenced by the State testing process. When discussing her plans and relationship to other topics, Beatrice explained:

> We didn't really have time then because we were trying to cover it before the (State) tests to really go in depth. I think when we talk about that I think that they will remember all of the evolution stuff because they really seemed to like that unit. (Pre-observation Interview)

Knowledge of the dimensions of science to assess. When it came to assessment of student knowledge, the aspects that were prioritized by Beatrice focused on content knowledge related to the topic. In the case of her initial assessment of the students, she queried them directly asking them write about the topic at hand. She did this regularly. When sharing her experience with the previous topic, she recalled: "Before I taught the evolution unit, I had asked them a set of questions like, 'what is everything you know about evolution?' " (Pre-observation Interview). Furthermore, when assessing student learning during the observations, correct understanding of content was important. When discussing the use of presentations as part of her assessment, she focused on one specific case and explained her reasoning in detail as follows:

> She [the student] had learned a helpful use for bacteria and kind of the raw material meets the bacteria and results in the new end product. She had a picture so I could tell that she learned the shape. I think it said something like, 'I, lacto-basils, rod shaped warrior, will defeat the evil milk!' There is a lot of information packed into her little thought bubbles. She said something about how it was located in the digestive tract or it could help out the digestive tract [because] they had to have a location, and that was there, too, so I could tell that she learned that as well. (Second Stimulated Recall Interview)

Knowledge of methods of assessment. Beatrice based her instructional decision making on an informal assessment of her students via questioning and interacting with them as they carried out their work. Her use of this informal assessment was formative and the results were used to modify her teaching. When discussing her lesson plans for the observation, Beatrice stated: "I was actually planning on it being more individual until the end, and then, based on their questions yesterday, I could tell that they weren't all getting it" (Pre-observation Interview).

Beatrice made use of formal, written assessments on her students to assess both prior knowledge and gauge learning. When discussing her lesson plans, Beatrice explained her rationale for her choice of teaching approach based on her students' responses to her activity the day before. Beatrice summarized the reasons for her decision as follows:

> One of the things that you had to do first was write down everything you know about bacteria. I was really surprised by how little they knew. Obviously they knew it will make you sick and it can make you sick, but there wasn't much after that. (Pre-observation Interview)

Factors influencing Beatrice's knowledge of students and assessment. In the case of Beatrice's second semester internship her school played an important role in the shaping of her knowledge of students and assessment. She was placed in a school that participated in a stated initiative to improve learning with the use of web-based resources. Moreover, it presented a strong emphasis on the use of inquiry, based on the 5-E approach. This influenced her planning and, to a certain extent, her belief on student learning. As far as her planning was concerned, Beatrice acknowledged the importance of the school philosophy in this when discussing her teaching approach for the lessons observed; hence, her explanation:"Yes, my school is an [Enhanced State Program] school, so they really try to stress the use of the computers and using them to find answers" (Pre-observation Interview).

Web-based resources. Given the nature of the school, Beatrice designed and carried out her class using a variety of web-based activities including the use of WebQuest. Nevertheless these activities, while they did provide an outline for her lesson planning, they did not influence her beliefs about students or assessment. The clearest evidence of this was connected to the fact that the rubric was provided in her lesson plan. This rubric focused on student research skills, specifically on their ability to successfully complete the task at hand, which was a PowerPoint presentation. The rubric focused on three specific criteria: creativity in the presentation of information, detail of the information and participation. However, throughout her interviews—she did not focus on any of these aspects, except for behavior issues in participation

On the other hand her use of specific WebQuest formats and resources shaped the way she approached her assessment of pre-existing knowledge. As part of assessing pre-existing knowledge at the beginning of a topic, Beatrice made reference to using written assignments to gauge pre-existing knowledge based on students. This approach was based on asking the students the question: "What is everything you know about [topic]?" (Pre-observation interview). She was more intent on determining if students had the correct pre-existing knowledge without consideration of potential misconceptions.

Her mentor teacher, Mr Dalmaud provided a strong influence in Beatrice's development. Beatrice felt comfortable with the freedom provided by her mentor teacher. Her mentor would allow her to carry out her plans while providing feedback to her afterwards. Beatrice confirmed this by saying: "Mr. Dalmaud just let me do it. We hadn't talked about anything, but he let me do my thing and then he gave me input" (Pre-observation Interview). However the interview with Mr. Dalmaud pointed to his influence on her use of the State test as a guideline to lesson sequencing and overall planning. Mr. Dalmaud made this influence explicit during his interview. When describing the ways in which he helped her, he explained:

> We sat down at the very beginning and looked at the curriculum and the goals that we needed to cover in the particular classes and where we wanted to be as far as (State) testing and what the kids needed. (Mentor Teacher Interview)

First Semester as Full Time Teacher

After completing her coursework over the summer, which focused on integrating the teaching of Science and Mathematics as well as completing her Action Research Project and Portfolio, Beatrice accepted a job at Bellamy middle school teaching seventh grade science. The lessons observed focused on experimental design, including working on a hypothesis and identifying dependent, independent, and controlled variables. The topic to be addressed was thermal conduction, and it was designed primarily as a practical activity. Students were provided with an instruction sheet and guiding questions as well as a data table to be filled in with data obtained during the activity. The goals of the class were based off the Common Core State standards. Her mentor at the school is the teacher across the hall and they share one lab among six science teachers.

Knowledge of learners. As far as students learning science, Beatrice stated that she believed that the best way to get her students to learn science is to provide them as much hands-on time as possible. Given the nature of the group to be observed, she believed that they also learned by discussion in class.

> They are very chatty, so we do a lot of discussion and a lot of talking and I try to do as much hands on stuff for them as possible … They do the best with demonstrations and not fooling around during them. (Pre-Observation Interview)

However Beatrice believed that when it came to teaching the conduction of heat, students have no explanations for certain phenomena they have experienced and as such she must provide explanations from scratch. She also believed that repeating the concept again in a lesson on a different topic will help them learn it better. When discussing students' experiences with conduction, she stated regarding the explanations they might have: "They had no explanation for it. We talked about conductors and insulators and conducting or transferring heat well. I stressed that pretty heavily because it comes up again with electricity" (Pre-observation Interview). She believed the explanations she provides are better understood by students if she provides them with an observable phenomenon to relate to as opposed to simply giving them the explanation. Beatrice reflected on this:"It is a lot easier for them to understand it if they see it, and I'm not just telling it to them, and then they are writing it down. They seem to internalize it a lot better" (Pre-observation Interview).

Knowledge of requirements for learning. Beatrice believed student learning occurs when the terminology is explained to them before exposing them to observable phenomena. When discussing possible prior knowledge students might have regarding the topic, Beatrice referred to the lessons that preceded the one that was observed; however, she clarified that it had taken place before a holiday and thus they might not remember it all. When designing her lesson plans, Beatrice also pointed out that repeating the content was likely to help them recall the information. When reflecting about expected prior knowledge, she elaborated:

> They know that there is this thing called specific heat. I don't know since it was just Thanksgiving, they seem a little rusty. We reviewed some stuff today, but I think that they will still be like, "what," tomorrow. They will know that there is specific heat, but they won't really remember what it is supposed to be. They know that certain metals conduct heat really well and other things, like fabric and plastic, don't. They know the

> insulator and conductor bit pretty well. I'm hoping that what we did today will have sparked more brain cells. (Pre-observation Interview)

While she elaborated on the importance of prior knowledge, both skills and content knowledge, not once did Beatrice refer to misconceptions and their role in student learning.

Knowledge of student difficulties. The first aspect Beatrice viewed as a difficulty, which students would be most likely to have, is the graphing of data, despite the fact that graphing was a skill they had addressed in mathematics. She elaborated on their graphing skills as follows:

> They had a lot of trouble with that and we have graphed a few other things during that practice, and they are just really bad at graphing. They did already learn that this year in math class, so I would think that they would not have so much trouble with it, but they do. (Pre-observation Interview)

However, as far as students working with the concepts to be addressed in class, Beatrice believed students would have no difficulties addressing the tasks on the worksheet, given that she planned on providing them with the explanations in the beginning. When asked how she would address student difficulties: "After we have talked about it as a group, I don't foresee that everybody will have a problem" (Pre-observation Interview).

Knowledge of assessment. Beatrice approached student assessment from multiple perspectives; she uses quizzes, student worksheets and tests as formal approaches. She clearly distinguished evaluation, perceived as awarding a summative grade, to assessment of their learning in formative fashion, at times using the same instrument to serve both purposes. In the lesson observed, the lab packet she gave the students served such a purpose. Beatrice intended it that way and made it explicit in her planning. She stated when asked about assessing learning:

“I will be walking around talking to them and seeing what they are doing: When they turn in the lab packet, they will be formally evaluated on their answers, and there are some follow up questions and stuff too” (Pre-observation interview).

Another aspect of assessment that was evident in Beatrice’s views is the importance of State tests. She referred to them in relationship to the State standards as guiding aspects of her planning. When explaining the importance of working on graphing, one of the areas she knew students would have difficulty with, Beatrice stated: “There is lots of graphing on the (State Test) and we are trying to integrate more (State Test) preparation into all facets of our teaching this year” (Second Stimulated Recall Interview).

Knowledge of the dimensions of science to assess. Her dimensions of assessment focused on two aspects, content and skills. Her informal and formal assessment of student understanding of experimental design, including formulating hypotheses and identifying variables, was highlighted in her use of the lab packets as her main assessment instrument. As far as skills were concerned, Beatrice focused on both data collection and data representation, specifically graphing, as the main dimensions of science to be assessed in this context, highlighting the importance of this skill because of the focus made by the State test. She clarifies this importance when discussing student difficulties stating: “. . .but [in] the (State Test), every chapter has a standardized test preparation section and it always includes graphing” (Pre-observation Interview).

Knowledge of methods of assessment. Beatrice used both formal and informal assessment of students to gauge their learning throughout the lesson. In this case, as stated previously, she takes advantage of the lab packet prepared for the activity to not only assist her in her informal assessment of student learning while the students work, but she also used it as a summative evaluation of their work. In addition to this, she used short quizzes and written tests. She combined multiple choice questions as well as short answer questions and application questions involving graphs. However, this structure followed mostly the state testing model as she clearly pointed out when elaborating on graphing and the test:

> We are trying to integrate more (State Test) preparation into all facets of our teaching this year. Since we've gone to the middle school that is, really, they are trying to make it more cohesive. We have been doing that, so we've been working on graphing and a lot of constructive response and more multiple choice strategies. (Pre-observation interview)

Factors influencing Beatrice's knowledge of students and assessment. Beatrice made reference to two sources of knowledge about students and assessment: her internship experience from the previous academic year and the school in which she teaches. In the case of the latter, she not only specifically addressed the team work aspect of her job, but also made it clear how the school culture had influenced her specific views on external, summative assessment.

Internships. When discussing the difficulties she was likely to encounter with her lesson plan, Beatrice clearly stated she expected to encounter difficulties in the graphing part of the activity. When asked why she would believe this, she referred to her teaching internships and explained:

> …because even my high school students would always have difficulty with graphing …, they had a lot of trouble with that and we have graphed a few other things during that practice and they are just really bad at graphing. (Pre-observation Interview)

School. Beatrice would refer to the importance of her work with her colleagues, mostly in terms of logistics. However, one of the most influential aspects seen throughout the interviews and observations is not how preparation for state testing is important, but how it is embedded in the school culture. This importance is stated by Beatrice when discussing the work done by her students:

> Our MAP scores for English are really low and so every team in our building has a smart goal, like a goal that our whole team is working towards and that is ours – for our team is working on constructed response answers. That is kind of the team-wide thing. (Second Stimulated Recall Interview)

Second Semester as Full Time Teacher

During her second spring semester in the study, Beatrice continued to teach at Bellamy Middle School. She taught seventh grade science and the topic for the lessons to be observed focused on weather patterns and, to a certain extent, whether they overlapped with the water cycle lessons that Beatrice taught in her first semester as a student teacher. The lessons were built around a group work activity that ended in the completion of a review sheet after the students shared their work with each other. The goals were taken from the State standards. The class had seven students with special education needs (SPED).

Knowledge of learners. Beatrice believed that in order for students to learn effectively, her classes must not be boring, when discussing different approaches she considered in her planning, she claimed: "Well I thought we could lecture, but that would be boring, so I thought that they're in groups of four now because I changed the layout of my room." (Pre-observation Interview). However her belief on how students actually learn the content was focused on them taking notes for review later on. Beatrice continued to use group work, which she adapted to this particular group of students. While she still acknowledges the importance of group work in student learning, she has since discovered that at times, classroom dynamics can interfere with learning. She explained her strategy on handling this when discussing a video segment of her class, in this case she chose to use a series of verbal warnings with the third warning being a 'third strike' which meant that they would not continue with the activity as it was planned and would be 'punished' working alone: "So when they are working together in a group they can work together, but as soon as they get to the third strike then they have to stop their group's work and they have to do the assignment individually" (Second Stimulated Recall Interview). In addition to this, Beatrice reviewed the previous class topic to ascertain student knowledge about the topic addressed and used that to act on it. Given that she was expecting no difficulties, she was surprised by the results, choosing to review the topics yet again at the beginning. She elaborated on her adaptation to the plans: "Like I said, we had to review the water cycle so that wasn't in my plans since we did that yesterday and they seemed to have no problem with it" (First Stimulated Recall Interview).

Knowledge of requirements for learning. Prior knowledge required for learning the content to be addressed had already been covered in their previous class by Beatrice. Essentially, her students were presented with a video that showed the different types of clouds and their shapes. Beatrice assumed they had covered some of the concepts in previous years, yet did not make any of them explicit, relying exclusively on the content of her previous lesson with them. When discussing this she stated: "They'll already know about the three types of clouds the cumulus, the stratus, and the cirrus because we talked about that in the video. And we already talked about their shape, so they have been exposed to that" (Pre-observation Interview). When prompted to elaborate on content from previous years she declared: "I'm sure they've learned about it. Fourth grade seems like a big earth science year" (Post-observation Interview), but she provided no details that influenced her planning.

Knowledge of student difficulties. Given that the necessary prior knowledge was provided to the students in the previous class, Beatrice did not expect any problems in addressing the content as planned. Her major concern was over behavioral issues. When asked to elaborate on any difficulties she expected, she clarified: "I don't think so, I think just that it's the end of the year and they really want to be chatty will be the only problem" (Post-observation Interview).

Knowledge of assessment. Beatrice's plans did not present informal assessment approaches and focused on two aspects: one was haiku, a form of poetry, and the other was a review section that touched on "key scientific facts that they need to know from here" (Pre-observation Interview). In the case of the former, she intended to use it in a formative way, seeking to focus essentially on the state standards.

Knowledge of the dimensions of science to assess. Beatrice's assessment of science focused on the guidelines provided by the State standards. In this case it was specifically the shape and formation of clouds. When asked how she would use haiku to assess their understanding of clouds, Beatrice explained it would focus on: "Mostly cloud shapes because the things that they have to know for the (State Standards) are like the different shapes and stuff … there will be a set of directions like it has to focus on shape or formation" (Pre-observation Interview). While Beatrice showed a clear view of what she needed to assess in terms of her goals, she conspicuously did not assess looking for any form of misconceptions or prior knowledge in her students.

Knowledge of methods of assessment. For this activity, Beatrice incorporated formal assessment in the form of poetry or haiku. At the end of the planned activities she expected her students to be able to construct three haiku poems that demonstrated their understanding of the science content addressed through the juxtaposition of ideas that were characteristic of haiku. She clarified her choice for this and also acknowledged her liking of haiku and its connection to her students' English classes while discussing her expected outcome during the planning stage of the observation as follows:

> I like haikus so I make them write them. That's how I got that. This year, they learned in creative writing about different types of poetry and they generally like haiku's because they don't have to rhyme, so they like writing them. So we're going to write more of them. (Pre-observation Interview)

When discussing the assessment to be observed throughout the presentation, Beatrice acknowledged her intention to use informal assessment of student work as they completed the activities she had planned including the presentations and notes. When asked directly, Beatrice explained in detail: "I'll informally be assessing them as they're making their posters and they'll have a guide … I'll be walking around and listening. Their fill-in notes will be an assessment to see if they filled it in properly" (Pre-observation Interview). She used this assessment in a formative manner during the observation, and when prompted in the simulated recall interview, she explained:

> … they had the basic shape. I think it was really spread out, but they didn't have the tiny, wispy, streaks for the cirrus clouds. So I was trying to encourage them to fix that and I think they were real over it. (Second Stimulated Recall Interview)

Factors influencing Beatrice's knowledge of students and assessment. External assessment was the most important influence on Beatrice's views of assessment. She bases goals on the State standards for the seventh grade. She acknowledged this fact during her interview. She recognized the fact that, except for a general education rationale, she had no personal belief in the importance of the goals. She selected the State standards as her choice for goals: "It's just on the GLES. So I do what the GLES tell me to do" (Pre-observation interview). Furthermore, when asked to elaborate on her personal views on the topic she stated: "The GLES say so, but they should probably know about them so their like educated people, but I survived this long without knowing about the different types of clouds" (Pre-observation Interview). Beatrice's choice and focus of assessment is thus guided by the educational goals that frame the lessons: the State standards.

End of program exit task

At the end of the ACP, Beatrice carried out the same three-step process designed to collect data over her views and understanding of science teaching that she did in the beginning. In one step designed a lesson sequence to teach the topic of heritable variation to 8th grade students. In the following step, she was interviewed, using the information from the lesson plan, in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. Beatrice chose to change the focus of her activity from Mendelian Genetics to Evolution and Natural Selection. She made this change because she believed that:

> … the Punnett square stuff is pretty straightforward, I find that a lot of kids get it because there is just a little chart and you line it up so they understand how it works, but

I think it's a little bit harder for them to understand why things change and the fact that they can change back. (Exit Task Interview)

Her approach focused on using hands on activities and on providing students with some kind of experience to illustrate the concept. She believed in the importance of using these experiences to motivate students in order to hook them because:

> … at this age their sheer wonder at the world is starting to be replaced by cynicism, and they want so badly to be grown-up. Science is one place where they can retain that wonder about the world and use their desire to be grown up. (Exit Video Analysis Task)

On the other hand her lesson plan is, at times, based on repetition of concepts in order to address difficulties learning so that:

> … questions here really start to lead into day two and then they go over them again in a group, and then we go over them together so it's more of a group discussion; so, I think even if they had questions that would address it in some way. (Exit Task Interview)

Knowledge of requirements for learning. Beatrice showed awareness of topics students would have covered prior to addressing heritable variation. In this case, she thought that

> (students) would already know about genes and how genes are passed on from parent to child, and I think that they would know that certain characteristics would be beneficial because they would have already studied different types of animals and they would have already talked about adaptations to different. (Exit Task Interview)

Not only was she aware of the prior knowledge but was also aware that different schools might address it at different times.

Knowledge of student difficulties. Beatrice highlighted graphing as one of the difficulties students would have when processing information. She believed that "even though it would be hard for them like if they work together they should at least be able to create a line graph" (Exit Task Interview). However, she foresaw little difficulty in accomplishing her goals because she thought "that it [the lesson plan] is scaffold[ed] pretty well because these questions here really start to lead into day two …" (Exit Task Interview). However, she mentioned no other difficulties (aside from graphing) and, while she acknowledges that misconceptions might exist, she did not pinpoint any particular one, but rather suggested that the hands on approach planned was such that "if anybody has any misconceptions or anything they can kind of figure them out right away before they do the second part" (Exit Task Interview).

Knowledge of assessment. Beatrice's views on assessment center on the topics of classroom assessment and external, state-based assessment. As far as graphs are concerned, in one part of her lesson plan, she highlighted the fact that "graphing skills are really stressed on the MAP and all other standardized tests,—that they need to know how to do that" (Exit Task Interview). She also suggested she would use her informal assessment in a formative manner and if the goals were not being achieved she might have to "do a bit more direct instruction" (Exit Task Interview).

Knowledge of the dimensions of science to assess. Beside the graphing skills, Beatrice focused on the informal assessment of prior knowledge based on observation of the students as they carried out the introductory activity. In addition to this, she intended to use the questions on her worksheet to see if the foundational knowledge of natural selection was being achieved by students. These questions focused on natural selection of camouflage patterns that aided in escaping predation:

1. Based on your fabric type, what type of punches did you think would be easy to see? What type did you think would blend in?

2. What do you think will happen to the genes of the punches that were eaten?

3. Based on who was eaten and who was not, what do you think the population will look like in five generations?

(Exit Lesson Plan)

Knowledge of methods of assessment. Beside the aforementioned use of informal assessment to determine prior knowledge, Beatrice also suggested, when asked, a couple of formal approaches to gauging student learning. She suggested that, while not mentioned in her lesson plans, she could "give a quiz or I could send home some homework, something like that" (Exit Task Interview).

Factors influencing Beatrice's knowledge of students and assessment. The teaching internship and the experience teaching were the most important factors in the shaping of Beatrice's views of students as learners and assessment. The first change in Beatrice's lesson plan was to change topics, while she initially argued that it was because "… the Punnett square stuff is pretty straightforward" (Exit Task Interview), she later clarified that some of the genetics content she addressed was probably "a little too in depth for them based on my previous experiences" (Exit Task Interview) suggesting that she still believed abstract or sub-microscopical level concepts were likely to be harder for this hypothetical group of students to comprehend. Her internship in a particularly conservative school also directed her focus on Natural Selection as opposed to 'Evolution' given that "those kids were really anti evolution" (Exit task interview). However she could focus in the former aspect because she "… had to look for more examples in nature because that was a really rural community so they understood how things changed in nature a lot better" (Exit Task Interview).

In addition to this, Beatrice explained her awareness of prior knowledge the students might have regarding the topic based on her experience teaching. When asked to elaborate on prior knowledge students might have, she states that the knowledge of genes and in inheritance is being given to the students of her current school “in seventh grade” (Exit Task Interview). She also relied on her teaching experience to conclude that

> … since I taught that last year, I didn’t really think that it was a two-day thing. They seemed to get the Punnett squares and then we practiced them as homework, and this seemed to be more suited to a two day unit and then exploring further in depth those ideas. (Exit Task Interview)

Beatrice also drew upon her teaching experience to conclude that students would also have problems with graphing. She outlined her reasoning in the following manner:

> In my new school they really stress a lot of graph making in the younger grades and the math teachers are really big on graph making, so I think that even though it would be hard for them like if they work together they should at least be able to create a line graph. (Exit Task Interview)

Entry vs. Exit Tasks

Beatrice’s Exit Task showed clear differences with her Entry Task data. One change that was evident came from her interaction with students throughout both her internship and her experience as a teacher. She showed awareness of student difficulty in the comprehension of topics related to heritable variation. She initially highlighted the role of genetics in both inheritance and variation; yet, at this point she argued that said content was likely “a little too in depth for [the students] …” (Exit Task Interview). However, as far as any other aspect of Knowledge of Students as Learners is concerned, her beliefs were essentially unchanged. She held on to the notion that students learn primarily by being lectured or by constantly reviewing topics (repetition). Beatrice also showed an awareness of the required prior knowledge for learning but assumed it to be foundational and necessary and, if it happened to be a misconception, it could be easily changed by lecturing; hence it had little if any consideration in her planning. She still believed that students needed to be having fun in science in order to learn, and group work was her preferred form of achieving this motivation. As far as her Knowledge of Assessment is concerned, Beatrice showed a structured view of assessment that did not exist in the initial data collection. This view of assessment considers the use of both formal and informal assessment approaches. She used both in a formative manner. In the case of formal assessment she considered the use of student products as opposed to only tests/quizzes to gauge their learning. However this formative assessment was not continuous and hinged upon the idea of re-teaching by repetition of concepts that might not have been learned by the students. The dimensions she intended to assess included content and skills and was heavily influenced by her intern/teaching context and the priority given at the schools she worked at to the State Grade Level Expectations.

Third Semester as Full Time Teacher

Beatrice worked as a full time teacher at private Catholic school, Denisson. The topic to be addressed at her new school was gravity and students would be studying the planets. Students are expected to create and present posters.

Knowledge of learners. While Beatrice stressed the importance of group work and student interaction, she also highlighted her students' ability to focus on work on their own; specifically, they were capable of taking notes. She believes these notes to be central to student learning even though she argued that her students learned best from group work or hands on activities. When prompted, Beatrice elaborated on her students' learning:

> They are a very verbal group, so they really like to study. I've never had children like this before; they really like to study and beat each other in facts … So we do a lot of hands on stuff; then, we follow it up with a lot of trivia games and they use the facts from class. They really like that. (Pre-observation Interview)

Nevertheless when asked to elaborate on the topic she stated:

> … They need to review, like I can't just give them the notes even though they love to study. I just can't just give them the notes and expect them to remember, so we were just reviewing so that way we could tie it in with these little activities with pertinent [content]. (Pre-observation Interview)

She made it clear that, while she knew note-taking and lecturing alone won't lead to learning, she also knew that repetition and linking content to things students can relate to are necessary.

Knowledge of requirements for learning. Given that the study of the planets was a new topic for her, she showed no awareness, even with her science background, as to what knowledge students should have for the content other than that of the lesson she taught previously.

Knowledge of student difficulties. Beatrice foresaw students having little difficulty in addressing the content in class, given that they are highly motivated and they have covered the necessary content previously. In addition to this, she did not address any misconception they might encounter while she presented generalizations that could be the result of misconceptions she had herself as she states regarding gravity and objects: “is just to reinforce that the larger an object is, the more gravity it has …” (Pre-observation Interview).

Knowledge of assessment. Beatrice started by reviewing homework, which she intended to use as a formal assessment of student understanding of weight and gravity. She intended to use it not only to determine if students have understood the topic, but also as part of their evaluation. When asked about how she would handle the homework, she stated: “I’ll grade it and hand it back” (Pre-observation Interview). In addition she showed more evidence of an increased focus on student evaluation and grading, in her assessment. She discusses the fact that there are higher expectations set for students in the school, which are achieved by having a higher percentage requirement per grade. Beatrice explained: “A 94 and above is and A, and 93 is a B. So it’s harder to get an A. And a 70 percent is an F instead of a C.” She also turned to using pre-tests in order to determine what the students know before working on a topic.

Knowledge of the dimensions of science to assess. In order to determine student understanding of gravity, Beatrice believed it is important to ascertain if they understood the fact that “… the larger the object is, the more gravity” (Pre Observation Interview). This was the focus of the previous lesson. She also recognizes that, in terms of content goals, and thus assessment goals, she was guided by the school curriculum as opposed to the State Standards. Given her lack of experience with the topic, she depended on her formal pre-testing to gauge student prior knowledge—a process of trial and error as she suggested when she explained it as follows: “I’m accustomed to looking at the (State Standards) and seeing what they already learned, right? Well I can’t do that here. So I give them a pretest so they are where I think they should be” (Pre-observation Interview).

Knowledge of methods of assessment. Beatrice planned to use three student products as part of her assessment. When responding to the prompts about her assessment plans, Beatrice detailed: “They will have homework for the second night in a row over gravity, and for the posters, they will be presenting to the class and filling in notes for that information” (Lesson Plan). While formal assessment focused on student evaluation, which wasBeatrice’s focus, she still relied on informal assessment throughout the activity to make instructional decisions. She elaborated on her use of class activities in assessing students: “Then I decided to make it formative assessments where they have to make things and they have to do projects and perform experiments” (Pre-observation Interview).

Factors influencing Beatrice’s knowledge of students and assessment.

School setting. Her new appointment was the source of her shift in assessment focus: She consistently referred to ‘grading’ as opposed to ‘assessing’ her students. Beatrice acknowledged this influence when discussing student expectations by stating: “So the grading scale is different. But the kids are still expected to get A’s. And they work really hard to do that. So it’s kind of like a culture shock” (Pre-observation Interview). Moreover, the fact that the school does not follow the State Grade Level Expectations (SGLE) also modified her use of assessment, specifically pre-tests.

Students. Beatrice acknowledged the effect and potential effects, of dealing with extremely motivated students. This scenario revealed her underlying belief as to the role of notes in student learning. She highlighted the fact that, given the motivation of students, it was possible for her to give only notes. Moreover she spontaneously reflected on her belief on group work regarding this view as follows:

And so, it's amazing to me. So I like to let them work, I'm kind of afraid that I'll turn into one of those teachers that loves to give notes just because I can, so I try to keep with the group projects. (Pre-observation Interview)

The Development of Beatrice's Knowledge of Learners

Beatrice showed an initial profile regarding students as learners that was based on the following notions:

Students as learners: Students are passive learners; motivation (having fun) is the most important factor for effective learning. Group work is a way of motivating students and making things fun for them.

Students have no prior knowledge on the topics at hand unless it is prerequisite knowledge from previous courses.

As long as the instructor provides correct explanations, students should have no difficulty in learning.

Beatrice's knowledge went through changes throughout the research process, and these changes are summarized in Tables 15 and 16. However at the end, she maintained her original stance on students as learners. While at the end of her first summer of courses, she decided that students might be able to make the connections on their own, but still focused on lecturing as the best way to achieve student learning. Her first summer courses shifted her focus on student prior knowledge and introduced the notion of misconceptions. However, throughout the process she viewed prior knowledge as foundational knowledge that students must have in order for the teacher to provide connections. While she believed that misconceptions hindered student learning, she also believed that they were easily dealt with by providing the students with accurate knowledge. The experiences from ASTEP and her teaching that resonated with her initial beliefs were incorporated more readily than those that did not. An example of this was her views on group work. Even when her experience as an intern suggested to her that her approach to group work was not working as expected she still held on to the importance of group work in student motivation towards the end of the investigation.

The Development of Beatrice's Knowledge of Assessment

Beatrice's initial knowledge of assessment showed no structured view on the topic. She did not include any explicit form of assessment in her lesson plan. Upon being questioned during the first interview, she considered using informal questioning of students as a way of finding out if 'students were getting it.' Her initial views of assessment, with regards to the components in Knowledge of Assessment in the PCK model are summarized as follows:

No structured view of assessment: Did not consider formal or informal approaches as part of lesson planning.

Methods of assessment: Given that she planned no assessment, her initial knowledge of assessment methods could not be determined save for her consideration of informal questioning of students to gauge their understanding.

Dimensions to assess. Since no plans for assessment were made, it was not possible to determine what dimensions Beatrice would have considered for assessing in the initial data collection task

Table 15

Development of Beatrice's knowledge of students as learners prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Students as learners	Students learn better when motivated (fun). Group work can motivate students.	Students learn by making connections (more likely to "stick"). Group work allows sharing ideas/brainstorming.	Class activities for engagement/motivation Hands-on is not for all. Students learn by listening/review/repetition.	Students learn by listening/review/repetition Class activities for engagement/motivation Hands-on is not for all. Technology helps motivation but can be a distraction
Prerequisites for learning	Students have no prior knowledge of topic.	Students must have foundational prior knowledge, which might or might not be present.	Students must have foundational prior knowledge which might or might not be present.	Students must have foundational prior knowledge which might or might not be present.
Difficulties in learning	None expected.	Aware of misconceptions but assumes she will have no difficulty teaching if she addresses these.	Abstract content that cannot be related to reality.	None expected unless addressing abstract concepts.

Table 16

Development of Beatrice's knowledge of student as learners—post-ASTEP

	3rd Observation	4th Observation	Exit Task	5th Observation
Students as learners	Students learn by being lectured on topics first. Students learn if they can connect to experiences (hands-on). Students learn by repetition.	Students learn by being lectured on topics first. Students learn by listening/review/repetition. Group work can motivate students. Students learn better when engaged/motivated (fun).	Students learn by listening/review/repetition Group work can motivate students. Students learn better when engaged/motivated (fun).	Students learn by being lectured on topics first. Students learn by listening/review/repetition. Relating to own experiences Students learn better when engaged/motivated (fun).
Pre-requisites for learning	Students must have foundational prior knowledge which might or might not be present.	Students must have foundational prior knowledge which is assumed to be present from previous courses.	Students must have foundational prior knowledge which is assumed to be present from previous courses.	Students must have foundational prior knowledge, which is assumed to be present from previous courses.
Difficulties in learning	None expected unless a skill has not been practiced enough (graphing).	No difficulties expected.	No difficulties expected: Misconceptions might exist but can be addressed by providing student correct information.	No difficulties expected:All content has been addressed previously.

Beatrice's views on assessment are influenced by both her work as an intern/teacher and her ASTEP coursework. These changes are summarized in Tables 17 and 18. At the end of her summer coursework, Beatrice had developed a clearer framework of assessment that resonated with her initial views. She readily incorporated using informal questioning of students, which reflected her initial, unplanned, form of assessment, into her views of assessment. As her work in ASTEP continued, she became open to using alternate forms of formal assessment to determine student learning, including the use of presentations (2nd observation). This allowed her to extend it, already without direct ASTEP influence to poetry (4th observation). However the dimensions she sought to assess were consistently related to the achievement of her teaching goals and, while she intended to use her achievements to inform re-teaching, they were not used to inform her instruction until the end of the learning process. Thus, at no point was the assessment truly embedded as part of her teaching. Throughout the process she clearly differentiated the summative assessment as hinging on formal instruments while formative assessment used both formal and informal approaches. The most important influence on her dimensions to assess was the state testing process and the grade level expectation associated with it. This shift occurred as she transitioned from an ASTEP student and intern to a full-time classroom teacher. At this point, diagnostic assessment and the assessment of misconceptions, which given her views of learning was secondary, gave way to a focus on state goals and assessments.

Table 17

Development of Beatrice's knowledge of assessment prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Views of Assessment	No structured view.	Formative assessment: Formal assessment & informal assessment. Assessment as a form of re-teaching/review. Assessment as a form of motivation/engagement.	Informal assessment to gauge prior knowledge. Formal assessment as a form of review (quizzes).	Assessment is both formal and informal. Assessment informs instruction as learning takes place.
Dimensions to Assess	No focus on any particular dimension.	Misconceptions	Prior Knowledge including misconceptions.	Prior Knowledge acknowledged but not elaborated on. Learning as it takes place
Methods of Assessment	None planned: Considers using informal questioning.	Considers using students products and informal questioning.	Informal assessment for Prior Knowledge/Misconceptions Alternative formal assessment used formatively. Attempts to integrate assessment into her teaching.	Informal questioning and observation used formatively. Formal Alternative assessments (Presentations) used formatively.

Table 18

Development of Beatrice's knowledge of assessment post-ASTEP

Entry Task	3rd Observation	4th Observation	Exit Task	5th Observation
Views of Assessment	Distinguishes summative assessments from formative ones. Formal assessment is summative but may inform re-teaching. Informal assessment for formative purposes.	Assessment oriented to State standards. Informal assessment used formatively. Formal assessment is used summatively or to inform re-teaching. Alternate assessment (Poetry).	Assessment oriented to state standards. Informal assessment used formatively for direct instruction.	Assessment oriented to State standards. Informal assessment used formatively. Formal assessment used summatively or to inform re-teaching. Grades motivate students.
Dimensions to Assess	Learning goals (summative) Skills/Knowledge assessed in state testing.	Learning goals (summative): Skills/Knowledge assessed in state testing.	Learning goals (summative). Skills/Knowledge assessed in state testing.	Learning goals (summative): Skills/Knowledge assessed in state testing.
Methods of Assessment	Formal assessment is summative/informs re-teaching. Formal and informal methods used formatively.	Formal assessment is summative/informs re-teaching. Formal and informal methods used formatively	Formal and informal methods used to inform re-teaching.	Formal assessment is summative/informs re-teaching. Formal and informal methods used formatively.

Catherine's Case

Background Information

Catherine was a white, non-Hispanic, female. Like Alice and Beatrice, she held a Bachelors degree in Biology. She met all the academic requirements for A-STEP and successfully obtained her high school certification. For her prior experience with K-12 students, she had been a camp counselor as well as a mentor in the Stand by Me Program. Throughout her time in ASTEP she interned at Avery High School teaching Anatomy and Physiology. Upon completing the program she went on to teach Biology at Ellis High School. At the time of the completion of this research, Catherine is no longer teaching and works at a major corporation in the Biotechnology industry.

Beginning the ACP

At the beginning of the ACP, Catherine carried out a three-step process designed to collect data over her views and understanding of science teaching. In one step, she designed a lesson sequence to teach the topic of heritable variation to eighth grade students. In the following step, she was interviewed, using the information from the lesson plan in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. At the beginning of her ACP program, Catherine believed most student learning occurred passively. Her lesson plans covered from Mendelian Genetics to Natural Selection. While she believed that in science you should "have an activity every day, something where you get up and move around, things like that, because science is hands on learning" (Entry Task Interview); however, she focused her lesson plan on lectures. Catherine also acknowledged the importance of student motivation in the learning process, stating that additional knowledge could be addressed if students were really interested. She would assess that interest by sometimes saying: "'We're going to stop here, but I'm going to show you where you can go with this,' and that way if students are really interested ..." (Entry Task Interview). Catherine also recognized relating the lesson content to students' lives. In her second day of planned lesson she intended to address as the central topic "... How does heritability affect you?" (Entry Task Interview).

Knowledge of requirements for learning. Catherine did not discuss any specific content knowledge as a requirement for students to learn the topic. She did, however, recognize that students might have had prior exposure to some of the terminology she planned to use in class, the sources of which were primarily the media. When asked about the knowledge students might have, Catherine elaborated: "Some stuff through the general media; you've heard about stuff … but I'm fairly certain they have so many CSI (Crime Scene Investigation with crime lab TV show) stuff, or they use DNA in the [TV] crime scene" (Entry Task Interview). Nevertheless she did not believe this prior knowledge had any importance in learning, even commenting on the video they were asked to analyze: "I did not like how he assumed prior knowledge of biology" (Focus Group). She believed that the knowledge required to address the concepts and activities in class should have been provided previously by the instructor. Furthermore, Catherine believed that activities, such as worksheets and labs should help reinforce the knowledge provided during lectures, and she concluded by saying: "So, hopefully by the time we have that activity set up, I will have spent time explaining, because you can't just have that activity without some background knowledge and hopefully everything will kind of fall into place" (Entry Task Interview).

Knowledge of student difficulties. Catherine foresaw students having difficulty with the more abstract concepts in her lecture, specifically the aspects of molecular genetics and DNA structure. She stated: "I'm like going to give like a five minute talk on DNA at the most, because I think they'd be overwhelmed. Like look at the helical structure and ok, this is what you guys have" (Entry Task Interview). However, Catherine believed that you should approach the topic from micro to macro level as she explained: "I kind of want to start with the whole DNA thing, because that's, you know, you can't do genetics without saying, oh yeah, DNA." (Entry Task Interview).

Knowledge of assessment. While Catherine's plan did not include any specific assessment instrument or intent, she had a clear idea of the need to assess students. She showed awareness of the need for formative assessment to take place in order to gauge student progress as opposed to simply relying on summative assessment. As she stated when she was reflecting on the importance of Punnett squares and the worksheet in her lesson plan: "You could drone on for hours about something and never really know if students are comprehending and then you get F's back on the tests; [then] you're like, oh, shoot, I guess they weren't understanding it" (Entry Task Interview). Catherine also stressed the importance of summative assessment in the form of tests while showing an understanding of formative assessments in order to improve student learning; hence, she reflected: "just to make sure they kind of understand where they're going with that, because that will be on the test." (Entry Task Interview). While Catherine focused on the importance of formative assessment on student learning, she also considered using it to modify her class activities. She reflected: "Are they understanding this? And that's my way to triage the situation, say, 'Maybe we need to spend a little bit more time; maybe we need to make the activity shorter' " (Entry Task Interview).

Knowledge of the dimensions of science to assess. Catherine's lesson plan centered on the use of Punnett squares to model inheritance patterns; consequently, when discussing assessment she focuses on assessing student ability to use them. She stated "And that's where the Punnett square comes in, because I think it's very important that after you teach, you have some way of following that up" (Entry Task Interview). Catherine focused on the importance of assessing the content covered in the previous lesson. Focusing on the use of the homework and student participation, she explained regarding her setup "So, I've got some, a few checkpoints along the way, the major one is, like, the homework for example …" (Entry Task Interview).

Knowledge of methods of assessment. When questioned, Catherine mentions the use of tests and quizzes. She does suggest informal assessment of students working on the worksheet while sharing answers with the entire class. She elaborated on her approach: "I can go around and check everything and then put the answers to the worksheet on the board and get some in class response right away" (Entry Task Interview). She also considered using the homework she had planned to send to gauge student learning from one session to the next.

Factors influencing Catherine's knowledge of students and assessment. Catherine draws primarily upon her experience as an undergraduate student as far as her knowledge of assessment and students is concerned. She recalls how the approach by certain instructors changed her opinion on how learning takes place in a classroom, Catherine specifically recalls one example she shared:

> I remember Dr. Cochrane. He gave us worksheets to take home, [you could then work with other] students and I liked that. Usually I'm not real big on group activities … It was nice to have a worksheet every now and then to make sure we were understanding a

> concept before it was time for the midterm. So that's, worksheets do reinforce, kind of, group activities, so I'm a believer in group activities now. (Entry Task Interview)

The primary reason for this, Catherine acknowledged was the fact the selected topic for the lesson planning task was closely related to her field of expertise, as she stated: "Oh, there's half my college career in like two days [of lesson plans], as far as I'm concerned" (Entry Task Interview).

End of Summer

At the end of the first summer in the ACP, Catherine had completed courses in Educational Psychology and Secondary Science Methods 1. She was then asked to reflect her initial lesson plan.

Knowledge of learners. Catherine still viewed learners as passive and lectures to be the focal point of student learning. When reflecting on her lesson plan from the Entry Task she stated: "You do have to have lectures, some things are just unavoidable" (End of Summer Interview). Nevertheless she became more conscious of the need for students to focus on the task at hand. She recognized the need for students to be engaged and focused in class and suggested that a modification of her plan would be:

> …break it up and then come back, because that just is going to be way too long. I noted here while in lecture, pass DNA model around, so prior I was kind of trying to think of a way to break it up, but I would say get them up out of their seat, go over somewhere else and look at a DNA model … get them up, get the blood flowing, because you start to get bored sitting there for too long. (End of Summer Interview)

Catherine also highlights the importance of group work in learning, a topic addressed in her summer courses. She related that group work provided students with "another person that can explain it maybe better than the teacher could" (End of Summer Interview).

Knowledge of requirements for learning. Catherine also recognized the fact that students in her class will posses prior knowledge of the topic to be addressed, while not necessarily the prerequisite prior knowledge, it will still be related. She asserted: "… you can't assume that they know x, y, and z before they walk in, but they may know a, b, and c, which you didn't even realize" (End of Summer Interview). Catherine intended to use this knowledge as a starting point for her lecture, as she stated "well what do we know, let's go from there" (End of Summer Interview). Nevertheless she did not provide specific examples of what knowledge would be requisite to addressing the topic of heritable variation.

Knowledge of student difficulties. Catherine makes no claim as to any difficulty, other than focusing during longer lectures, which she believed students might have during the lessons she planned.

Knowledge of assessment. While she did not provide any concrete examples as to how she planned on accomplishing what students' prior knowledge consisted of, Catherine emphasized the importance of determining prior knowledge; she stated: "I would definitely [find out] what it is they know prior to starting, because students will bring a lot of stuff …" (End of Summer interview). She stresses the importance of formative assessment guiding her instruction, especially at the beginning of her lesson to "make sure we're on the same page" (End of Summer Interview).

Knowledge of the dimensions of science to assess. While Catherine did not address any specific dimension to assess, she stressed the importance of determining prior knowledge that is relevant to the topic at hand.

Knowledge of methods of assessment. Catherine indicated that she preferred the idea of talking to them one-on-one in order to get an idea of how much they had learned. Given the logistical constraints to this approach, she recognized common forms of formal assessment and claimed all of them would be applicable to her plan. When prompted to explain her beliefs on this she elaborated:

> What I would like to have is have the students explain back to me. (However) you can't sit down with every student and do that, which is okay. [You can] test them or quiz them … Realistically, probably tests and quizzes and assessments, things like that. (End of Summer Interview)

In addition to this, Catherine suggested the use of informal assessment approaches in order to gauge student learning as the lessons progressed, basing her knowledge not only on how the activities were being fulfilled by the students but also on her method, which was to "go around and kind of listen and see where people are coming up with stuff, and then I've got the homework" (End of Summer Interview). This was consistent with the aspects of assessment addressed in the summer coursework in ASTEP.

Factors influencing Catherine's knowledge of students and assessment. While Catherine recognized that her summer coursework exposed her to ideas she was not aware of,e.g., misconceptions, formative assessments and student ideas, but she also admitted that for her, it was difficult to find alternatives to the lecture format. "[After] five years of college, (all of which have) been lecture based, it's kind of hard to get out of that framework" (End of

Summer Interview). She did, however, recognize the possibility of student-centered instruction especially since "… having students take over the class is not a bad thing; it's a good thing and, that's when they can really start to learn. I'm still learning how to do that, though, with comfort" (End of Summer Interview).

First Semester Internship

During her first fall semester in the program, Catherine took her Secondary Science Methods II course while teaching at Avery High School. The course was Anatomy and Physiology, an elective course. The topic of the observed lesson was muscle contraction in a class of grade 11 and 12 students.

Knowledge of learners. Catherine believed that students learn by being exposed directly to the content presented by the instructor. Her lesson plans consisted of an overhead-based lecture where she presented the content to the students. As far as their ability to understand it, she claimed "I think every student in this class is fully capable of comprehending the material that's being presented" (Pre-observation Interview). However Catherine did acknowledge that, given the nature of the group and the course, it was possible that students would learn better with hands-on activities; however, she related this mostly to student interests. When reflecting on her students' learning of science, she shared:

> Next semester we'll be doing dissections, and the students are really looking forward to doing that because clearly, if they're looking at going into the medical profession they like hands on stuff. So they really learn best with those activities. (Pre-observation Interview)

Catherine also believed that the nature of the course will determine the best approach to teaching it; hence, when discussing her choice of strategy, she noted that because of: "... time constraints and some concepts of anatomy, you just have to do a lecture style. There is no way around it" (Pre-observation interview). Moreover Catherine believed that the best approach to teaching the content was to address the molecular level first and move on to a larger scale, in her own words: "… in order to really fully appreciate exercise you have to understand how muscle contractions work" (Pre-observation Interview). However she did show conflict insofar as student learning and her lecture approach was concerned as she shared:

> So with a lecture style at least you know they're taking notes. But, when you get them in group work, and they're doing the projects or whatever, and you're doing one on one, and they're learning that way, you get a chance to know [if they] are really learning. Yeah in lecture there [are] taking notes, [but] they may not really be learning. So my preferred style is if they can come back here and do this [group work]. (First Stimulated Recall Interview)

Knowledge of requirements for learning. While Catherine does not allude to any specific knowledge that is prerequisite to the content of her lesson, she does recognize the content addressed as being foundational to subsequent topics. When discussing the importance and connections to the topic she elaborated: "I feel like this is really an important day and if they don't get this, then, there are some big concepts to grasp" (Pre-observation Interview).

Knowledge of student difficulties. Catherine believed the only aspect of her lecture that might be difficult for students pertained to addressing cellular respiration as a source of energy for contraction, specifically the formation and regeneration of ATP; she explained:

> We're just going to say ATP to ADP, ATP to ADP, we're just going to kind of run over it and as long as they understand that they'll be ok. We're not going to get into the nitty-gritty about the Krebs cycle and all that. Those are the only two things I can see major

> problems with if they can't remember that or put those two concepts together. (Pre-observation Interview)

However, she had seen her mentor teacher teach the topic previously and explained: "She presented it in a way yesterday that was simple and straightforward and I'm hoping to do the same today" (Pre-observation Interview).

Catherine also acknowledged that students come in with prior knowledge and misconceptions. She shared "I've found that no student comes in as a blank slate. That was a nice idea I had a long time ago but now I know they're not like that at all" (Pre-observation Interview). However she does not share any misconception pertinent to the topic of the lesson. Her comment indicated that she was aware of the notion of misconceptions and acknowledged experiences with it, but she did not connect this notion with her practice. This can only mean that, in terms of her mental schema, the notion of misconceptions coexists in a parallel manner with the idea that, in terms of teaching practice, students are blank slates. In this case her plans suggest that, despite her statement to the contrary, the latter view is the one she currently takes as applicable.

Knowledge of assessment. Catherine's claimed she had no form of assessment planned for the lessons observed. Nevertheless she stated "We're going to be assessing from prior knowledge just what we have covered like a review, let's refresh our memory and the like." This short quiz, prepared by the students prior to their long break, was used as a way to help them refresh their memories. This is consistent with her views on learning by repetition showing she still believed students can achieve learning goals if provided with the information repeatedly.

Catherine showed evidence of coexisting views on student learning at this point. While she acknowledged that students will have relevant prior knowledge of the topics she was to address, she had no intention of assessing it; she stated:

> None of them are blank slates. They all have some pre-conceived idea of what's going on. Some of them are completely wrong. A lot of them come in with the information from sophomore bio(logy). But we can't assume that everyone remembers. So we'll do, today, for example, we're going to give a brief head-nod to cellular respiration. And we're not really going to go in depth in that but we're kind of assuming that they do have some background knowledge of that. (Pre-observation Interview)

This suggests that, while she is aware of the notion of prior knowledge, its role in student learning is not relevant in her schema and thus assessing it is not important. Setting aside the importance of prior knowledge is coherent with her view that students can learn if lectured or provided with notes. In essence she is aware of prior knowledge, but its inconsistency with her prevalent views of learning results in it being set aside as an inadequate alternative to the views she holds on learning.

Knowledge of the dimensions of science to assess. Beside knowledge from the previous class and that related to cellular respiration, Catherine focuses on the content knowledge of the topic to be addressed: muscle fibers, exercise, and then muscle fatigue.

Knowledge of methods of assessment. Catherine did not consider her review of homework, which she intended to use to provide her feedback on her instruction, as assessment per se as she shared when discussing assessment:

> Homework will be a helpful check in what I'm talking [about] with the students, and conversing while I'm up there with the overhead – that will cue me in on some

assessments of ... [leading to the realization that] ‘wait, we're not getting this, let's go back. (Pre-observation Interview)

Nevertheless she claimed “we have no formative assessment planned” (Pre-observation Interview)

Factors influencing Catherine’s knowledge of students and assessment.

Coursework. Catherine acknowledged her coursework as a source of new ideas for her teaching. The course focused specifically on instructional strategies based off the 5E model and formative assessments. However, she also expressed how she found it difficult to incorporate the approaches she worked on in class to her own classroom practice, she explained regarding the coursework, “They're really trying to drive home the idea of inquiry in the ASTEP program right now and I think it's a great idea. It's just really hard to make it applicable for anatomy” (First Stimulated Recall Interview).

Researchers. Catherine modified her plans as far as assessment was concerned, after her initial interview and acknowledged this when initiating the conversation after the second observation, wherein she shared: “I was kind of lamenting that we do not have any other forms of assessment other than like the homework and this quiz” (Second Stimulated Recall Interview).

Second Semester Internship

During her first spring semester in the program, Catherine took the Secondary Science Methods III course, which focused primarily on curriculum planning and assessment. She continued her internship in Avery under the Supervision of Ms Fullerton. The observed lesson topic was the cardiovascular system. The lessons observed included a video, quiz and worksheets. During the second day, students modeled the circulation of blood.

Knowledge of learners. Catherine had believed that students can learn better if they are more actively involved in classroom activities. However, she still relied on note-taking as a significant part of her teaching, as her mentor, Ms. Fullerton, shared with us:

> She typically plans for the students to do lots of notes first on any given topic, and then perhaps some little activity. But by activity, it's usually you just get up and move to the lab benches and work on some paper product based on the notes that we just did. (Mentor Teacher Interview)

Catherine struggled to reconcile her own didactic, teacher-centered, view on teaching with the student-centered approach that the ASTEP program and the perspective of her mentor Teacher advocated. Her mentor, Ms. Fullerton, presented Catherine with a student-centered view of learning based on an adaptation of the learning cycle different to the 5E proposed in ASTEP. Ms. Fullerton focused on determining students' learning styles, as defined by Fleming (1995), into Verbal, Auditory or Kinesthetic (VAK) styles and planned her lessons according to the students' preferred styles as she explained when discussing Catherine's views on student learning

> She has had the benefit of being here since the first day of school with me, so we've seen the same kids kind of grow accustomed, so she watched me figure out what they're good at. At the beginning of the year we did do a little survey about auditory, visual, and kinesthetic learners, and typically most kids who are doing well in science classes and in our classroom really are more visual and auditory. In the class that you all have seen, most of those kids are actually kinesthetic in that setting. (Mentor Teacher Interview)

This approach, while student centered, caused dissonance in a manner different to that of ASTEP given that it focused on how information is provided to students while setting aside any prior knowledge students might have regarding the topic. The student-centered view presented by Ms. Fullerton did not challenge Catherine's views on prior knowledge and its role on learning, as proposed by ASTEP, while allowing her to reinforce her confidence on providing information for students, as long as she focused on the appropriate form of communication. Moreover, given that the students observed in this particular class were deemed to be kinesthetic learners, the use of hands-on activities as mechanisms of engaging or motivating students was a notion that resonated and thus supported Catherine's beliefs on this matter.

Catherine also asserted that students come to class not only with prior knowledge, in some form or another, of the topic at hand, but also with misconceptions about the topic. However, even though Catherine acknowledged students come to class with a variety of misconceptions, she sometimes held the view that, under certain circumstances students are essentially blank slates. As she states when discussing her assessment of prior knowledge on circulation: "So there's no prior knowledge of that. So even though I'm going to [encourage] them trying to figure out prior knowledge, the worksheet today is starting from square one essentially" (Pre-observation Interview).

Knowledge of requirements for learning. Catherine related previously covered content as a prerequisite to learning about heart structure, specifically tissues; she explained: "We will be talking about how the heart is made of connective tissues, and we've already talked about tissues earlier in the year" (Pre-observation Interview).

Knowledge of student difficulties. Catherine acknowledged the possibility of students holding common misconceptions about the cardiovascular system including the notion that "… blood is blue in the veins but red outside the body and that blood does not return to the heart" (Pre-Observation Interview). Not only did she show an understanding of topic-specific learning difficulties, but she recognized the persistent nature of misconceptions elaborating on the first examples as follows:

> They pick up that misconception from looking at pictures. I may not get into it while you all are here, but definitely when we talk about blood after spring break, and the function and components of blood itself, I will say, “This is the color of blood when it has oxygen, which is a brighter red, and without, it’s a darker red. When is it blue?” I’m going to wait and see what they say because I just told them the only colors that there are. I know someone is going to come in and say it’s blue, and that’s a hard thing. When I learned that it wasn’t blue, I was like, “no, no it’s blue.” That may be something that students are still going to walk away saying it’s blue because it is so ingrained. They will say, “Look at the pictures. (Pre-observation Interview)

In addition to misconceptions, Catherine related that some students would also struggle with the more abstract content presented. She provided another example of topic-specific PCK in reference to the previous chapter on the respiratory system. Catherine shared:

> One or two seem to really struggle when it comes to physiology, when it comes to kind of abstract ideas. When we talked about the lungs, they were really having difficulty grasping the idea of oxygen diffusing across the alveoli and to the blood or into the capillaries because of the high to low concentrations. (Pre-observation Interview)

Knowledge of assessment. Catherine showed a more organized mental schema in terms of assessment. She categorized her assessment of students as formal or informal with ease and provided us with a working definition of it. For this observation, her informal assessment was based off the activities she chose to use. When prompted to elaborate on her use of information gained, not only did she acknowledge gauging student progress but also used the experience to modify her teaching as she stated: "… when I go home tonight, I'm going to think back and kind of re-evaluate … I may take out the heart model …" (First Stimulated Recall Interview). The Mentor Teacher confirmed Catherine's interaction with students: "She is also more inclined to stop and ask question to the students in order to gauge their learning" (Mentor Teacher Interview).

Knowledge of the dimensions of science to assess. At this point in time, Catherine believed it was important to assess student prior knowledge of the topic to be addressed as well as necessary prerequisite knowledge for the topics at hand. In this case her focus was on vocabulary associated with the content, specifically on the names and functions of the organs that make up the cardiovascular system as well as the overall functioning of the system as a whole.

Knowledge of methods of assessment. Catherine used a quiz in a summative, formal manner to assess student learning from the previous lesson (Lesson Plans). In addition to this, Catherine had a clear idea of how she intended to use her class discussion as an informal formative assessment to determine prior knowledge. She elaborated on this by saying: "I am going to try and use the discussion time as an informal assessment to see prior knowledge and get on the same page as the kids as far as what they've done" (Pre-observation interview). Moreover, she also shared her intention to use her class modeling activity as another form of informal assessment to gauge student knowledge:

> Now we're going to make a heart and we're going to make the blood go through the heart," which was not what the worksheet was asking them to do. So I'm going to be kind of informally assessing on, "ok, so you did the worksheet. You wrote down definitions. Can you apply that to a big heart? (Pre-observation Interview)

Catherine also showed awareness of formal assessment approaches but clarified that "There will be a formal assessment with the test, but for these two days there will be no official formal assessment" (Pre-observation Interview). She made a clear distinction between different forms of assessment from her own perspective:

> For me when I say informal, I mean something I can hear from the student just through conversation or from looking at their drawing on the ground – [but] nothing [is informal] where I'm actually taking a grade or where they [are] handing something in and I'm putting a grade at the top. Informal can be graded, but I kind of take formal as a paper and pencil test or things you're handing in. Informal is more hearsay where I hear the students saying it, so I know they're on. When they ask me if something is right, I use that as an informal assessment. I ask them what they think it is and they answer. Then I decide if they're fine on their own or if they need guidance. So that's my long winded definition. (Second Stimulated Recall Interview)

This shows clear evidence of the development of clearly defined categories for assessment: formal and informal. However her personal definition of the categories digresses from that presented in ASTEP and shows reconciliation of ideas based on her pre-existing notions of assessment.

Factors influencing Catherine's knowledge of students and assessment. The ASTEP coursework seemed to have been the predominant factor influencing Catherine's views of students and assessment. In this particular case, Catherine's course assignments were focused on the circulatory system. One assignment specifically related to the design of an inquiry-based plan following the 5-E model. It was this project that Catherine used to design and carry out her lesson plan. The main influence of her coursework, as she stated, was a project that required

Catherine to design a 5E learning sequence. This sequence was based on the views of teaching and learning that prospective teachers were asked to develop as part of their ASTEP program. In the case of Catherine, it provided a framework that conflicted with her views, but forced her to think about aspects of learning and assessment she would not otherwise have addressed. Among these were the notions of prior knowledge, specifically misconceptions, and the ideas of informal, formative assessment centered on prior knowledge and knowledge development. None of these aspects were part of her original views of learning and assessment. This conflict, up to this point, had shown no evidence of personal resolution – simply awareness of them as views that were alternative to her own. As she noted, when discussing the sources of her ideas:

> … from doing my blood pressure, [I applied] the 5E project and the PCK project [concepts from] last semester. I did that on the circulatory system as well. So I've already done a lot of research on this and misconceptions. Between both projects, I'm fairly aware of general misconceptions, and the [main] misconception is that blood gets off the track. (Pre-observation Interview)

First Semester as Full-time Teacher

During her second fall semester in the study, Catherine was hired at Ellis High School as a biology teacher. She worked as a full-time teacher. The lessons observed in the first semester addressed the topic of population biology. As per school policy, Catherine had a mentor teacher who was an experienced teacher from the biology department.

Knowledge of learners. While Catherine asserted that her students learned best by "more hands on and spend[ing] a lot more time with the concepts" she still relied heavily on lectures. She explained this based on time constraints and a tight schedule, which is the result of all the department having a common assessment instrument; "There's not too much hands on

… Unfortunately again we all have the common assessment I don't have that time even have I have the foresight I may not have the time." (Pre-observation interview). When it came to Ecology, Catherine accepted her mentor's view, by saying he had "told me that a lot of the ecology for the kids can get pretty boring because it's just new terms. They don't actually get to go out and see the ecology." (Pre-observation Interview).

Knowledge of requirements for learning. Catherine provided no requirements for students learning the content she presented. In fact she claimed that it was likely many of the students had "… encountered pretty much every topic we've been covering. Not as in depth but they should have encountered it before in the past" (Pre-observation Interview).

Knowledge of student difficulties. Catherine explained that her students have been exposed to the content before and should not have problem with any of the topics except for "… the density dependent and the density independent factors. Just because I confuse the two constantly, about what's an independent and what's a dependent factor." (Pre-observation Interview).

Knowledge of assessment. Catherine acknowledged the importance of assessment but instances of planned assessment were conspicuously absent from her planning. She suggested using the warm-up exercise as an improvised informal assessment and that she could determine how much they have learned by "the questions they asked … When I see a class that is very talkative; sometimes I know ahead of time they are having problems" (Pre-observation Interview).

In addition to informal assessment, Catherine mentioned two instances of formal assessment. The first of these, a series of packets prepared by Catherine, functioned mostly as a strategy aimed to repeat content to students in order to review it again and learn by repetition.

> The reinforcement packets that we do will tell me if they understand it. A lot of times, unfortunately, the kids don't even start to really pay attention until we actually sit down and start 'okay here's a packet I have to go through and I have to understand this stuff in order to fill it out'. (Pre-observation Interview)

The other instance is the common assessment that is carried throughout the department. However, the latter served as a summative assessment instrument and was not used to guide instructions but rather to ensure homogeneity among teachers and evaluate students. She elaborated on the nature of the common assessment: "We all give common assessments here so we have to decide what chapters are in the common assessment …which is basically the final of the semester" (Pre-observation Interview).

Knowledge of the dimensions of science to assess. Catherine mentions no specific dimensions of science to assess except for the fact that "…chapters one through five are all in the common assessment" (Per-observation Interview)."

Knowledge of methods of assessment. Catherine acknowledges informal assessment and formal, written assessment of students but plans for neither. The only assessment that is mentioned by her, besides the state testing, is the common assessment carried out by her department.

Factors influencing Catherine's knowledge of students and assessment. The school context was the most important factor influencing Catherine's views of students and assesessment. While she did not explicitly mention it, the existence of a common assessment across the department reinforced Catherine's didactic view of students. In this case the common assessment instrument provided a prescribed timetable, as she stated when discussing the planning of hands-on activities: "Unfortunately again we all have the common assessment, [which is] I don’t have that time” (Pre-observation Interview). Given that, she viewed interactive activities, such as those highlighted in her ASTEP coursework, as more time consuming than lectures, she never discarded the view that students learn through direct instruction, and her teacher-centered views become predominant. Moreover, other notions that she related to the 5E model such as the role of prior knowledge and misconceptions in learning were set aside due to her conclusion that they were not necessary. This tight scheduling coupled with the emphasis on summative formal assessment proposed in her department made informal assessment a discarded priority in her planning.

Second semester as Full-time Teacher

During her second spring semester in the study, Catherine continued to teach biology at Ellis. The topic of the observed lesson was energy in cells; the focus was primarily on ATP.

Knowledge of learners. Catherine continued to make the case for her students learning better with hands on activities, but equated hands on to labs, as she elaborated: “…they like hands on, they are starting to get a little frustrated because of the fact that I really have to check the labs at the door” (Pre-observation Interview). Her perception of time constraint, a notion prevalent in her teaching context while working at Ellis made her reconsider the predominant use of lecturing in her plans, although she was still confident that students would learn the content presented to them through lectures. Moreover she also equated inquiry to hands-on learning. When asked what alternative approaches she would take, if time were not an issue, Catherine proposed a lab activity as a way to confirm or reinforce the material covered in class. As she elaborated:

> So you could almost do that as an inquiry – of saying ‘Okay what do we see?’ [and] list off the organelles; it’s kind of a repeat of the previous chapter, and then they actually see

certain things happening, and then, whenever we actually start talking about them, they are like, 'oh that's what we were seeing'. (Pre-observation Interview)

Knowledge of requirements for learning. Catherine assumed in the beginning that students were blank slates and had no prior knowledge about the content to be addressed, although she admitted this theory was at odds with what she was taught in ASTEP. As she later stated: "I'll admit [that it is] silly for me to walk in blind in this topic because students are never a blank slate and I'm basically assuming that walking into this" (Pre-observation Interview).

Knowledge of student difficulties. Catherine made no reference to any difficulty her students might have with the topic. Moreover, she did not consider any form of misconceptions that they might have had prior to coming to class or might develop as a result of the teaching. This was most likely due to the fact that it was her first time teaching the topic at this level. This reinforced the notion that the idea of misconceptions was not incorporated into her views despite having covered it in her ASTEP courses. This claim was supported by the fact that that she pointed out how she purposefully sought out misconceptions for her ASTEP project during her second semester as an intern but conspicuously failed to do so at this point. This suggests that her fallback, faced by the challenge of teaching a topic in which she had less content knowledge, was to return to her original, student-centered, views on learning.

Knowledge of assessment. While the plans did not explicitly mention assessment, Catherine intends to use the worksheets to informally assess student learning. She also planned to use formal assessment in the form of a quiz, using the worksheet as a guideline. As she explained:

> The worksheets is one thing I'll be essentially informally assessing … but whenever you come back next time I'll be formally be assessing them over their worksheet based on

> the quiz I've yet to write, and I'll probably do the same thing then. (Pre-observation Interview)

In addition to this, her assessment focused on following the common assessment procedures used by her department.

Knowledge of the dimensions of science to assess. The dimensions of assessment that Catherine focused on were guided by the State standards. She essentially wanted the students to be able to recall the basic content associated with energy processes that take part in the mitochondrion and chloroplast. As she explained: "The (State standards) don't require that they basically do any more than summarize or explain the processes that are going on inside the cell as far as cellular respiration and photosynthesis (Pre-observation Interview).

Knowledge of methods of assessment. While assessment was not initially planned for the observation period, Catherine acknowledged the use of informal assessment as part of the formative assessment, and quizzes as part of her summative assessment. However, she considered informal assessment as the result of incidental rather than planned interaction with her students; as she explains:

> For me when I say informal, I mean something I can hear from the student just through conversation or from looking at their drawing on the ground, nothing where I'm actually taking a grade or when they are handing something in. (Second Stimulated Recall Interview)

Moreover she considered only formal assessments in grading her students while informal assessments were not used in grading. When referring to her intended use of worksheets in the lesson she said:

> The worksheets is one thing I'll be essentially informally assessing. . . The kids I'm sure will be a little frustrated when they find out I'm not giving them any points for that because if it's not worth points it's not worth doing, but whenever you come back next time, I'll be formally be assessing them over their worksheet based on the quiz I've yet to write. (Pre-observation Interview)

Factors influencing Catherine's knowledge of students and assessment.

School environment. The fact that her peer teacher focused on covering State Standard content with a limited time and budget constraint made it easy for Catherine to turn to her teacher-centered didactic approach. As she explained regarding her choices on lesson planning:

> …chapter 9 does offer one or two lab possibilities but given the room setup that I have and given the amount of time that I've been told to spend on chapter nine, I don't have a lot of time to do lab activities, etc., because we have to move into genetics which is the next part, and the GLE's really focus on the genetics versus the [inaudible] and they do mention the respiration and the photosynthesis … I don't really have the money either, I've already spent all of my meager budget so as far as getting supplies … (Pre-observation Interview)

Another aspect of the context that influenced Catherine's views was the common assessments that are required by her department. The department first set her goals for learning and made her reconsider the aspects which she believed were important to learning. The department directives coupled with the fact that she had little experience with the topics, caused Catherine to design her plans based on her student-centered views of learning. In essence, the constraint placed by common assessments, based off State standards, put Catherine in a situation where the views proposed by her ASTEP coursework seemed, to her, inconsistent.

This dissonance was resolved by her opting for student-centered views which, in her experience, were easier to accommodate to the requirements of her work.

Researchers. Catherine's responses were influenced in two ways by the presence of researchers, who also happened to be her instructors in ASTEP. First, she tried to design her plans according to their expectations; hence, when describing her planning process, she said: "I wanted to plan something, like I said earlier, exciting for while you guys were here" (Pre-observation Interview). Moreover, as mentioned previously, when discussing student prior knowledge, she recognized her assumption that the students were 'blank-slates,' yet indirectly, she acknowledged that was not what she was told in her ASTEP course. However, despite her reference to the presence of the researchers as a consideration in her planning she did not carry out any activity or task that deviated from what was seen in prior observations. As the researcher in charge of the observation stated in her notes, "Catherine is fairly conservative in her approach. She likes the facts. She has little idea of what concepts one can teach in the material she taught on circulation." (Researcher notes, Fourth Observation Cycle for Catherine). This did not reflect a change in Catherine's understanding of students or of her assessment capabilities, but instead, pointed to co-existing perceptions regarding these aspects of PCK, which caused some conflict between her own beliefs and those she was exposed to during the ASTEP program.

End of program exit task

At the end of the research study, Catherine carried out the same three-step process designed to collect data over her views and understanding of science teaching that she did in the beginning. In one step, she designed a lesson sequence to teach the topic of heritable variation to eighth grade students. In the following step, she was interviewed using the information from the lesson plan in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. Catherine believed that motivation and fun were important in getting students involved in the process of learning. She sought to encourage student involvement by planning group work activities as follow up to her introductions and lecture arguing students were more likely to be motivated by this. In her own words, students would react like: "'Hey, I get to work with a partner, 'Whoo hoo!' They would be far more intrigued and far more willing to work if it was an easier activity and they're with someone else." (Exit Task interview). Another aspect Catherine considered important in getting students motivated was relating content to student experiences. She explained her reasoning as follows: "In order I guess to really prepare for this I try and again just try to make the connections with the students lives because that's most relevant and they'll learn the best whenever you do that" (Exit Task Interview).

While she acknowledged that students are likely to have prior knowledge on the topic to be addressed, she still believed understanding vocabulary was necessary before addressing the content itself, functionally being blank slates, as she elaborated:

> Obviously you can't understand the basic prompt unless you understand that word. So if they have no knowledge of that or any grasp of that concept, they are not going to be able to understand heritable variation among species. And then the second part would be the variation. (Exit Task Interview)

Consequently, Catherine focused on lecturing as a way to introduce new content to her students, making it the second part of her new lesson following the warm-up activity (Exit Task

Lesson Plan) which she had not considered in the Entry Task. Catherine's approach was mostly unchanged: She still believed that learners would learn primarily by being lectured and focused her approach based on this conviction, as she explained when asked to elaborate on her lesson plan:

> Maybe we can poll the class and see if we look more like our moms and dads, something like that. But then that was going to lead into a short PowerPoint, which I do love my PowerPoints. Unfortunately I'm still kind of addicted to them. Our book comes with decent PowerPoints. But prior to jumping in and having my students take notes, I wanted them to you know, we're going to jump into the vocab. (Exit Task Interview)

Knowledge of requirements for learning. In contrast to the Entry Task, Catherine shows an awareness of prior knowledge and expects some content, specifically, heredity, to have been covered beforehand. She recognized two aspects of this, relevant foundational knowledge and misconceptions. However Catherine equated misconceptions to not understanding the use of scientific terminology to explain observations, namely inheritance and heritable variation. She outlined this when explaining the purpose of her initial warm-up activity and how it related to the end of her plan:

> Kind of to elicit prior misconceptions but then I was thinking how do I do this? What's the best way to do this? …Well you know, I have my dad's eyes, I have my mom's nose. Things like that. So actually, they don't realize it but they're talking about heredity and they are actually talking about heritable variation with the species and they don't even realize it. And so I wanted to just kind of throw that out there, and then we'd kind of break down and then hopefully at the end of this two-day segment, we then come back to that idea, with the [vocabulary] attached to it. (Exit Task Interview)

Like in the Entry Task, Catherine also emphasized the importance of getting students involved and motivated; yet, on this occasion, she sought to get the students engaged with the topic by using a warm-up activity, as she explained when asked to elaborate on her plans: “So I started off kind of with a warm-up written up on the board. I wanted to get them thinking about the concept of heredity without just saying this is heredity” (Exit Task Interview).

Knowledge of student difficulties. Catherine was aware that student might have misconceptions regarding heritable variation and considered this in her planning, as she elaborated when reflecting on her warm-up: “So I started off kind of with a warm-up written up on the board. I wanted to get them thinking about the concept of heredity without just saying, this is heredity – kind of to elicit prior misconceptions” (Exit Task Interview). She also mentioned specific misconceptions that students might have, like the notion of evolution of individuals vs. populations. Catherine explained her approach as follows: “And then we’ll get more specifically into natural selection and evolution and the misconceptions of how individuals evolve. And it’s not individuals, it’s populations of all individuals” (Exit Task Interview).

However, beside misconceptions and vocabulary, the only other difficulty Catherine foresaw students having was in making the connection between the activities. As she mentioned when asked about expected difficulties: “I almost think it’s just in the connection with the activities. That was something I was really worried about when I was setting this up” (Exit Task Interview).

Knowledge of assessment. Catherine showed awareness of different approaches to assessment, including formal and informal approaches. She was also clear on what she intended to accomplish with her assessment, be it a formative assessment of student learning or grades.

She planned to use her informal assessment to determine the need to review prerequisite content that students might have forgotten or address misconceptions they might have.

Knowledge of the dimensions of science to assess. When discussing informal assessment in her warm-up activity, Catherine chose to focus on assessing student handling of the appropriate terminology. She also considered assessing prior knowledge, specifically focusing on misconceptions in order to address them. As she explained when asked about her initial activities:

> And then I want them to turn and discuss with their row partner; 'oh well I thought it was this, but actually this is what heredity is.' 'I didn't even realize that.' I mean, if they are in eighth grade, they probably have been exposed to these topics but misconceptions, things like that, are going to pop up. I want them to identify what it is [so] they know the trouble spots. But then I'll just be informally evaluating the students. I'll go around and listen to them talk, and see if there's any, well 'I thought it was this. . .' but. . . 'Whoa! Whoa!' 'It is not that at all.' (Exit Task Interview)

Knowledge of methods of assessment. Catherine planned for both formal and informal assessments at several points in her plan in different ways including a quiz and an exit slip. Catherine continued to equate formal assessment to grading, although she did suggest using it in a formative manner and included other forms of formal assessment such as an exit slip. She explained this in detail when discussing her approach to evaluating her students as follows:

> I want to do an informal evaluation, walking around. You know listening to (the students) … I had an idea of making a quiz at the end of the second day initially. I'd feel comfortable putting a quiz somewhere maybe even in the middle of the third day if we

were to cover everything as planned. But I like the exit slip because that will, that's a really big indicator and I can make that worth points. (Exit Task Interview)

Factors influencing Catherine's knowledge of students and assessment.

Catherine explicitly acknowledged the influence of her mentor teacher during her student teaching in ASTEP as an important source of her knowledge on students and assessment. She explicitly acknowledged her mentor's influence in test writing, as she shared, "Telling me about how she had been taught in her undergrad that whenever you have multiple choice, that all the answers are supposed to be the same length, things like that." (Exit Task Interview). In addition to this, the ASTEP context provided concepts and strategies that, while at odds with some of Catherine's beliefs, were incorporated into her views of teaching and learning. This will be explored in further detail as part of the cross-case analysis.

Entry vs. Exit Tasks

Catherine's views of students as learners varied very little from her initial views as determined by the Entry Task. She was still convinced that lecturing students, especially providing vocabulary, was the backbone of learning. However, she has incorporated concepts presented by her ASTEP courses in a manner consistent with her initial beliefs. For example, Catherine now uses the terms misconception and prior knowledge to explain her views of learning. However she believed that misconceptions arise from lack of vocabulary or incorrect use of terminology. Moreover she assumes that it is possible to correct said misconceptions by providing students with the correct explanations.

For Catherine assessment meant incorporating the terms presented to her throughout ASTEP in a manner consistent with her initial beliefs. In contrast to her Entry Task, Catherine now considered informal assessment as a valid form of gauging student learning, mostly associating this to the influence of both ASTEP and her experience teaching, as she summarized when discussing assessment: "And then I realized, I can walk around and listen, and oh, hey, they actually are getting it. Let's move on" (Exit Task Interview). However, she refers to informal assessment when discussing incidental interaction with students or class work activities and considers graded instances such as tests as the only forms of formal assessment. She focuses on the use of the activities in a formative manner for future planning while testing was essentially used for accountability purposes.

Third Semester as Full-time Teacher

Catherine worked as full time teacher in Ellis High School teaching primarily biology. However, the lesson observed was in earth sciences, and the topic of the lesson observed was formation and modification of landforms; hence, it was not possible to schedule an observation that allowed us to observe a lesson that was the same or closely related to the ones observed in the previous two visits.

Knowledge of learners. Catherine still claimed that her students learn best with hands-on activities. However, like in previous instances the lesson was based on an extensive lecture: "Catherine taught most of the 90 minute lesson as a lecture" (Observers Notes). She still believed that students learn by lecture though she still claimed that students learn better by experiencing things hands-on; however, her activities were oriented more towards motivating students and getting them focused than on developing ideas as she was still focusing on giving them notes. This was seen when discussing her initial activity:

> Before I give that to them in the notes, I have an activity. Each partner will have a pie pan with 200 milliliters of sand in it. I'm going to give them a graduated cylinder and have them figure it out. Last year we called it the "Perfect Sand Castle". They have

> fun. Last year when I tried this, it kind of worked but the kids get frustrated. (Pre-observation Interview)

Catherine showed a view that tried to reconcile a teacher-centered approach with a student centered one by arguing that learning can occur in either scenario. As she explained when prompted by the observer: “You can learn from a teach[er]-centered [lessons], but as far as actually knowing what you’re doing, it doesn’t really click until you do it and get those hands-on activities and learn from your own experiences” (Post-observation Interview).

Knowledge of requirements for learning. Catherine mentioned no requirements for learning the topic of the lesson. She did, however, state that students might have absolutely no prior knowledge on the topic as she stated when discussing the composition of her classes: “I have 15 students out of 150 who have had no science background” (Pre-observation Interview).

Knowledge of student difficulties. Catherine shows awareness of content that would be difficult for students. In the case of the topic at hand, she claimed:

> I would say it’s the idea of remembering and applying it on a test where I give them a situation they’ve seen before. I felt like they had a stronger grasp this year than last year’s students but time will tell. I think for me what is the most difficult is the difference between a slum and landslide. (Stimulated Recall Interview)

In the case of the latter, she argued the difficulty stemmed from telling the difference between the shapes, especially in images. Catherine did not mention any misconceptions students might have.

Knowledge of assessment. No assessment was planned for the observed lesson. However Catherine’s discussion of the class activities highlighted her preference for formal, summative tests. She based the goals in her class on the State standards,

Knowledge of the dimensions of science to assess. Catherine made reference to the State standards as the guidelines to her class and thus her assessment; in the specific case of the content at hand, it was: "Explain external processes that result in the formation and modification of landforms" (Stimulated Recall Interview).

Knowledge of methods of assessment. Catherine did not discuss details of assessment, but her plan and discussion focused on her use of formal, summative assessment in the form of tests. However her tests seem to resemble repetition exercises focused on content, "I'm going to pick one of those pictures from each of the different things I showed and do that on the test and we're going to keep seeing them over and over." (Stimulated Recall Interview).

Factors influencing Catherine's knowledge of students and assessment.

Researchers: The presence of a short activity suggested to the observer that it was quite likely set up because of his presence, and this further reinforced the idea that her view on learning is based on the belief the students learn through note-taking and lectures; "She had one activity consisting of students using pie pans of sand and water to help them think about the idea of mass movement of soil. I view this as an attempt to show me what she thought I wanted to see." (Observer Notes).

Coursework. Catherine acknowledged that, despite the coursework in ASTEP, she still used a teacher-centered, lecture-based approach to teaching, which she claimed as her preferred teaching approach "Lecturing comes naturally and it's easy and safe." (Stimulated Recall Interview), which is in contrast to the views presented in ASTEP: "I remember being taught … you guys have explained to us that student-centered is better and preferred as far a student learning" (Stimulated Recall Interview). For Catherine the ASTEP program had provided her with an alternative view on learning and assessment that was at odds with her initial beliefs and, at this point in time, she had managed to reconcile the differences only partially, mostly by explaining the concepts presented in ASTEP according to how they differed from her own view on the issues.

The Development of Catherine's Knowledge of Learners

Upon entering the ASTEP program, Catherine showed a view of students as learners, which was influenced by her experiences as a K-16 student and based on the following notions:

Students are passive learners; they learn by lecturing.

Motivation is important to learning.

Hands-on activities provide real life experiences which improve learning by providing students with confirmation of the topics presented in lecture/notes.

While it is possible that students have prior knowledge, it is not important to consider in lesson planning.

Students have difficulty comprehending concepts they cannot visualize or relate to in their everyday experiences.

As Catherine progresses through the ASTEP program and into teaching, her views of students are modified both by her experiences as an intern and as a full-time teacher as follows:

Students are passive learners: At the end of her first semester of classes, Catherine still believed that lecturing was the way in which students learn. She did acknowledge the possibility of them learning in other ways, but assumed it was a matter of teacher preference. This view did not change throughout any of the semesters spent either as an intern or as a full-time teacher. Her plans and lessons were based on lecturing and providing notes to students.

Motivation is important to learning: Catherine's view on the importance of getting students involved and motivated did not change over time. However it did provide a perception that was receptive to some of the views presented to her in ASTEP. She took the emphasis put into group work during her first semester as a student in ASTEP and found it suitable to her beliefs in that it is: a) a way of repeating information and b) allows students to not only get motivated but also focused. She showed evidence of a different view on group work during her first semester as an intern by relating it to her beliefs about the importance of providing real-life experiences to reinforce concepts – an issue addressed in her coursework during that semester. However, she shifted back to viewing group work as a form of repeating information provided in lectures or for confirmation activities during her second semester as an intern. At the time of the Exit Task, she showed clearly that she had incorporated only the motivation value of group work into her views on student learning and no further change was seen in the final observation cycle.

Hands-on activities provide students with confirmatory, real-life experiences; While nothing suggested any change from this stance after her initial summer courses, by the time Catherine was in her first semester as an intern she suggested that students would learn by ‘doing’ as opposed to just listening, a view that was at odds with her initial views of learning. This notion is likely brought about by the emphasis on the 5E model of the ASTEP program. This suggests that she considers two distinct views on learning simultaneously. However her experiences throughout her second semester as an intern reinforced her views on activities being primarily used for confirmation or motivation. By her second semester as a teacher, Catherine had reconciled her views on inquiry by equating inquiry to labs which in turn are the same, in her mind, as hands-on. The logical conclusion for her was, therefore, that inquiry is equal to labs. As such, by her second semester as teacher, in her mind the lack of resources and time to do labs hinders her ability to do inquiry. Given that she views lecturing as a primary form of learning, she discards the use of inquiry, as presented in ASTEP, under the context under which she teaches.

Students might have prior knowledge but it is not important in learning: When it comes to prior knowledge, Catherine's views changed little, if at all, throughout the process. By the end of her initial summer courses and after being exposed to the notion of prior knowledge and misconception in her ASTEP coursework, she still viewed prior knowledge primarily as prerequisite knowledge to be built upon. This addresses the issue of misconceptions, also an emphasis in her first ASTEP courses, where she accepted the notion of misconceptions as prior knowledge that provides an incorrect foundation upon which to provide students with new concepts that must be addressed. However, addressing misconceptions was done simply by providing the students with correct information via notes or lectures; a belief consistent with her views on learning.

Students have difficulty comprehending concepts they cannot visualize or relate to their every day experiences. When it came to student difficulties, Catherine's views showed little change little excepr for once during her second semester as an intern. Here, she acknowledged that learning can be hindered by misconceptions based on inaccurate representations of reality. However, this view on learning difficulties seemed to not be alternative to her dominant view on difficulties being unlikely unless students lacked foundational prior knowledge. The idea that this is a competing conception was reinforced by the fact that she addressed misconceptions again during the Exit Task data collection activity; yet, it was conspicuously absent from any observation cycle save for the two previously mentioned. Thus, this discarded alternative view was likely the result of her view about the researchers in the process, seeking to provide them with the results she believed they wanted to observe as was acknowledged by her and at least one of the observers and the interviewer.

The development of Catherine's knowledge of assessment

At the beginning of the ASTEP program, Catherine showed no structured view for assessment. Her plans had no assessment included in them. Catherine's knowledge of assessment was elicited during the interview. Her initial views of assessment as part of her PCK are detailed in Tables 21 and 22 and summarized as follows:

No structured view of assessment, did not consider assessment as part of lesson planning.

Methods of assessment. When asked, Catherine considered using student products (worksheets/homework) as sources of data on student learning.

Dimensions to assess. When asked during the interview about what dimensions she would consider assessing, Catherine focused on the calculations involved in explaining inheritance.

As she progressed through ASTEP, Catherine's views on assessment change were influenced both by her experiences teaching and her coursework. Initially, her coursework provided her with a suitable explanatory framework that organized her thoughts on gauging student learning. She clearly separated assessment into two divisions using the terminology presented to her in ASTEP; hence, assessments were either formal or informal. However, she equated the formal assessment as tests/quizzes only. She considered other forms of alternative formal assessment as informal. This view was persistent in and up to the end of her first year as a teacher. However in her exit task interview she considered the use of student products as formal assessment, which deviated from her previously stated beliefs. This suggests the

Table 19

Development of Catherine's knowledge of students as learners prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Students as learners	Students learn by hearing lectures. Motivation is important to learning. Relating to own experiences is important to learning. Activities are needed for confirmation.	Students learn by hearing lectures. Motivation is important to learning. Group work provides a way of repeating information. Group work/activities are given to regain focus.	Students learn by hearing lectures. Hands on activity to provide real-life experiences. Group work helps students work – students are more likely to learn when 'doing' than when listening. Claims students are not blank slates.	Students learn by taking notes. Class activities are to provide breaks/motivation in class work. Class activities are also used for repetition/confirmation of concepts. Believes students are blank slates, though some prior knowledge might exist
Pre-requisites for learning	Students might have prior knowledge, but it is not relevant to learning.	Students might have prior knowledge and it might be relevant to learning and can serve as a prerequisite.	Students have no prior knowledge if content is foundational; otherwise, it was considered a prerequisite for learning.	Prior knowledge is a foundation for learning new concepts.
Difficulties in learning	Sub-microscopical concepts that cannot be visualized will be difficult to teach. Concepts that extend beyond their every-day experiences are difficult to teach.	No difficulties other than maintaining focus during lectures.	No difficulties if correct foundational content has been given to students.	Acknowledges the persistent nature of misconceptions based off of inaccurate representations of reality. Topic-specific misconceptions are present. Abstract notions such as the explanation of passive transport at a molecular level are important.

Table 20

Development of Catherine’s knowledge of student as learners post-ASTEP

Entry Task	3rd Observation	4th Observation	Exit Task	5th Observation
Students as learners	Students learn by taking notes. Students learn by repetition. Students learn by lecturing and providing them with terminology at the beginning.	Students learn mostly by lecturing. Argues that students learn better 'hands-on.' 'Hands-on' = labs = Inquiry.	Students learn by lecturing, reviewing/providing vocabulary first. Activities are for focus/motivation or confirmation	Students learn by lecturing or taking notes Class activities are for motivation for real life-experiences.
Pre-requisites for learning	Considers no pre-requisites for learning. Acknowledges that some content might have been covered superficially in prior classes.	Students have no prior knowledge of the topic.	Prior knowledge is a foundation for learning new concepts.	Prior knowledge is a foundation for learning new concepts.
Difficulties in learning	Expects no difficulties given that content has been addressed previously	No difficulties considered or expected. No reference made to misconceptions.	Misconceptions might exist and must be elicited and addressed before teaching. Misconceptions relate to use of proper terminology.	Difficulties come from the lack of understanding of terminology. References to misconceptions are conspicuously absent.

concepts, as addressed in ASTEP, while not prioritized, were likely a part of her views on assessment. At the final observation she still seemed to equate formal assessment to testing which further reinforced the notion of this being the dominant view in her mind set regarding assessment. Given this view of assessment, she used what she called formal assessment in a summative manner while using all other forms of assessment to gauge student learning. As far as informal approaches to assessment are concerned, Catherine did not initially consider informal approaches to assessment as assessment *per se*. However, after her first few courses she did make reference to observation and interaction with students as a way to gauge student learning. By the end of her first year teaching, Catherine mentioned observation and incidental interaction with students as part of her approach to assessment and this was further highlighted in her Exit Task suggesting a shift in her views of assessment. However, the final observation did not confirm this shift suggesting she prioritized her original views using the schema provided by the ASTEP course content.

As far as dimensions to assess, Catherine focused primarily on conceptual understanding based on vocabulary. However, when the topic allowed it, she also sought to assess appropriate use of algorithms and calculations. The only exception to this was during her time as an intern when she also suggested assessing students' prior knowledge and even misconceptions; both of these topics were in her ASTEP program. However, this was absent from all the observations of her as a teacher; yet, was present in her Exit Task interview. Based on her acknowledgement of a desire to show observers what she believed they wanted to see, this suggests that she did understand that prior knowledge and misconceptions exist but, given that they have no role in her views of students as learners, these concepts, as addressed in ASTEP, were not incorporated into her views of assessment.

Table 21

Development of Catherine's knowledge of assessment prior to and during ASTEP

	Entry Tasks	End of Summer	1st Observation	2nd Observation
Views of Assessment	No structured view of assessment. Considered formal summative assessment. Considered the need for formative assessment.	Summative assessment for learning goals. Diagnostic formative assessment to ensure every student is 'on the same page'.	While she acknowledged the existence of prior knowledge she discarded using diagnostic assessment. Assessment provides an opportunity to review concepts to remember them.	Differentiates formal an informal assessment. Re-defines them in terms of her prior knowledge Uses informal methods to inform instruction.
Dimensions to Assess	Ability to carry out correct calculations using models.	Prior knowledge still not clearly defined.	Prerequisite prior knowledge from relevant topics and pre-existing conceptions of topics had to be addressed.	Prerequisite prior knowledge of relevant topics was considered with a focus on vocabulary.
Methods of Assessment	Considered alternate formal assessments (Homework /Worksheets Considered informal assessment to gauge student comprehension	Considered formal assessment used in a summative manner. Considered using informal assessment for prior knowledge	Considered only formal assessment in the form of tests/quizzes. Other forms of formal sources of student learning were used but not considered assessment.	Formal assessment was used in summative manner. Tests were the only form of formal assessment. Informal assessment used formatively but never summatively. Informal assessment was used to determine prior knowledge.

Table 22

Development of Catherine's knowledge of assessment post-ASTEP

Entry Tasks	3rd Observation	4th Observation	Exit Task	5th Observation
Views of Assessment	Assessment was not considered in planning. Suggested the use of warm-up exercises as improved assessment. Assessment works as a form of review.	Formal assessment used summatively and for grades. Informal assessment used formatively to inform future planning and gauge student learning.	Formal assessment used both formatively and summatively yet linked always to grades. Informal assessment is incidental and used to gauge student progress.	Assessment not considered in planning. Summative assessment in form of tests. Assessment works as a form of review.
Dimensions to Assess	Content determined by departmental policies.	Content to be addressed considered to be guided by State standards. She focused mostly on the aspects requiring recalling information.	Considered vocabulary and misconceptions as derived from lack of vocabulary or improper use of it.	Content determined by departmental policies and State standards. Focused on vocabulary.
Methods of Assessment	Formal assessment used summatively. Informal assessment used formatively.	Informal assessment is incidental unplanned and ungraded. Formal assessment is comprised of tests and quizzes only.	Informal assessment is incidental unplanned and ungraded. Considers using other forms of formal assessment besides tests and quizzes.	Formal assessment in the form of testing.

Danielle's Case

Background Information

Danielle was a non-Hispanic white female. Her bachelor's degree was in biology, and she was the sole participant to sign up only for High School Certification. She completed all the internships required for this at Bellamy High School. She was then hired at Fairview High School, a private school in the suburbs of a large city in the US Midwest, as a full time biology teacher. Her previous experiences with K-12 students included being a tutor and also a mentor for the Big Brothers Big Sisters program and the Women of Worth program.

Beginning the ACP

At the beginning of the ACP, Danielle carried out a three-step process designed to collect data over her views and understanding of science teaching. In step one, she designed a lesson sequence to teach the topic of heritable variation to eighth grade students. In the following step, she was interviewed, using the information from the lesson plan in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. Danielle believed that students learned best through lectures and stated: "While lecture is not the most exciting way to learn, it is sometimes the most optimal way to teach students about the basics of a concept" (Video Analysis Task). However, Danielle also had the impression that students would learn better if she provided situations that would make them interested in the topic at hand. She intended to have students participate in discussion over inheritance because "it keeps the students more engaged. I feel like if you're just talking to them they're just not as interested in listening" (Entry Task Interview). Moreover, she believed that students could also be motivated by having them explore the concept within the context of their own lives. For this she intended to use analogies that were comparable to daily experiences, which she believed eighth graders would have. She elaborated on her use of videogame as an analogy to achieve this:

> … We'll be going through and trying to put that into a perspective that an eighth grader can understand, and so I related it to video games because I know that's something that all eighth graders have done and they would understand. (Entry Task Interview)

However she does believe that there is an inherent motivation in students that escapes the classroom environment: She discusses this, referring to an excitement factor (a description she implied, but which was not precisely stated), when asked about her best day of teaching. As she explained when asked to describe her "best day" expectations:

> There is a very large difference between students who are taking the required Biology 1 course and those taking the optional advanced Biology 2 course. Students who have chosen to take a course are in a completely different mindset than those who are taking a required course, and this is an important aspect to take into consideration. It will be a lot more work on my part to engage students who are not as willing to learn than it will be to encourage those who are excited about learning and want to be in class. (Video Analysis Task)

Danielle also believed that students will likely have no prior knowledge over the topic of heritable variation. When asked as to how she thought students would handle the initial discussion, Danielle surmised: "I would think it would be a little bit difficult just because this idea has never been presented to them and so that's why I thought this is pretty basic" (Entry Task Interview).

Knowledge of requirements for learning. Danielle shows awareness of the topics that students might need in order to be able to address the content presented in her lesson plan. While she initially claimed to be unsure about the content, upon further probing, she elaborated (Dashes represent pauses):

> Before these two days I would think that mainly teaching basic – the idea of DNA and genetics – not necessarily genetics but DNA – and how DNA works – again in a very basic idea. But, if they don't understand what DNA is they're going to have trouble knowing what a gene is and then what an allele is, so more of just like the background information I guess of how DNA works and makes us who we are – and starting off with that before building up to heritability. (Pre-observation Interview)

She essentially believes that in order to understand a phenomenon at a macro level, her students must have a working knowledge of the underlying molecular mechanisms that support it.

Knowledge of student difficulties. Danielle believes that the most likely difficulty students will have throughout the lesson would be: "kind of remembering from the first day to the second day. You have to continue with topics. I know that's kind of difficult and it is a short amount of time to go over such a huge topic …" (Entry Task Interview).

Knowledge of assessment. Danielle's lesson plan did not explicitly mention any intention to assess students. However upon interviewing her, it was evident that she was aware of the need to gauge student learning as she progressed. She was aware of the need to carry out formative assessment. When asked about the thought process behind her use of a worksheet, Danielle elaborated:

> After doing that and kind of asking them what questions they had, (I'm sure they'd have some [questions]), just kind of getting this general idea across though I thought it would be a good idea just to kind of gauge where everyone was, [to] have a short worksheet … (Entry Task Interview)

Not only did Danielle show awareness of the need for formative assessment but also of informal assessment, albeit with a preference to using a formal instrument, as she explained later on:

> I thought about just asking them in class and having kids raise their hand, but again you sometimes have some kids that just understand and some that don't, and the ones that don't – you wouldn't necessarily know because they're just not raising their hands, and so I thought by doing a worksheet, it'd be an easy way to tell for each student which ones are actually grasping what I'm talking about and which ones aren't. (Pre-observation Interview)

Knowledge of the dimensions of science to assess. Danielle mentions no specific dimension of science to assess save for the ability of students to apply their knowledge to their daily experience; as she detailed in her plans: "For example, the first question would state: "Tall is dominant, short is recessive. If a person got the tall allele from their dad and short allele from their mom, are they likely to be tall or short" (Lesson Plan). However, her concern also gravitated around students understanding the connection between observable phenomena, such as variation and abstract concepts such as genes and alleles. As she highlighted when discussing her goals: "The main idea of how heritable variation arises from alleles and from genes, and I feel like I attempted to get that point across, at least the basic idea of that point through this lesson plan" (Entry Task).

Knowledge of methods of assessment. Danielle intended to assess student learning using a formal instrument; as she outlined in her lesson plan: "To determine how well students are grasping the idea of alleles and the dominant versus recessive allele, I may have them do a simple worksheet exercise" (Lesson Plan). Her discussion over the use of the worksheet shows she is familiar with the notion of formal assessment, specifically using tests, quizzes or worksheets. Danielle links this process to the verification of learning on part of the instruction, as she explained:

> … but then when you're actually forced to write it on a quiz or a paper, you realize – I didn't understand that. I heard it and it made sense, but I didn't really understand it so having them actually write it down in their own would be a way to tell [if] they actually personally were following what I was saying … (Entry Task Interview).

Factors influencing Danielle's knowledge of students and assessment. At this point in time, Danielle's knowledge was shaped primarily by her experience as a student, as she elaborated when asked for the source of the ideas in her lesson plan and the use of worksheets:

> Mainly from classes I've had. I feel like when you're sitting in class you can feel like you understand something but then when you're actually forced to write it on a quiz or a paper you realize I didn't understand that. (Entry Task Interview)

These experiences she believed were important in shaping her views on learning and assessment as she stated when asked to reflect on any other sources of her ideas or teaching: "Not that I can particularly think of outside of my classroom experience in undergraduate [classes]" (Entry Task Interview).

End of Summer

At the end of the first summer in the ACP, Danielle had completed courses in Educational Psychology and Secondary Science Methods 1. She was then asked to reflect on her initial lesson plan.

Knowledge of learners. Danielle considered that students would learn better if they were more actively involved in classes. She refers specifically to two aspects: group work and inquiry. In the case of the former, she recognized that group work got students more involved and, thus, engaged in class, facilitating their learning, as she recalled from her summer experience:

> I didn't actually realize how much group work really made a difference until I was looking for it. And just today (this was my first day student teaching) ... they did the small group work, and already I could see it made more people talk, got more students to talk. (End of Summer Interview)

In the case of inquiry, she highlighted the importance of students deciding what focus to give to lab activities and again focused on how this approach was more likely to get students excited and involved in the activities. When asked to explain her view, Danielle explained:

> So I think getting to see that, in this experience, will help, and so hopefully, I can take that kind of idea because I think it's ... it's a lot more fun if the kids get to pick what they do because they actually want to do it then. (End of Summer Interview)

Knowledge of requirements for learning: While Danielle was aware that students might have some knowledge related to the topic of the lesson, she believed that, for the most part "… I can assume they really haven't had much bio yet … thus considering that they would have to be given explanations and content as if they were indeed blank slates" (End of Summer Interview).

Knowledge of student difficulties. Danielle's first concern was the fact that students would have difficulty comprehending the terminology used, as she explained when elaborating on her lesson focus: "Maybe having them do more with definitions because, just to kind of hammer those in a little bit more ... because that can be [helpful] sometimes terminology can be more difficult than concepts especially in science." In addition to this, Danielle showed awareness of the fact that some analogies or demonstrations might foster misconceptions in students. She reflected on her own misconceptions and compared it to the analogy she had initially intended to use in which she would have purple and yellow paint and, at one point, would mix them in order to illustrate the concept of genetic dominance:

> I know a lot of, I mean I had that misunderstanding where I always thought that brown hair was dominant to blonde hair because it's darker so it's like, covers it, that whole idea with color. And I think that could be confusing to kids, so, I'm not sure if I would still do the paint idea. I thought that was a good idea at the time to kind of visualize, but it could almost cause more misconceptions, especially with the color idea. (End of Summer Interview)

Knowledge of assessment. While Danielle assumed that, for the most part, her students came to class without prior knowledge of the topic, she did acknowledge the need to assess for prior knowledge because it provides the foundational knowledge students need to build more knowledge on. As she stated when discussing the importance of diagnostic assessment:

> … [Students should be] starting with what they know and then building from there, rather than starting with what the textbook says to start with and building, because you could be on totally different levels, and you'll never get through if they have no clue what you're talking about to begin with. (End of Summer interview)

This claim not only alludes to her belief that it is important to assess incoming knowledge but also speaks of her belief that it is likely students will have no specific knowledge about the topic to be addressed.

In addition to this, Danielle shows awareness of the use of state standardized testing as a form of summative assessment. While she does not elaborate on the details, she showed some awareness, based on secondary sources, of the possible influence external testing had on teaching, as she explained:

> I've heard it's just one of those things that when you get closer to the testing times, for example, and teachers, I've heard that teachers just hate that they have to kind of conform to what's on those tests, but you want those kids to do well. (End of Summer Interview)

Knowledge of the dimensions of science to assess. Danielle does not mention any specific dimensions of science to assess. However, her assessment focuses primarily on the areas she sees as most important concept informing her of their learning, which is students' understanding of terminology and possible prior knowledge.

Knowledge of methods of assessment. Danielle was aware of the importance of using informal assessment in a formative manner, suggesting not only questioning but also observation. As she elaborated when discussing her approach to assessment:

> … not just you give them a quiz at the end of the unit, but each day, just informally kind of watching how the students are doing, keeping it in your mind: like this group seems to be doing pretty well; this group seems to be not doing so well. Just to gauge the whole level of the whole classroom so you kind of know, like, I said where to go next. (End of Summer Interview)

She also acknowledged the use of formal instruments to guide instruction but assumed that "…the word quiz would automatically make (the students) think it was graded" (End of Summer Interview). Nevertheless Danielle was unsure as to how to properly design and use formal assessment, as she explained later:

> … but as far as formal assessment, I do feel a little bit nervous about that still and about writing tests that are tough enough that you're really trying to find out if they know things, but not so difficult that the kids just get discouraged. (End of Summer Interview)

Factors influencing Danielle's knowledge of students and assessment. Danielle drew primarily from her experiences as a student (both high school and undergraduate). However she merges these with content and activities addressed throughout her summer coursework, especially regarding informal assessment and group work. As she concludes when trying to focus on the sources of her ideas:

> I know a lot of students feel uncomfortable, myself included, in high school. I hated talking in front of the whole class, but if I was in the small groups, it didn't feel kind as overwhelmed, I suppose, so I guess a combination of kind of what I've watched and we talked about that quite a bit in class this summer. (End of Summer Interview)

Her ASTEP courses also provided new ideas on which to reflect. Evidence of this reflection is shown when she acknowledged the potential of her lesson plan to generate misconceptions regarding the mechanisms that determine dominance in inherited traits. She pondered on the viability of her plan and stated: "I'm not sure if I would still do the paint idea; I thought that was a good idea at the time to kind of visualize, but it could almost cause more misconceptions, especially with the color idea" (Exit Task Interview).

First Semester Internship

During her first fall semester in the program, Danielle took her second Secondary Science Methods course while teaching Biology at Bellamy High School, a public school in a small Midwestern town. Her mentor was Ms. Davis. She taught on a modified block schedule, meeting at times on consecutive days and at other times on every other day. The unit being addressed for the observation was cellular transport. The topics of the lessons observed were osmosis and diffusion.

Knowledge of learners. Danielle believed that students learned by lecturing to them and providing them with notes. Even though the observation was a situation in which students would have to carry out observations on their own and analyze them, the content had already been addressed in previous lessons and completed in the unit test. As she shared with us when discussing the initial plans: “They have already taken their test on this unit. They took the test I guess last Thursday, and then, we started the egg lab on Friday.”

Knowledge of requirements for learning. As far as content is concerned, Danielle believed that it was important that students know the basic structure of the cellular components involved in passive transport across membranes. Danielle believed that understanding at a molecular or microscopic level would be important prior to addressing diffusion and osmosis. As she explained when discussing the connection to other topics: “We have mentioned cell membrane and cell wall; we didn’t really go very deeply into any of them. I feel like this fits in with what we have done previously” (Pre-observation Interview). Moreover, in order for students to learn, she believed they should be engaged and involved in class. Danielle explained regarding her beliefs as to how class dynamics influence learning: “Students should try to stay engaged in what we are working on” (First Stimulated Recall).

Knowledge of student difficulties. Danielle identified two aspects of her plan where the students would or did have difficulty working. In the first place, she foresaw them having difficulty with terminology. Danielle knew "they didn't really have a good grasp on hypertonic and hypotonic before" in reference to the material covered previously and assessed informally by her. Danielle believed this was possibly in relationship to switching the perspective from the solvent to the solute, and she elaborated on that while discussing one of the videos:

> … the way (the student) had it in her head, the reason she was getting it backwards was because she was thinking hypotonic is more, she had more in her head, and thought it meant more solute and not more water. (First Stimulated Recall Interview)

Danielle was also aware of difficulties students might have regarding the activity planned. She highlighted that, despite having covered the notion of dependent and independent variables as well as constants and controls. Danielle expected the students to "get thrown off by control versus constant. They have trouble deciding which is constant" (First Stimulated Recall Interview). She also was concerned that the modeling approach using the egg might not be comprehended by students. As far as analyzing the data was concerned, Danielle also noted that students would have issues with the graphs. The first issue was selecting the type of graph to use, as she explained:

> I know they have done them before, and so this did show them they can use either one. That is all they really talked about is that they know those two types of graphs and they never know when to use which one. (Second Stimulated Recall Interview)

Finally Danielle was concerned that some students might not understand the analogy, failing to realize the egg was modeling a cell. As she shared her concerns, she stated: "We were just concerned that they weren't connecting that the egg was the cell" (Pre-observation Interview).

Knowledge of assessment. Danielle clearly distinguished between formal and informal assessment. Throughout this observation, she highlighted the formal aspects of assessment, specifically quizzes and tests. She used the quiz at the beginning of the observation to gauge student knowledge about the topics previously addressed; she was thoughtful of the test structure and accommodated students trying to take advantage of test design. She elaborated on the beginning of the lessons:

> So we are going to start with that quiz and it shouldn't take too long. It's just four questions. They're all the exact same format. We did four instead of three because always they just assume because one of them is hypo and one of them so and the last one of them has to be hyper, every single time. (Pre-observation Interview)

This showed that she was thoughtful and reflective on the test structure based on her experience teaching, which suggested that her views of students were strongly influenced by her experiences. In this case, she adapted the test to address a potential shortcoming in structure that might render it less effective in determining student learning.

Knowledge of the dimensions of science to assess. When using formal assessment, Danielle focused on assessing student understanding of terminology addressed in class. She focused especially on the area where she knew students might have the most difficulty, addressing both the use of the terminology and the model. Case four outlined her approach in the following manner: "(Students) weren't connecting that the egg was the cell and these solutions are the hypertonic, hypotonic so this quiz – it's still putting it in the context of an egg in a solution (Pre-observation Interview).

Knowledge of methods of assessment. Danielle not only made use of a formal assessment instrument, she also sought to assess students informally and takes advantage of this to adapt her teaching and assist students that are having difficulties. She elaborated on this: "So we can talk them through it, and then they realize they know the answer. That seems to be a very informal way, walking around and helping them, and helping them, I see how they're doing" (Pre-observation Interview).

Factors influencing Danielle's knowledge of students and assessment.

Mentor teacher. The interview with Ms. Davis highlighted the fact that the focus was primarily in a lecture-then-lab sequence. Ms. Davis discussed Danielle's ability to bring together the lectures with the labs. She described the lab as being "… really inquiry-based hands-on lab," despite the fact that the lab was delivered after the content had been covered (Mentor Teacher Interview).

Current students and prior experiences. While Danielle suggested that students helped her understand that it "…it is important to go over a concept in multiple ways" (Pre-observation Interview). Her continuing reflection points at the fact that she was not addressing multiple learning styles, but rather believed in learning by repetition. She explained her perspective as follows:

> These guys have shown me that because we did the notes. For example, we did a short PowerPoint on this topic, and they got it a little bit. Then, we let them do a worksheet with it. They got it a little bit more. Then we did a project with it. It seems like each time we put the same concept into different arenas, I guess they seem to understand it more and more. I think it is just learning it and being able to put it all together. (Pre-observation Interview)

Second Semester Internship

During her second fall semester in the program Danielle continued to teach at Bellamy High School under the same mentor teacher. The topic of the lesson was evolution. It focused specifically on the homologous and vestigial structures as well as the biochemical evidence supporting evolution.

Knowledge of learners. Danielle's view of learners and learning is still didactic; lectures exposing the students to the content precede activities and labs. Moreover, she focused on students taking notes even reflecting on her intention to start the lesson with a quiz: "Actually it may be with notes because I have had issues with people not wanting to take notes lately so I am trying to reward for taking notes" (Pre-observation Interview). Furthermore, Danielle continued to believe that learning would be enhanced by repetition, as she explained when, during the stimulated recall, we presented her with a situation in which her assessment determined that 100% of the students had grasped the concept addressed:

> I think we'll still review it. Especially because, I think, over the weekend, it's just hard, I think, for students to remember everything from the last week. You'd like to think that they put it on their long-term memory, but that's not necessarily how it goes. So definitely we'll review it again and try to think of new examples. (First Stimulated Recall Interview)

In addition to believing that students learn better if they are allowed to work hands on, Danielle believed the group of students observed thrived on group work. She was aware of collaboration among students facilitating learning. When describing the students she elaborated:

> This group of students seems to learn very well through collaborative learning, through doing group work. And I found that when we did the second group activity (it was just last week with natural selection) when we did the post questions that I had them do in the beginning and in the middle, the exact same questions, it made a huge difference after we did this group work. So they seem to really feed off of each other and do really well doing collaborative learning. (Pre-observation Interview)

However, Danielle's use of group work or hands on learning served mostly as a break in between lectures. Nevertheless she acknowledged the importance of these breaks in terms of student focus and motivation.

> And so I have really found that breaking up, even more than I realized I needed to, breaking up what we do in class is really important and it's helped a lot. … They seem to learn better this way. I think more than anything, because they are getting a lot more chance to work with the concepts. (Pre-observation Interview)

Another aspect that Danielle indicated as a motivation for students was their evaluation. Her conclusion was summarized as follows: "I think there are a couple of things that motivate these students. Partly it's their grades, so I especially on them slap more motivation at the end of the quarter" (First Stimulated Recall Interview). In terms of labs, Danielle believed in their importance not only in motivating and engaging students, but also as reinforcements to help students understand concepts presented in lecture. With this in mind, she stated: "…we have done (labs) that really illustrate the concept" (Pre-observation Interview).

Knowledge of requirements for learning. One of the big topics that Danielle considers important in order to learn this topic is DNA, and the processes involved in protein synthesis, as she elaborated when discussing her plans: "We did a really big unit on DNA. And then we are going to be doing this activity, biochemical evidence for evolution. So students will be comparing amino acid sequences of humans, gorillas, and horses” (Pre-observation Interview).

Knowledge of student difficulties. While Danielle argued for the need to understand microscopic and sub-microscopic level structures, molecules and mechanisms, she did acknowledge students would have difficulty with them, specifically:

> … having difficulty with, they can’t picture what these structures are. I mean, we showed them pictures; we even did stuff with slides; but even that isn’t very powerful for them to picture all these different organelles, why it’s so important. (First Stimulated Recall Interview)

Furthermore, Danielle foresaw students having difficulty remembering certain concepts from previous topics; specifically, the more abstract notions of protein synthesis. As she explained when talking about the connections between topics: “So I think they are going to remember really easily what amino acids are, how we get the amino acids, like from codons. Translation, probably not as much” (Pre-observation Interview).

Knowledge of assessment. Danielle relied consistently on both formal and informal methods as formative assessment strategies. However, she only planned for formal assessment, while informal assessment was used as the opportunity arose. Student products that are used for assessment were also used in student evaluation. As elaborated when discussing her planned assessment: “… my assessment during this activity is going to be mainly while I help, when I’m walking around helping the students, I mean obviously, when they turn it in I will be able to grade it” (Pre-observation Interview). While Danielle was intent on using assessment in a formative manner, her approach to addressing issues arising from assessment was consistent with her views of student learning. As she explained when discussing the sequence of her lessons and tests:

> We did a worksheet with this on Tuesday, and so possibly [I will] try to find another activity we could do that illustrates this concept, and take the time that before we would ever, I would have already assessed someone in an actual test of this to go back over it and re-teach. (First Stimulated Recall Interview)

Knowledge of the dimensions of science to assess. Danielle's assessment focused on the understanding of concepts, specifically to demonstrate knowledge of definitions; she clarified this position when discussing the structure of her worksheet: "So it would be like portions of definitions. They'll fill in blanks there, add in things like that …" (First Stimulated Recall Interview). Danielle also expected students to demonstrate this understanding by comparison, as she puts it: "examples of homologous structures and maybe kind of defining the difference between the two, things like that" (Pre-observation Interview). Danielle also expected students to understand what she believes are the mechanisms that drive evolution, in her mind – adaptation and natural selection; hence, she claimed: "… the big thing that I would hope students understand with evolution is we really focused a lot on how adaptations sort of drive evolution" (Pre-observation Interview).

Knowledge of methods of assessment. Danielle shows consistent use of both formal assessment instruments, such as tests and quizzes, as well as informal approaches. She elaborated when asked about gauging student conceptual understanding of molecular level genetics: "I'm hoping that by kind of walking around helping the students with this activity, I will get an initial idea" (Pre-observation Interview). She also expressed her intent to use worksheets as a summative assessment, as explained when talking about the follow-up on her lessons:

> So Monday, [I] come back with possibly a little mini check or another worksheet where they can't use their notes or can't work together, something like that to see if they actually have this idea under wraps, and if it's sunk in or if it just kind of breezed over for them. (Pre-observation Interview)

Factors influencing Danielle's knowledge of students and assessment.

Mentor teacher. Danielle acknowledged her mentor's teaching style was similar to hers. This reinforced her views on students as learners, as she explained when discussing her mentor's style, and which provided students with content via notes and then used activities as either ways to repeat the content or confirm through exercises:"She does a lot of activities. Her notes are short like this, and there's talking involved during the notes, and so [we have] very similar teaching styles" (First Stimulated Recall). From her mentor's perspective, one of the aspects that was central to Danielle's methodology was her awareness of the need to present information more than once to students, as Ms. Davis explained:

> I think she has become more aware …that doing something once or presenting information one time does not mean that students have mastered it. And, I went to a conference and I came back, sharing with her that they say that students need to have a concept, or they need to work with a concept six to eleven different times before they have actually learned it. And that means not saying six or eleven times over and over, but you need to have a variety of activities to reinforce that learning. (Mentor Teacher Interview)

Coursework: Danielle's courses addressed assessment. While this enabled her to use adequate terminology during the interview and allowed for a clearer view of her beliefs, it did not modify her understanding of assessment. Moreover, in the case of informal assessment, it reinforced her existing beliefs about the importance of using this approach to gauge student learning as it takes place. As she shared with us:

> … we have talked about it, I guess in our class this semester. We talked a lot about assessment. I mean it just seemed kind of obvious to me, because you can see how they are, you can see as people are working. (Pre-observation Interview)

Another aspect of her coursework that was discussed by Danielle was student learning by inquiry. Danielle felt that the inquiry style approach proposed throughout her courses was, at this point in time, at odds with how she believed high school students learn. When discussing inquiry and her teaching Danielle explained:

> I think, in my opinion, doing full open inquiry is impossible in high school, and maybe that's not fair for me to say. Maybe some people can. For me, though, it just doesn't work because it's way too much, putting way too much responsibility in the student's hands, and I don't think they even like it. They like having more direction. (First Stimulated Recall Interview)

First semester as Full Time Teacher

During her second fall semester in the study, Danielle taught in Fairview High School, a private school in the suburbs of a major mid-west city. The class observed was part of the topic of cell biology. It began with the lesson that preceded the egg lab analogous to the one that was observed in Spring/Winter 2007.

Knowledge of learners. Danielle's believed student learning is centered on lecturing and note taking. She planned her lesson centered on lectures or taking notes. She elaborated on her lesson plans as follows:

> We finished up a unit on the basic information about cells, like the structures and all that, and we just started in on focusing on cell membranes so on Monday we will be doing the second part of the notes we have been taking on cell membranes, and we will be talking about tonicity with cells and solutions. (Pre-observation Interview)

Even a quiz included at the beginning of the lessons was viewed primarily as an opportunity to re-address a topic that was consistent with her belief of teaching by repetition. When discussing her initial plans she elaborated:

> … at the very beginning of class they're going to do a short [test], it's not really a pop quiz, it's a few questions they have to answer based on what we talked about yesterday in class which is the introduction of cell membranes, and then we will just go over those answers; it's more of a review than anything, but it's not a quiz. (Pre-observation Interview)

Knowledge of requirements for learning. While Danielle connected osmosis to the preceding topic, cells and cell structure, she viewed cell membranes as something she needed to start from scratch. She elaborated on this while discussing her plans:

> Well we did an overview of all the cell structures and now we are kind of zeroing in on cell membranes, and we probably won't do this focused of a study on any of the other cell structures mainly because we have talked about all of them quite a bit and cell membranes really just have a whole other element to them. (Pre-observation Interview)

Knowledge of student difficulties. Danielle points at concepts related to microscopic or sub-microscopic components as particularly difficult for students to grasp, which she emphasized when discussing her plans:

> I would like to do that so they can see on the microscopic level, and we need to make sure that we have microscopes and everything available but that is tough. The abstract concepts are really… that's going to be something I'm going to struggle with. (First Stimulated Recall Interview)

In addition to this, Danielle believed that students will have difficulty understanding the terms hypertonic and hypotonic, especially since she argued it was a matter of distinguishing a reference point for the application of the terms. Moreover, she admitted she had issues with this herself as she detailed when talking about her lesson plan:

> I really refreshed myself more than anything to make sure I could explain very clearly hypertonic, hypotonic, isotonic, those properties. Mainly because it is difficult to confuse whether you are referring to the solution or to the cell; for example, it is just really refreshing on how I wanted to teach it in order to remain consistent so the students wouldn't get confused because it is easy for me to get confused in my head too. (Pre-observation Interview)

Knowledge of assessment. Danielle discusses the use of both formal and informal approaches to assessment. She views formal, written assessments mainly as a form of summative assessment related to student evaluation. Moreover, quizzes and tests, while addressing the topic, are considered primarily forms of review, a way of constantly re-addressing the topic with the students. When asked to elaborate on a 'pre-assessment' that was not present in her initial plans, Danielle explained:

> That was over what we had taken notes on Wednesday, and we had talked about the structure of the cell membrane, and that's really all we had done Wednesday, and since we had, the kids didn't have school Friday and I didn't have them on Thursday, so since it had been a while … (First Stimulated Recall Interview)

While Danielle did not plan for informal assessments, she identified moments that could be used for that purpose and elaborated on how she would approach such situations. As she explained with regards to her second day: "I think as we are discussing the purpose of doing the lab, I will be able to assess whether they are making a connection between why we are doing it and the topics we have been talking about (Pre-observation Interview).

Danielle uses assessment to determine whether or not she has to "… go back in their notes and re-talk about each of those situations" (Pre-observation Interview), which is consistent with her view of teaching by repetition.

Knowledge of the dimensions of science to assess. When it comes to formal assessment, Danielle focused on conceptual understanding of the terms provided to the students in class. She showed particular emphasis on the students remembering vocabulary, including using vocabulary to construct meaning. In this regard, Danielle outlined how she believed students operated through her assessment:

> I've just noticed that if you just read the word facilitated diffusion, that's two big words that are very science sounding and it's tough for them to, I think, just hear those words and hear the definition and remember. But if they can think about, 'Oh, facilitated diffusion, those are two big words, but oh, I know what facilitated means. We talked about that helping.' And then remember, 'Oh, that's right, proteins are helping.' So just

> kind of making those connections between words they already know. (First Stimulated Recall)

As far as informal assessment is concerned, Danielle was less focused and had a different focus, looking more for connections between topics and concepts than actual vocabulary. In regard to her informal assessment of students as they worked in the lab, she stated: “I will be able to assess whether they are making a connection between why we are doing it and the topics we have been talking about” (Pre-observation Interview).

Knowledge of methods of assessment. Danielle planned out her use of formal assessment instruments prior to the observation, and while she used them mostly as a form of review, she also identified them as a way to gauge student learning:

> … because of this three day week (so that’s kind of a long time), so we will see how much they remember after five days but so that will give me an idea as far as the first section of notes we have talked about. (Pre-observation Interview)

Danielle also identifies instances in which her planned activities can be used to carry out informal assessment of student learning, and she explained this when discussing the use of white boards for students to share their group work:

> I think then doing the white board activity, I will be able to assess how much they are understanding, just initially their understanding of osmosis and again that will be in groups so it is a little bit tougher to tell because again you are not assessing them individual[ly], but it will give me a bigger picture of how the class is doing with the topic. (Pre-observation Interview)

Factors influencing Danielle’s knowledge of students and assessment. Danielle recognized Ms. Davis as the most significant influence in the shaping of her ideas about teaching and learning. She formed an analogy to her ASTEP courses highlighting two aspects, in her own words: "… because she did teach similar to the way we discussed teaching in the ASTEP program. She's a very hands-on, interactive teacher" (Second Stimulated Recall Interview). However, she does not make any statements as to any influences at Fairview suggesting that she attempted to reconcile the views of ASTEP with a relevant example, and in her view, with real experience in the program. In this case she equated hands-on as interactive thereby connecting her experiences to the 5E model that was focused on in ASTEP.

Second semester as Full Time Teacher

During her second spring semester in the study, Danielle continued to teach at Denisson. The lesson observed was genetics, with students were working on Punnett squares and inheritance.

Knowledge of learners. Danielle believed that students learn primarily by listening to lectures and taking notes. She also believed students are blank slates and that her role was "helping them to understand information that they have never known before so it's a lot of it is me kind of telling them about the information and then working with it" (Pre-observation Interview). Danielle also believed that learning would take place more efficiently by repetition; thus, she sought to address the topic recurrently as needed. As she explained: "…check that Sponge Bob worksheet in class and use that as a chance then to review one more time the incomplete dominance idea" (Pre-observation Interview). She is so intent on providing knowledge to the students that Danielle claimed "Sometimes, I am surprised with what they figure out on their own, like they have already figured out the idea of multiple alleles and they have asked about blood types, and they did kind of figure that out" (Pre-observation Interview).

Furthermore when asked directly about how she believed students learned best, Danielle elaborated:

> I think in general they learn best working in small groups, like working together, working with the concepts and then kind of figuring out (what's the word I am looking for?) [the] kind of outcome or the underlying idea through working through the concepts rather than me just telling them about it even when we do take notes in class …. (Pre-observation Interview)

Given that this view is inconsistent with the planning and answers she provided earlier, it is likely that it is a competing conception. Danielle viewed this as an alternative explanation that responded to the question made by the interviewer but, as such, it was not a priority in her schema regarding students as learners.

Knowledge of requirements for learning. Danielle believes that students were more likely to learn something that is related to their everyday lives, which is consistent with her views on abstract concepts being the most important aspect of student difficulties. As such she tried to relate examples to situations, events or situations which she believed fit this requirement. As she elaborated when discussing her choice of example for explaining the use of Punnett squares:

> …instead of using, for example, guinea pigs with black or white hair and doing your crosses – using like Sponge Bob having round eyes, or oval eyes or yellow body or orange body, things like that, so it's the exact same thing it's just putting it in context of that cartoon and so I found it and my kids last year tend to respond well to it because most of them watched that and it's the same this year so .... (Pre-observation Interview)

Danielle is also aware of content that she believed is important for students to understand before they can fully comprehend inheritance as outlined with Punnett squares. Danielle expected her students to understand the cellular mechanisms and molecular components involved. She considered microscopic and submicroscopic structures and mechanisms as the most relevant requirements for learning. Danielle focused specifically on DNA and cell division. She explained the connections when outlining the overall lesson sequence prior to the observation:

> … we did DNA right before this and right before that we did mitosis and meiosis and right before that we had done cell, like the big entry unit to cells, so I think we kind of have been building. I guess we started just with basic cells, went from there to mitosis you know how cell forms and then to meiosis with sex cells, so that's the inheritance and we built on that with DNA and then genetics. (Pre-observation Interview)

Knowledge of student difficulties. Danielle recognized that students would have difficulty establishing connections between topics that focused on molecular structures and cells. When asked to explain the difficulties students were having Danielle stated:

> … the one I had the biggest trouble with was just doing the unit on cells, like organelles and everything, cell parts, I mean of course cells are essential to who we are because that's what we are made of, but that's so abstract for them to think about that. (Second Stimulated Recall Interview)

Danielle also acknowledged that students would have difficulty with the added combinations presented by a dihybrid cross when compared to a monohybrid one. She argued that this difficulty was due to the nature of the task and the fact that students had not been exposed to the task enough, as Danielle explained:

> They seem to have trouble making sure they get all of the genotypes down and counting them up and keeping track of the phenotypes and I think it's really just that they haven't worked with it enough because it is, it is very involved and it is kind of tedious work until you have down it …. (Pre-observation Interview)

She also contended that some of the difficulties students had when working with Punnett squares was due to the fact that "… we need more practice with that" (First Stimulated Recall Interview)

Another area of difficulty students had that was acknowledged by Danielle was the topic of dominance. She believed students had difficulty understanding the complexity behind determining genotypes based on phenotypes due to their understanding of dominance in genetics. As Danielle explained the issues students had during the first observation:

> They seem to understand if you've got one dominant gene, they're going to have that dominant characteristic. They seem to have trouble understanding like if you have a brown dog with a long tail that was dominant right. Can we look at that dog and know if it was homozygous or heterozygous? and we can't. They seem to really be struggling with that; like 'why can't you look at it and know' or 'why can't you look at its parents and know', and I keep trying to tell them it's more complicated than that, but that's been tough for them to understand – you can't just look at an organism and know if it is homozygous dominant or hetero(zygous). (First Stimulated Recall Interview).

Knowledge of assessment. Danielle's plans did not detail any specific intent to assess. When interviewed, Danielle acknowledge the use of formal assessment instruments such as quizzes and worksheets, she used them primarily as ways of repeating content so students could learn it. As she stated regarding the quiz from the previous lesson: "[When I] return quiz students took on Friday and go over correct answers, students will make corrections on their quiz for future use (studying for final) and ask any questions they have …" (Lesson Plans). Moreover her use of tests and quizzes was determined by school requirements in terms of student evaluation, as Danielle explained: "…just because the school does require us to do traditional final exams and I really think it is tough on the kids if they haven't had an exam throughout the year to prepare for then the final …." (Pre-observation Interview).

Knowledge of the dimensions of science to assess. In the case of Mendelian genetics, Danielle focuses her assessment on her students' ability to successfully determine or predict inheritance patterns based on information provided. As she outlined in her plan regarding the use of the worksheet in class:

Students will work independently on a review worksheet of dihybrid crosses; I will walk around to help students who need it (some have struggled with these; some picked them up quickly)

We will go over the dihybrid worksheet together; [we] will probably go over number 1 and 2, then give students a little more time before going over 3-5.

(Lesson Plans)

Knowledge of methods of assessment. Danielle showed awareness of both formal and informal approaches to assessment. However, while formal assessment is stated in her lesson plans, she does not make explicit her intention to assess, or act on the assessment, until asked in the interviews. At this point Cas4 highlights her intention to informally assess students as they work on the worksheets. She explained her approach as follows:

> I think a lot of the assessment will be as we're doing those dihybrid review worksheets; for example, me just going around helping them, we are going to go over them together as a whole, so a lot of that is of course informal assessment . (Pre-observation Interview)

However Danielle was not certain about her use of the worksheet as a formal assessment instrument, as she continued to explain: "I haven't decided. I may have the kids turn their worksheet in, even though we will go over in class, just so I can look at their work and see how they are writing it out." (Pre-observation Interview).

As far as formal assessment and evaluation of students, Danielle acknowledged that her use of tests was dependent not only on school requirements but also on the relative importance of the chapter. As she explained:

> I usually don't do end of unit tests. I do quizzes throughout and don't necessarily do a test at the end of every unit. I think that I will for this one, partial because it is going to end up having been a pretty big unit for this semester …. (Pre-observation Interview)

Factors influencing Danielle's knowledge of students and assessment.

Mentor teacher. When discussing her experiences teaching, Danielle highlighted the importance of her Davis. She recalled her mentor helped primarily in two aspects. Firstly she reminded her of the importance of revisiting topics from different perspectives, as Danielle explained: "… she really helped me to understand how to explain things from multiple viewpoints …" (Second Stimulated Recall Interview). In addition to this Danielle recalled the importance of her mentor in reminding her of the lack of prior knowledge the students had, as she stated: "She just helped me to understand. I think I had forgotten … how little kids know coming into high school with a (biology course) that they really haven't had much in the past …" (Second Stimulated Recall Interview). Danielle contrasted her experience with Ms. Davis comparing her personal experiences as a student and considering them, in a way, opposites. Danielle described her experience as a student as follows:

> …was all we did just kind of took notes from her and then she would give us a study guide which was exactly the format of the test, and we would take a test, and college is kind of like that too actually … .(Second Stimulated Recall Interview)

Coursework. Danielle acknowledged her ASTEP courses as the source of her understanding of the theoretical foundations of her teaching practice. However, she believed them impractical in terms of application. When discussing the importance of her ASTEP courses, Danielle elaborated:

> I understand why we had to do it, but doing it – all of the educational psychology and the theory and you know all of that. I understand that we need that background but it really didn't help me at all – but really the actual creating of lessons and learning different ways to teach a lesson – that was huge for me. (Second Stimulated Recall Interview)

This included the use of the 5E approach that was highlighted during the courses she took by pieces and adapted it to her view of students and learning. To do this, Danielle focused on keeping students engaged while not really considering the particular order of her lesson plans. As she explained about her planning:

> I don't necessarily when I am thinking about a lesson, think about doing it in the 5E order. But I do go back and see 'okay that is one idea I could do too, what's the first one, [to] keep their interest, engaged, and I do think about that and try and think 'okay what could I do initially?' But I really haven't found myself necessarily doing the 5E format. (Second Stimulated Recall Interview)

End of Program Exit Task

At the end of the ACP, Alice carried out the same three step process designed to collect data over her views and understanding of science teaching that she did in the beginning. In one step, she designed a lesson sequence to teach the topic of heritable variation to eighth grade students. In the following step, she was interviewed, using the information from the lesson plan, in order to further elaborate on her views and knowledge of science teaching as far as PCK is concerned. She also observed and reflected upon a video showing a reform-based science class.

Knowledge of learners. At this point in time, Danielle questions her view of students learning directly from her lectures. She emphasizes providing vocabulary to the students even in her initial activity, as she states when asked to explain this activity: "And it's a way to introduce a lot of the vocabulary associated with heredity" (Exit Task Interview). Yet Danielle also states that students are more likely to learn if they become familiar with the phenomena to be studied before new terminology is introduced. As Danielle explained while discussing how she would present concepts to students:

> And so the kids go through then and figure out whether they would have capital letters or lower case letters. And again, not use the word allele, not use the word genotype yet, because I think in an introduction, that's kind of too much at first. (Exit Task Interview)

Danielle recognized her struggle between this approach and the approach observed throughout the year. She recognized the difficulty she has in reconciling her views on learning with those presented in the ASTEP program and lets this come forth when discussing the video or a model lesson presented to participants as part of the data collection:

> I do not think I really realized how hard that is until [I] started teaching, and it is so hard not to jump in and try to explain what the kids are explaining and re-explain it. Two

years ago I did not even realize that, whereas now I have really picked up on that. (Video Analysis Task)

Danielle also highlighted the importance of group work in student learning, especially when it came to investigations even when addressing topics via direct instruction. She expressed this when discussing student learning as follows:

> So I think they work really well in small groups, whether it be doing an investigation like this, an activity, if it's a small investigation, even if it is more tradition teaching, but then kind of discussing the ideas in small groups, they just seem to work well that way. (Exit Task Interview)

Knowledge of requirements for learning. Danielle relates the topic of heritable variation to DNA and cell biology, as she explained: "But DNA for sure. And I think, I'd thought about doing genetics before DNA, but I think it's just logical to do DNA first and then genetics …" (Exit Task Interview). Danielle also believed that students existing knowledge, however simple, would provide her with a starting point for her plans: She assumed that:

> (Students) know that they get their genes from their parents. They do know that. And they know why they look similar to their mom and dad, and why they look similar to their siblings. I mean they definitely get that. Whether they know that for every single gene they have one from mom and one from dad and whether they know why their two parents with brown eyes could have produced their brother who has blue eyes – I don't know that they understand all that. I don't think they know how, but they know that that's all connected somehow. And I think that's about it, but that's a pretty good basis. (Exit Task Interview)

Moreover, Danielle acknowledged the importance of "… having (students) do an investigation or do a lab and figure stuff out before you really explain it" (Exit Task Interview].

Knowledge of student difficulties. While Danielle acknowledged the possibility of students having misconceptions, she did not recall any specific misconception on the topic of heritable variation. Danielle's view of students' difficulties focuses on complexity and level of abstraction of the phenomena and the themes to be addressed in class. She highlighted the case of polygenic traits while discussing her approach to the topic given her experience as a teacher in the following manner:

> … something like eye color and hair color – they really are very . . . and skin tone, and those are all examples of multiple alleles and polygenic traits, which we talked about both of those terms this year, and I use those as examples. … I just told them, when we get down to the chemical basis of it and the proteins that are expressed and all that, it gets pretty complex. (Exit Task Interview)

Knowledge of assessment. Danielle's new plan includes instances in which she intends to assess students. Here she states:

> I think (assessment) was something that until I had our classes and until I had my mentor program and everything, it's like I didn't even think about it. I didn't even think about, oh I guess I need something to wrap this up or some homework for them to do to see if they even get it. (Exit Task Interview)

Danielle intended to use student products as well as her observations of students working to gauge student learning. Given the time frame for the lessons in the exercise she planned to rely primarily on informal assessment. As Danielle explained when discussing her outline:

> I have included in here a little bit of discussion at the end of each day about, like asking the kids some examples of what their parents' traits are and where they think they got their traits. But a lot of this is really informal assessment, which I do a lot of though. A lot of it is just listening to the kids talk and hearing their ideas. (Exit Task Interview)

Knowledge of the dimensions of science to assess. Danielle does not point out at specific content or dimensions to assess in her students. She claimed "A lot of it is just listening to the kids talk and hearing their ideas" (Exit Task Interview).

Knowledge of methods of assessment. Danielle is aware of both formal, written assessment, and informal assessment. While she focused on her use of informal assessment, she acknowledged the importance of an initial assessment of student knowledge using a more formal approach, such as a quiz at the beginning of the class. Danielle explicitly recognized the importance of assessment when discussing the lack of it in her Entry Task plan, stating: "… so I've definitely realized the importance of lots of worksheets and mini quizzes and projects and everything" (Exit Task Interview).

Factors influencing Danielle's knowledge of students and assessment.

Coursework. Danielle acknowledged her ASTEP courses as an important source of her understanding of student learning allowing her to view it from a different perspective. She claimed: "I mean we definitely in this program, you know were really reiterating the whole exploring [of] an idea before you really learn about it, before explaining" (Exit Task Interview).

Teaching experience. Danielle drew significantly from her experience teaching, especially regarding her view of students as learners. She recalled addressing the topics of inheritance, meiosis and DNA as follows:

> I did DNA before (genetics) this year and it really seemed to fall into place pretty nicely. We did meiosis right before that, which kind of falls into this as well. But DNA for sure. And I think, I'd thought about doing genetics before DNA, but I think it's just logical to do DNA first and then genetics, it worked really well. (Exit Task Interview)

Her reflection suggests that she considers reformulating her beliefs as to how students learn based on the difficulties she has observed using the concepts presented in ASTEP as an alternative explanatory framework.

Entry vs. Exit Task

Many aspects of Danielle's views on students as learners and assessment remain unchanged at this point in the investigation. For the most part, she still emphasized lecture and the repetition of concepts as the way in which students learn. However, she was not aware of students' prior knowledge, and she still believed that it is possible that prior knowledge did not apply to foundational topics. Nevertheless her view on student difficulties, especially when discussing how students relate to abstract concepts, was guiding her consideration of the appropriateness of these beliefs. She considered teaching from macro to micro, where students observe the phenomena first, and then the teacher offers the explanations. Moreover she suggested that the views on learning presented in ASTEP are likely to provide a suitable framework to support her ideas.

As far as assessment is concerned, Danielle was the only participant to suggest the use of instances of formal assessment to gauge learning in her Entry Task despite not showing evidence of a coherent assessment framework. At the time of the Exit task, she had taken the experiences from her internship and teaching and incorporated them with the assessment principles presented to her in ASTEP thereby developing a coherent assessment framework that was explicitly included in her lesson planning. Student products and activities that she planned for in the Entry Task, she now clearly related to student assessment, and she shared the decision with us when recalling her thoughts from the Entry Task interview, “I didn’t even think about, oh I guess I need something to wrap this up or some homework for them to do to see if they even get it” (Exit Task Interview).

Third Semester as Full-time Teacher

Danielle continued to work at Fairview as a full time teacher very much in the same role as she had had the previous year. Her topic was cell division, including mitosis and meiosis, which followed cellular respiration. The central idea of the lesson planned was to explain the importance of cell division from the perspective of diffusion efficiency based on surface area-to-volume ratio.

Knowledge of learners. Danielle believed that students learned primarily by taking notes and listening to lectures She believed that, regarding the topic of cell division, students were essentially blank slates as they had not covered the topic in previous classes. Danielle stated “Oh, they don’t know a whole lot because they haven’t had anything about cell division before” (Pre-observation Interview).

Danielle believed that students learned better by “Doing a lot of review together like going through material, and then (rather than moving on) going back through it a number of times …” (Pre-observation Interview). Moreover she believed that visual representations, such as cell diagrams would help because “… the more visual and the more concrete something is at [age] 14 and 15 is just a lot easier to understand because again the ideas of cells are so small …” (Pre-observation Interview).

Knowledge of requirements for learning. Given that Danielle believed the topic of cell division was a foundational topic and that students had no prior conceptions regarding the concepts, she did not consider prerequisite knowledge or misconceptions in her plans or discussion. However, given the use of mathematics in her lesson, she wanted students to be capable of working with concepts of surface area and volume even though previous teaching experience led her to:

> … talk some about actually using a little bit a mass as far as surface area and volume. Some of the kids have learned that in math class, some have not, yet, so we will probably have to go over that. (Pre-observation Interview)

In addition, she believed learning would improve if the content would be readdressed, in some way or other, which could be meaningful to the students. In the specific case of cell division she intended to make it meaningful by establishing causality, that is, by giving the student a reason as to why cell division was necessary. As she explained

> I just think it's tough for them to understand why they are even, what the point of the unit is. They get so bogged down on just vocab[ulary] and things, like, so for them to understand the overarching reason that we are even learning about the material I think makes it a lot more meaningful to them. (Pre-observation Interview)

Knowledge of student difficulties. Danielle believed that, given the level of abstraction of the topic, that students would have difficulty with vocabulary:

> One thing that is really tough for these guys is just vocab[ulary] so just [by] getting more familiar with the vocab[ulary], they can get past that just to understand the actual processes and ideas without the terminology getting in the way; so just going over vocab

a lot so that it feels more comfortable to them is more helpful. (Pre-observation Interview)

In addition to the difficulty with vocabulary and the level of abstraction of the phenomena to be explained, Danielle assumed that students would have difficulty with the mathematical principles she believed necessary to understand them. She expected them to have "… a lot of trouble understanding why for surface area, we do it with cubes because that's the easiest one to demo with of, course, math wise anyway …" (Pre-observation Interview).

Knowledge of assessment. Most of the assessment Danielle carried out was informal and used in a formative manner. She viewed formal assessment, especially tests, more as summative or evaluation oriented exercises that impacted student motivation in class. As such, she reviewed quizzes and tests at the beginning of her lesson because "… (students) always want to know right away how they've done and so give them that opportunity. It's tough to have to sit and wait for a grade, you know; it's hard to focus and concentrate on other things" (Pre-observation interview). Moreover, formal assessment that was used in a formative manner was not used for evaluation; as she explained about the use of the worksheet intended for the lesson: "…[in] the next class period, we are going to go over the worksheet as a whole class, and it won't be graded for points; it will be completion because [this will be] the first time they've seen this" (Pre-observation Interview).

Knowledge of the dimensions of science to assess. While Danielle does not mention or discuss specific topics to assess, she intended to focus on her students' ability to solve the surface area-to-volume questions that were part of the worksheet. Danielle elaborated on her strategy: "… I would rather they just give them a try so we will go through the whole worksheet together, and let them correct what they have missed, and fix things …” (Pre-observation Interview).

Knowledge of methods of assessment. Danielle planned and discussed both formal and informal methods of assessment. Her informal approach consisted primarily of her being “…able to walk around, see how they are doing” (Pre-observation Interview). In the case of her formal assessment, this focused primarily on summative evaluation of student performance.

Factors influencing Danielle’s knowledge of students and assessment.

Teaching experience. Danielle primarily relied on her teaching experience from the previous year, especially as far as her understanding of students as learners was concerned. She shared with us her thoughts as she contrasted her assumptions from the previous class she taught:

> … even those ideas [about] what surface area is and what volume is – where last year I kind of assumed they knew those terms so we are going to go through that a lot more slowly – and then the idea of ratios – all of them seemed to have trouble with last year …. (Pre-observation Interview)

Coursework. Danielle highlights the fact that her views on learning differ from the views presented in her ASTEP coursework. She specifically pointed out the use of the 5E instructional model as an area where her approach was at odds with what was taught to her. Danielle viewed the 5E instructional model as a formal, structured, lesson approach that she did not always find useful. She explained her view of the 5E as follows:

> I think sometimes that can be a really useful approach, but not necessarily all the time, and I also – I have a really tough time with writing up a whole – not that I don’t think –

I don’t think most teachers write up a whole formal lesson plan.” (Stimulated Recall Interview)

The Development of Danielle’s Knowledge of Learners

Danielle shows an initial profile regarding students as learners based on the following notions:

Students are passive learners.

Relating to their own experiences improves student learning,

Students have observations but not explanations of natural phenomena.

Students have no scientific knowledge,

Curiosity improves student learning,

Most student difficulties arise from dealing with abstract notions that cannot be visualized easily because of the either the microscopic nature of the content or the generalization beyond their experiences.

As Danielle moved through the program she adapted these views of students based on the knowledge she acquired from her experiences both in class and as an intern. These initial concepts changed as follows:

Students are passive learners. At the end of the first summer in the program, when reflecting on her plan, she realized it was quite teacher-centered; however, the modifications she suggested still made students passive participants in the learning process. Throughout her first year and her experience in the internship as well as exposure to methods courses, she struggled with the notion of keeping students active in class and in their learning. She compared the 5E model, which tends to be highly student-centered, to the approach she and her mentor teacher used arguing that even though there were some differences, they stemmed from the lack of time needed to carry out a complete 5E cycle. In her second year as an intern, being responsible for her own class, which happened to be a CWC rather than an honors class, she fell back to working with students as passive learners. Her views of students as passive learners and lecturing and providing notes as well as repetition as forms of achieving her educational goals are evident at this stage. However her views of students being active in class do resurface both in the exit task and in the observation of her first class as a teacher having completed the program. This suggests that, while her methods courses might have successfully exposed her to a variety of pedagogical views that included student-centered approaches and inquiry, the reality of her class as a teacher presented her with a situation in which she believed the principles were inapplicable, and she resorted to the only experience she had known to work, which was her experience as a student. This suggested that both notions co-existed in her schema on student learners; the one we observed was dependent on the situation in which she was working.

Relating content to student reality improves student learning: This is a view that Danielle held throughout the whole process, and it seemed to facilitate incorporating the notion of hands-on experience as another way students learn better. This resonated with her mentor teacher's approach to teaching and was further reinforced by the activity-based components of her coursework. This also resonated with group work (in lab groups or in pairs). This made the 'talk to your neighbor' approach one of the easiest for her to incorporate into her teaching as it allowed students to share points of view that might be closer to their reality and not necessarily exactly what the teacher had told them.

Students have observations but not explanations of natural phenomena and no scientific knowledge. This notion relates to prerequisite knowledge and misconceptions. As she moved through the program, Danielle brought in the notion of misconceptions as part of her understanding of student prior knowledge, incorporating it as 'wrong knowledge' that needs to be corrected by her as a teacher. As she experienced teaching a sequence of courses throughout the first two years, she made more connections that allowed her to be aware of prerequisite knowledge for the topics to be taught. However, she did not necessarily transpose it to grade levels she had not experienced. Nevertheless, even at that end of the investigation, she still believed students came in with little prior scientific knowledge unless it was a topic like genetic engineering that had significant media coverage.

The Development of Danielle's Knowledge of Assessment

At the beginning of the investigation, Danielle showed no structured view of assessment. No instance for assessment was included in her lesson plan. However, upon questioning, she did share with us some of her views on how she would gauge student learning. Her initial views on assessment, summarized in Tables 25 and 26, were as follows:

No structured view of assessment: Danielle does not plan any form of assessment in either of the two days she planned for the Entry Task.

Methods of assessment: When asked to elaborate on how she would determine student learning, she suggested using the student products from the lesson plan (worksheets) or quizzes. However, she also considered using informal questioning of students to achieve this.

Dimensions to assess: When asked about this, Danielle focused on assessing conceptual understanding.

As Danielle went through the ASTEP program and experiences teaching, both as an intern and as a full time teacher, she developed a coherent framework for assessment based on the terminology and concepts she was exposed to during ASTEP. At the end of the first summer, she clearly distinguished formal approaches to assessment from informal ones and by

Table 23

Development of Danielle's knowledge of students as learners prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Students as learners	Students learn through lecturing. Motivation/engagement is important for learning. Motivation has a component beyond the scope of the classroom.	Motivation facilitates learning. Group work helps motivate/engage students. Inquiry = lab work = motivation.	Students learn with lecturing or note-taking. Activities serve motiva-tion/confirmation purposes. Motivation/engagement facilitates learning.	Students learn via lecturing/note-taking which precedes labs. Activities provide confirmation/repetition/motivation. Students learn better by repetition. Group work helps motivation. Grades motivate students. Group work fosters collaborative learning.
Prerequisites for learning	Students will not have prior knowledge about the content. Foundational knowledge must be presented to students (micro to macro).	Students will not have prior knowledge about the content. Foundational knowledge must be presented to students (micro to macro).	Prior knowledge, if it exists, is foundational and a prerequisite for learning. Micro before Macro.	Prior knowledge, if it exists, is foundational and a prerequisite for learning. Micro before Macro.
Difficulties in learning	Students will have problems with continuity from one lesson to the next.	Students will have difficulty with complex terminology. Misconceptions can hinder learning.	Students will have difficulty with complex terminology. Students will have difficulty with data analysis and use of graphs. Students will have difficulty with sub-microscopic phenomena. Inaccuracy of analogies.	Students will have difficulty with complex terminology. Students will have difficulty with sub-microscopic phenomena. Students will have difficulty with abstract concepts.

Table 24

Development of Danielle's knowledge of student as learners post-ASTEP

Entry Task	3rd Observation	4th Observation	Exit Task	5th Observation
Students as learners	Students learn via lecturing/note-taking. Students learn by repetition.	Students learn via lecturing/note-taking. Students learn by repetition. Students learn by sharing ideas and working in groups.	Students learn by lecturing to them. Vocabulary should be provided first. Group work is important to learning. Contradicting view that labs first can help lectures.	Students learn via lecturing/note-taking. Students learn by repetition.
Prerequisites for learning	Prior knowledge is foundational or non-existent.	Prior knowledge is foundational or non-existent. Students learn better if they can relate to their everyday lives	Students will have prior knowledge Prior knowledge is foundational Micro before macro	Prior knowledge is foundational or non-existent
Difficulties in learning	Students will have difficulty with complex terminology Difficulties with sub-microscopic phenomena Difficulties with abstract concepts	Students will have difficulty with complex terminology. Students will have difficulty with sub-microscopic phenomena. Students will have difficulty with abstract concepts. Students will have difficulties if concept has not been addressed enough	Aware of student difficulties in terms of relating one topic to another. Aware of the possibility of misconceptions (none stated). Students will have difficulty with abstract phenomena.	Students will have difficulty with mathematical calculations and concepts. Students will have difficulties with sub-microscopic phenomena, Students will have difficulties with abstract concepts, Danielle does not consider misconceptions.

the beginning of her first year as teacher, she used both approaches to inform herself of student progress. She used this information primarily for re-teaching purposes as she viewed quizzes and assignments as one of the many ways she could reiterate information presented to students. This view was held consistently throughout the remainder of the investigation. While the lesson plans consistently planned for instances of formal assessment, be it tests, worksheets or other assessment instruments, informal assessment planning was absent. However, in the plan she prepared for the Exit Task, Danielle explicitly considered the use of informal approaches to assessing her students suggesting that, while she is aware of the notion of informal assessment, it is not a priority in her lesson planning and probably a secondary idea in terms of her PCK.

As far as what dimensions should be assessed, Danielle focused throughout the investigation on conceptual understanding with an emphasis on vocabulary. There are two exceptions to this: Assessing the application of mathematical principles and calculations when the topic accommodated it, and diagnostic assessment of prior knowledge including misconceptions. While the first one is content dependent and thus likely to repeat itself under similar circumstances, the second one had a temporal timeframe: it occurred only during her time as a student in ASTEP. This is likely the result of the emphasis placed by ASTEP course on prior knowledge, especially misconceptions, which is important in the learning process as assumed in the 5E model. However, her intention to assess any form of pre-existing knowledge was no longer on her agenda after she started working as a full time teacher. It does resurface during the Exit Task data collection suggesting that, while it is not part of her PCK framework, it is a concept that she considered to be part of the learning process even though it had little relevance to her planning.

Table 25

Development of Danielle's knowledge of assessment prior to and during ASTEP

	Entry Task	End of Summer	1st Observation	2nd Observation
Views of Assessment	No assessment planned. No structured view of assessment. Considers informal assessment to gauge student learning. Considers the use of formal assessment formatively.	Initial awareness of standardized state testing. Considers using formal and informal assessment formatively.	Assessment to inform of student progress.	Plans for formal assessment only. Informal assessment is an afterthought.
Dimensions to Assess	Conceptual understanding	Conceptual understanding. Diagnostic test for prior knowledge. Summative testing for accountability in the form of state testing.	Formal diagnostic test for pre-requisite prior knowledge. Informal observation to gauge student progress. Assessment of conceptual understanding.	Conceptual understanding. Vocabulary.
Methods of Assessment	Suggested the use of both formal (worksheets/quizzes) and informal (questioning) methods formatively.	Informal assessment in a formative manner to gauge progress. Aware of formal summative assessment.	Distinguished between formal and informal assessment.	Formal assessment for grades. Informal assessment to gauge student progress and inform re-teaching.

Table 26

Development of Danielle's knowledge of assessment post-ASTEP

Entry Task	3rd Observation	4th Observation	Exit Task	5th Observation
Views of Assessment	Formal assessment provides an opportunity to re-teach/repeat concepts. Formal assessment is planned Informal assessment is an afterthought.	Formal assessment provides an opportunity to re-teach/repeat concepts Formal assessment is not planned for observation but is considered in the overall plan Informal assessment is an afterthought	Added assessment to lesson planning. Used homework as formal assessment. Planned to incorporate for informal assessment in class and labs.	Formal assessment used both formatively and summatively.
Dimensions to Assess	Conceptual understanding. Vocabulary. Ability to connect concepts from different topics.	Conveyed conceptual understanding. Applied algorithms to numerical problems	Conveyed Conceptual Understanding. Pre-requisite prior knowledge. Possible misconceptions. No specific aspects mentioned.	Conveyed conceptual understanding of mathematical principles. Calculations
Methods of Assessment	Formal and informal assessment used formatively to inform re-teaching. Formative assessment allowed for an opportunity to repeat concepts. Informal assessment needed to gauge student progress and inform reteaching.	Formal and informal assessment used formatively informs re-teaching. Formative assessment allowed an opportunity to repeat concepts. Informal assessment was used to gauge student progress and inform re-teaching. Considered using worksheets for informal assessment.	Used formal and informal approaches formatively and at various points in the lesson plan. Highlighted non-traditional forms of formal assessment. Emphasized observation to gauge student progress and determine re-teaching.	Informal assessment used formatively. Observation and questioning of students used informally. Formal assessment used mostly in a summative manner. Used alternative formal assessments in addition to tests and quizzes.

Cross-case Analysis

In this section I will present assertions that address the five sub-questions that guided this study.   These assertions are based on the major themes found to be common among the development of the participants' conceptions of students as learners and assessment.

Sub-questions

1. What conceptions of students as learners do ACP-track teaching interns have at different points in time, from the beginning of the ACP to the beginning of their second year as full-time teachers? (Answered by Assertion 1)
2. What conceptions of assessment do ACP-track teaching interns have at different times, from the beginning of ACP to the beginning of their second year as full-time teachers? (Answered by Assertion 2)
3. In what ways do the experiences in the ACP and teaching influence teaching interns' conceptions of students as learners over time, from the beginning of the program and into their second year as full-time teachers? (Answered by Assertion 3)
4. In what ways do their experiences in the ACP and teaching influence teaching interns' conceptions of assessment over time from, from the beginning of the program and into their second year as full-time teachers? (Answered by Assertion 4)
5. In what ways do the conceptions of students as learners held by ACP-track teaching interns interact with their conceptions of assessment throughout the

ACP and into their second year as full-time teachers? (Answered by Assertion 5)

Assertion 1: Participants believed students to be passive learners with no prior knowledge and focused primarily on providing information to them. Over time, participants kept these initial ideas but developed co-existing, reform-based notions of students as learners which they believed, based on their experiences, to be only partially applicable and, thus, were not prioritized in their schema.

The comparison between the entry task interview and the end of the first summer provided an initial glimpse into this development as interns compared their initial views on students with the views presented to them during their summer courses. At the beginning of the program, all the participants believed that their students would have no prior knowledge about the topic in the Lesson Planning Task. They all believed students to be passive learners and focused primarily on providing information to the students. Alice, Beatrice and Danielle also believed in the importance of engaging students to improve learning. All three highlighted the importance of using analogies or phenomena related to common aspects of students' life as a form of achieving this engagement, Danielle explained the importance of this clearly when discussing group work. As she elaborated regarding students working together: "… it keeps the students more engaged because I feel like if you're just talking to them they're just not as interested and listening. Whereas maybe if you're talking about them they're more excited because they're learning about themselves" (Danielle, Entry Task Interview). Alice actually selected to have her students document inheritance of their own ancestry. Her reasons for this personal linking with the past were brought out in her discussion on students relating what they learn to their personal lives:

> And it would give them an opportunity to get their parents involved and to learn more about their own family as opposed to just learning about heredity and genetics, and I think it's always easier to learn when you relate it back to your own personal life and situation. So that's what I kind of wanted them to get out of that. (Alice – Entry Task Interview)

Beatrice also added a component of entertainment as a way to keep students engaged. In this case, she chose an approach, which was entirely unrelated to her course content by designing a puzzle for the students. As she explained in her interview:

> I think they'd like how it is kind of like a puzzle, you know, it's not just spelled out there. It's not just matching – you have to look and it's kind of like a puzzle. It's something that spells out something, and it's kind of silly and really light hearted. I think sometimes science can get bogged down in facts and we forget to make it fun, because science is fun. (Beatrice – Entry Task Interview)

At the end of the summer semester, Alice, Beatrice and Danielle acknowledged some notions that indicated they considered student-centered approaches as ways to enhance student learning such as allowing students to develop their own investigations or fostering group work in class activities. Catherine acknowledged this view of learning but recognized she has difficulty believing it can be effective, mostly based on her experiences as a student. As she states: "[After] five years of college, (all of which have) been lecture based, it's kind of hard to get out of that framework" (Catherine – End of Summer Interview). All the participants highlighted the importance of student prior knowledge, a central aspect of student-centered learning by inquiry and part of their summer coursework. However, their primary emphasis was around this prior knowledge either being correct, thus allowing them to proceed with teaching, or it being incorrect and thus a misconception that needed to be addressed before learning could take place. Beatrice illustrated this quite clearly when discussing her views on assessment:

> It's just basically, like, finding out, like, what they know and then you like, hidden misconceptions they might have and, yeah, it's just kind of making sure everybody's on the same page. They do have those misconceptions, you can kind of address them, you know. (Beatrice – End of Summer Interview)

Throughout their time as interns and first-year teachers, participants developed their views on student learning based both on their graduate teacher education classes and their classroom experiences. All participants presented didactic views on teaching and learning at the beginning of their internships. This was reflected in the fact that their lesson plans focused on delivering content to students via lectures or notes. To them, students learn when the teacher provides them with vocabulary (Beatrice), when the teachers provide them with content (Catherine and Danielle) or when teachers make the connection between prior content and the new content via notes and/or lectures (Alice). While they all emphasized the importance of hands-on activities in learning, these are carried out exclusively as reinforcement activities after the content has been given to the students either via notes or lectures. In the case of Catherine, when asked how she believed students learned best, she would consistently reply with a statement similar to the one she provided in her first observation cycle pre-observation interview. "Because clearly if they're looking at going into the medical profession, they like hands on stuff.

So they really learn best with those activities" (Catherine – Pre-observation Interview, Fall 2006), yet the lesson plan would be structured so that, after collecting homework she would proceed to: "The middle of class [where] I will be lecturing, and students will be taking notes" (Catherine – Lesson Plans, Fall 2006). During the fourth observation cycle in Spring 2008, Beatrice answered the same interview question in a similar manner: "I think it helps that we do more hands on stuff" (Beatrice – Pre-observation Interview, Spring 2008). However, despite the lesson being activity oriented, she shared with us the content had been addressed in a previous lecture, as she summarized "… they'll already know about the three types of clouds the cumulus, the stratus, and the cirrus because we talked about that in the video. And we already talked about their shape, so they have been exposed to that" (Beatrice – Pre-observation Interview, Spring 2008). She made it clear that learning was expected to have occurred prior to the activity and what we observed was just designed to consolidate the knowledge students were assumed to have acquired in previous lessons. Danielle focused throughout the investigation on the importance of providing the students with vocabulary. Despite arguing that students need to "… have information given to them several times, if possible in different ways" (Danielle - Second Stimulated Recall Interview, Fall 2007), she always gravitated to delivering vocabulary at the beginning of the topics, as she shared with us when discussing the best way to learn abstract concepts in cell biology in the Fall 2008 observation: "… you just really have to slow down and reinforce the ideas quite a bit because it is a lot of vocab and things for them to take in at once" (Danielle – Pre-observation Interview, Fall 2008). Alice is similar in a way to Danielle and consistently demonstrated a belief that vocabulary was to provide the groundwork for learning by hands-on activities. In her own words, in reference to her plans when discussing her Fall 2007 lesson observation,

> … this is the groundwork, the framework, the terminology–all that stuff and them making those note cards. Those are all the terms that are going to right now not mean something to them, but when we actually put it all together, they're all going to start to mean something to them (Alice – Second Stimulated Recall Interview, Fall 2007).

While group work was seen as important by Alice, Beatrice and Catherine, they focused on it from a didactic, repetitive perspective. Alice used group work for students to repeat information to each other, while Beatrice and Catherine used it to keep students engaged either by being entertained or allowing them to 'take a break' (Catherine, Pre-observation Interview, Spring 2007).

The comparison between the Exit Task activity and the semesters immediately preceding and following it provided a clear view of the co-existing, albeit non-competing, conceptions of students as learners. During the Summer Exit Task data collection, participants presented views and ideas consistent with student-centered approaches to teaching. Alice and Danielle highlighted the importance of prior knowledge in developing new knowledge (Exit Task Interviews) and the importance of exploring these conceptions (Danielle – Exit Task Interview). Danielle also highlighted the need to be aware of different approaches to teaching a topic to help students learn from different perspectives as opposed to simple repetition (Danielle – Exit Task Interview). Beatrice, Catherine and Danielle discussed the importance of knowing and understanding the source of student misconceptions on heritable variation prior to teaching (Exit Task

Interviews). Alice, Catherine and Danielle highlighted the importance of group work so as to either encourage them to share ideas (Alice) or to engage and motivate students (Catherine and Danielle). Furthermore, they all highlighted the importance of relating content to be taught to student prior knowledge and experiences to enhance learning (Alice), or "… get them hooked" (Beatrice – Summer Exit Task Interview).

Data collected in the first fall semester following the Summer Exit Task presented the other side of the co-existing conceptions of student learning. The most salient example was Danielle who first emphasized that students "… do not learn by repetition" (Danielle – Summer Exit Task Focus Group) but rather that the teacher "… leads students to discovery" (Danielle – Summer Exit Task Interview); however, Danielle planned an activity that focused on repetition for learning. In this case, she planned to start the topic on cell division by just "… [talking] about why it is that cell divides like what [is] the need for cell division" (Danielle – Pre-observation Interview, Fall 2008); and then, she repeated the same concepts with an egg analogy as a way of reinforcing the idea in a different manner.

Beatrice focused her teaching on giving notes while acknowledging that this is the way in which learning takes place after students are motivated via group work. Catherine also showed an approach consistent with her didactic view of students in planning a teacher-centered lecture, even acknowledging it was at odds with the principles addressed in her ASTEP courses. At the time, Catherine had nearly finished her first year as a full time teacher at Ellis High School; she shared with us that she had "… mastered the teacher oriented [approach] definitely. I can give a lecture, and now I'm looking for more of a challenge" (Catherine – Second Stimulated Recall, Fall 2007).

Participants claimed that they believed their students learned best when exposed to hands-on activities, working in groups and in general taking an approach they believed analogous to the 5E model presented in ASTEP. Their plans reflected a view that was different from the model proposed by ASTEP. The hands-on activities they planned were either confirmation activities or interactive exercises designed to motivate students or help them regain focus as opposed to providing opportunities for exploration or elaboration. Moreover, all activities described as hands-on by the participants followed lectures or note-taking on part of the students. As far as group work was concerned, it either served primarily as a way of making classes fun (Beatrice), provided a form of repeating content in a different manner (Alice and Danielle) or was simply the consequence of having lab-work (Catherine).

In essence participants added reform-oriented, student-centered conceptions of students and learning to their knowledge base. However, this new knowledge was not prioritized, and it was considered applicable only within the context of the experiences in their ACP program and not in their day-to-day teaching.

Assertion 2: Participants expanded their conceptions related to assessment without forming a cohesive, integrated view on assessment as part of the learning process. This lack of integration results in personal views on assessment being trumped by institutional and state requirements, and informal assessment becomes an afterthought in lesson planning. (Assessment is used as a form of reviewing content).

While the participants initially did not consider assessment as a component of their lesson planning, by the end of the first semester, they were aware of the importance of gauging student learning. After the first summer, participants distinguished formal from informal assessment but related the former to either diagnostic or summative purposes while the latter was referred to for formative purposes. None of the participants mentioned assessment as part of their initial lesson plans. However, when prompted as to how they would determine if students were learning, they all mentioned informal approaches to assessment as the primary way to gauge student learning mostly through questioning. In addition to this, Danielle and Catherine considered the use of student products such as worksheets or quizzes and tests, respectively. At the end of their first summer courses, participants could easily differentiate between formal and informal assessment, acknowledging the latter as part of their interaction with students.

At the beginning of their internship, three of the four participants highlighted the importance of formal, diagnostic assessment of prior knowledge. They discussed the use of informal assessment, primarily through questioning and observation of students as formative strategies for assessment, which further established the formal/summative and informal/formative relationships. This dichotomy was clearly present in Catherine's views of assessment in her second semester of internship when she defined an alternative form of formal assessment–a worksheet–as informal. As she explained how she would "use the worksheet to informally assess [the students]" and that she had "… no formal assessment on this yet. There will be a formal assessment with the test, but for these two days there will be no official formal assessment" (Catherine – Pre-observation Interview, Winter 2007). However, by her first semester as teacher, she acknowledged that non-evaluative assessment was an afterthought in her lesson planning.

As with Catherine, Alice and Danielle also highlighted the dichotomy between formal/ summative and informal/formative assessment throughout their internship/teaching semesters. While they initially sought to incorporate formal, formative instances for assessment, as time passed, their formative assessment became exclusively informal and was not included in their planning. Formal assessment was functionally equated to student evaluation and associated with accountability.

By the final data point, assessment for each participant was shaped primarily by their school context. Participants returned to their initial assessment paradigm in which explicit planning of assessment was missing from all the lesson plans and was only discussed when prompted, and informal assessment was an afterthought in lesson planning. Assessment was built around the need to address institutional goals and was an afterthought in the teaching process. Alice and Catherine built their assessment around the need to satisfy both state and institutional standards, as well as student evaluation. Alice, as with the previous spring semester, considered formal assessment necessary only in the case of addressing the State standards. Given that they were both at private institutions state testing was not required. Beatrice and Danielle both used formal assessment in a summative manner focused primarily on student evaluation.

Essentially the participants' views on assessment showed three aspects: First, in terms of methods, the classification provided by ASTEP provided a suitable nomenclature for them to accommodate their views. However, each of them accommodated this based on her initial views of assessment taking into consideration the priorities of the institutions they worked at. That is, their intended use of assessment tools, be it for formative or summative purposes, was influenced by school and state policies. However if no such regulations existed, it is possible that they were likely to disregard the need for assessment in their planning and, if inclined to gauge student learning, their preference would quite likely lean toward informal approaches.

Assertion 3: Over time, participant knowledge of students was influenced by three factors; their experiences as students, ASTEP coursework, and the context of their teaching/internship. A synergistic interaction between their experiences as students and the context of their coursework or internship/teaching provided support that favored the stability of their initial conceptions.

Throughout the study, participants were exposed to different contexts that challenged their views on learning. In each instance, they sought to reconcile their existing understanding of students as learners with their experiences over time. The first instance of this was observed in the transition between the first and second data points. In this case the participants, when discussing their initial lesson plans at the end of first summer of coursework, emphasized plans that were harmonious with the learning concepts addressed during their summer courses. All participants mentioned, to varying degrees, the usefulness of student-centered approaches based on inquiry as ways of improving student learning. For example, Catherine mentioned little usefulness of the approaches presented in ASTEP during the Fall 2007 observation as she discussed her views of the students' ability to carry out inquiry based activities: "it is definitely a cook book activity … I don't think they are [ready for a higher] level of inquiry" (Catherine – Second Stimulated Recall Interview, Fall 2007). Moreover all the participants referred back to their experiences as K-16 students as reference points, which allowed them to compare the ideas presented in ASTEP, especially after the first semester of summer courses. As Catherine explained when comparing the expectations of her summer coursework to her experiences in college as a student:

> Getting around the room, doing stuff, going and getting up and looking at things and again, just staying away from the main lecture base, which is what I've had. Five years of college–it's all been lecture based. It's kind of hard to get out of that framework. (Catherine, End of Summer Interview)

Beatrice shared the same kind of experiences when discussing her beliefs about the role of the teacher in the classroom at the beginning of the program, "I would say probably especially in college where they just lecture the whole time" (Beatrice Entry Task Interview).

As students progressed in the program, their work, both in their courses and as interns, provided them with new experiences against which to compare their view on learning. In the Fall 2006 observation, Alice equated labs and group work to inquiry, in her own words when referring to the class dynamics in her internship: "… it's probably pretty, you know, like inquiry-based. We do a lot of kind of group work and labs" (Alice – Second Stimulated Recall Interview, Fall 2006). Danielle highlighted her belief on the limitations of the setup in the first semester of her first year as a full time teacher by referring to the need for more time to carry out inquiry-based work, as she stated when asked to discuss alternative ways of teaching her lesson plan, "It would've been nice to do. Just timing; with having a 3 day week last week and only seeing some of the kids once, it just didn't work" (Danielle – First Stimulated Recall Interview, Fall 2007). They each integrated these views into their own pre-existing notions of learning, highlighting the aspects of inquiry that more closely related to their initial beliefs. Alice, Beatrice and

Danielle highlighted the importance of student engagement in learning along with the initial component of the 5E instruction cycle presented to them in their methods course. Catherine highlighted the importance in getting students focused and motivated to help them learn. Beatrice reaffirmed her beliefs on the importance of group work in student learning by developing a rational explanation as to how interaction among small groups of students allowed them to '… brainstorm and exchange ideas" (Beatrice – End of Summer Interview).

As participants continued to progress through their program and took over intern and teaching responsibilities, they further developed their understanding of students as learners. Beatrice designed her lessons and focused primarily on her belief in the importance of group work while Alice, Catherine and Danielle focused on lecture based approaches and notes to guide student learning. Context played an important role in the development of their understanding of students as learners. For Alice and Danielle, their teaching context provided strong support for their didactic beliefs of student learning, reinforcing the notion that students learn primarily from lecturing or taking notes. While they stated that they believed students learn better in hands-on activities, these activities were usually followed by lectures; moreover, they were guided activities, at the conclusion of which, the teacher provided summarizing notes. Alice eventually obtained a full-time teaching position at the school she interned. She was also assigned a different class, a non-honors class. This experience served as reinforcement to her didactic views on teaching. The lack of motivation on the part of her students led her to conclude that student-centered approaches "… do not work with everyone" (Alice – Pre-observation

Interview, Fall, 2007). Hence, her first full-time position provided support for a teaching approach that was based on lecturing and providing students with summary notes.

While Danielle changed schools after graduation, in both cases, she was exposed to didactic mentors in a context that supported the teacher-centered approach to teaching. She believed that student learning takes place by repetition and while she used hand-on activities, like Alice, these were designed as follow-up and reinforcement to prior lectures and notes.

On the other hand, Beatrice experienced two different institutions that presented different emphases on learning. She started at Bellamy Middle School, where emphasis was placed on external school testing. The didactic approach presented by her mentor conflicted with the student-centered approach presented by her summer courses. She attempted to reconcile her views yet indicated a preference for the didactic aspect because "… it works in a real classroom …" (Beatrice – Second Stimulated Recall Interview, Fall 2006). Yet upon changing schools for the second semester the conflict was reversed: Carson High School focused on the use of technology and inquiry to guide student learning, which challenged Beatrice's didactic views on learning and aligned more closely to the views presented in her ASTEP program. She struggled to reconcile her paradigm with the teaching approach required of her. However, she attempted to work around the issues from her personal perspective by, for example, providing vocabulary prior to class activities (Beatrice – Spring 2007, Pre-observation interview). Her planning further emphasized prior knowledge either as a prerequisite for understanding or as misconceptions. When Beatrice changed schools the following semester, the institutional emphasis on inquiry was removed from the context and a stronger emphasis was placed on external student evaluation by state testing. To accommodate the shift in context, Beatrice aligned her planning and discussion of lessons with the didactic view she presented at the beginning of the program. As a result of this, she placed less emphasis on prior knowledge and misconceptions, as well as on student difficulties. She focused on the importance of student engagement, primarily via group work, and on providing students with the knowledge and vocabulary she believed necessary to understand the topics at hand.

For Catherine, her initial experience as an intern prompted her to try out the approaches discussed in her ASTEP courses. She was initially disappointed at the explicit dislike of her students for her lecturing approach during her first semester; hence, she gained encouragement from her ASTEP PCK project during the second semester, and attempted to take a more student-centered approach to teaching (Catherine – Second Post-Observation Interview, Fall 2007). However, upon finishing her ASTEP coursework and moving to Ellis High School, the stimulus provided by ASTEP no longer seemed applicable. Her new teaching context, which focused on pacing the delivery of content evenly throughout all classes via a didactic perspective, resonated and reinforced the didactic views on learning she presented at the beginning of the program. In addition, any views about learning that were inconsistent with the participants' prior views of students and learning were set aside and discarded (at least from an operational perspective) from their PCK. The salient example across all cases was the disassociation related to prior knowledge and misconceptions. These concepts were incorporated into the planning or elicited in interviews only at four points: during End of Summer Interviews, the first and second internship observations and the Exit Task Interviews.

These circumstances occurred when the influence of ASTEP was greater either because of being exposed to coursework or because they were in the presence of their former instructors planning a hypothetical scenario under controlled conditions (See Tables 11, 15, 19 and 23).

In essence, after being exposed to the views of teaching and learning in ASTEP with an emphasis on the 5E model, each participant rationalized the components of the model, their experiences as interns and teachers in a manner that was coherent with their initial beliefs about teaching and learning. For example Beatrice had initially emphasized the importance of group work and student motivation; thus, the aspects of the 5E that were more appealing to her was the group work carried out during the engage phase of the 5E. This resonated with her views on learning, and she acknowledged during the End of Summer Interview when discussing her original plan: "So I'd like to have some more group work in there, which is a really good way, like science as inquiry and group work really work well together. So I like both of those" (Beatrice – End of Summer Interview). Danielle equated inquiry to students taking complete responsibility over their learning, but this did not resonate with her views of learning based on lecturing and notes; thus, she rejected the view and argued that "… it just doesn't work because it's way too much, putting way too much responsibility in the student's hands, and I don't think they even like it" (Danielle – First Stimulated Recall Interview, Fall 2007).

Assertion 4: Over time, participants developed a personal framework about assessment that integrated their initial understanding of assessment with the theoretical framework provided by their coursework. This framework shifted over

time and, at different points in time, its functional form was based on coherency with the context of the institution at which they taught.

As with their views on student learning, participant views on assessment showed the development of competing notions about the importance of assessment in the learning process. The development of their knowledge of assessment was reliant upon consistency with the predominant context at the time of the interview: summer classes or teaching/internship. This process was essentially the same for all participants initially. None of them showed an organized view of assessment during the initial data collection. In all four cases, none had planned any form of assessment and their views had to be elicited in the interviews (See Tables 13, 17, 21 and 25). Moreover, all but one participant defaulted to informal approaches to assessment upon being questioned. The exception was Danielle. She was the only one to suggest the use of student products as assessment instruments. In her case, that instrument was a worksheet. The views of assessment presented in the ASTEP courses reinforced this notion, and she developed a clear view of assessment over time that was consistent with her initial views of assessment (See Tables 25 and 26). Other participants, (e.g., Catherine) showed a similar form of incorporating the views of assessment presented in ASTEP into their personal views. However, in this case, she redefined the terminology employed in ASTEP to align with her views of assessment. She considered testing to be a form of formal assessment as she stated: “but I kind of take formal as a paper and pencil test or things you’re handing in” (Catherine – Second Stimulated Recall Interview, Winter 2007).

Another example of assessment conceptions changing based on experience was Beatrice. She probably experienced the greatest shifts in terms of the assessment concept emphasized by the schools, as she went from a school that emphasized state standards (Bellamy Middle School), to a school that emphasized inquiry and the process of learning. Her declared views on assessment reflected the emphasis of the institution responsible for her employment at the time of the interviews (See Table 17). Furthermore, Beatrice returned to Bellamy Middle School and the influence of the state standards on her assessment goals was clearly reflected both in her Fall 2006 and Fall 2007 interviews. In the former she responded as to the importance of the state standards in her planning and assessment. She replied “Well right now they’re like that [state standards] and the actual content in the textbook is all I have to go on, so I guess they do it a lot” (Beatrice–Second Stimulate Recall Interview, Fall 2006) while in the Fall 2007 interview, she laconically stated her reason for choosing certain topics to assess as: “That is what the GLE’s told me to do” (Beatrice–Pre-observation Interview, Fall 2007). Alice provided a situation similar to that of Beatrice, in which the state standards essentially prescribed the dimensions that were important to assess, be it laboratory skills (Winter 2007 and Fall 2008), analysis skills (Fall 2007) or content as required by the school and state standards (See Tables 13 and 14). However Alice added an additional twist to this claim in that one of the lesson plans she taught was not part of the required state standards. In this lesson, she did not consider the use of formal assessment, defaulting to informal assessment, as was the case in her original lesson planning task. As she explained to us when discussing the assessment of said unit; “[We] don’t take a test over this unit and this particular unit is not part of our GLE’s or our standards that we have to teach” (Alice, Pre-observation Interview, winter 2008).

Assertion 5: The integration of knowledge about students and learning is reliant upon coherency between different views of learning and assessment to which the participants are exposed. This coherency determines if and how knowledge in these areas is incorporated into their personal views of teaching and learning. Competing conceptions, while evident in the interviews, are reconciled based on the context.

At each point in time, participants' plans and interview discussions presented views on assessment and student learning that were coherent with each other. At the beginning of the program, all participants presented didactic views of students as learners, viewing them as blank slates and planned on using lecture-based, teacher-centered, approaches. None of them considered using instances of assessment as part of the learning process save when prompted, and even then, formative assessment was mostly equated to informal questioning of students. Upon completing their first summer courses, all the participants explicitly acknowledged, and differentiated between formal and informal assessment approaches, recognizing the importance of them both as diagnostic instruments and formative assessment approaches. Participants discussed the use of formal, formative assessment mainly in the form of diagnostic assessment. They did this mostly in order to determine pre-existing knowledge, primarily in the form of misconceptions. This is consistent with the need to address misconceptions presented to them over the summer as well as the way in which the idea of prior knowledge had been incorporated into their didactic framework as discussed in the first assertion (See Tables 11, 13, 15, 17, 19, 21, 23 and 25).

Throughout the data points collected during the participants' internship and initial teaching, shifts in the participants' views on assessment and learning developed coherently with each other and the most influencing factor was the context in which the internship/teaching takes place. In the case of Catherine and Beatrice, both initially worked to include instances of formative assessment throughout their planning, but by the time their first semester as teachers was well underway, their plans no longer considered this approach to assessment. Furthermore, given that their institutional goals were built around the State Standards, their approach to assessment was also guided by these. There was no dissonance with their knowledge of learning because this focus on formal, summative assessment was coherent with the didactic views of learners, which they presented throughout the process. Alice also had a view of assessment coherent with her beliefs on student learning, seeing formal, summative assessment as relevant only when related to state or institutional goals. On the other hand, Danielle worked at a private school where state testing was a non-issue. However, both Alice and Danielle equated informal assessment as formative and intended to guide instructional decisions in a manner consistent with their didactic views of students. Both Alice and Danielle believed that students learn by repetition; as such, they discussed their assessment approaches as means to either repeat/review information or as checkpoints to determine if the content needed to be re-taught.

However, the analysis of the Summer Exit Task and the following semester showed that participants held competing views of assessment as well as different views on student learning by the end of their first year as teachers. All participants planned and discussed the use of formal and informal assessment approaches, and they used both in a summative and formative manner. This discussion was consistent with the student-centered views on learning they presented and discussed in their lesson planning, showing views on assessment and learning that, while different to those presented in the previous interviews and observations, were consistent with each other. Nevertheless, the level of dissonance was different among participants. While all relied on informal assessment to guide instruction, Beatrice and Catherine showed the strongest didactic inclination, using the assessment data to act by direct instruction either on misconceptions or to re-teach the content. On the other side of the spectrum, Alice showed greater flexibility by considering the use of other ways to address the content. However, the observations and interviews following the Summer Exit Task were inconsistent with the progression observed from the semester prior to the Summer Task. In all cases, the participants showed views of learning and assessment that were didactic and consistent with each other. That is: students learned by lectures, notes and repetition with hands on and group work activities providing reinforcement or a change of pace/motivation while informal assessment served exclusively as a formative purpose with formal assessment being either a diagnostic or a summative evaluation.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

This investigation sought to look into the development of prospective teachers through an ACP and into their first two years of teaching. It focused on two aspects of their knowledge for teaching: their understanding of students as learners and their knowledge of assessment. Furthermore, it sought not only to determine what it is that teachers learned throughout this process but also to determine any mechanisms, situations or experiences that influenced the development of these aspects. To this purpose five sub-questions were addressed: 1) What conceptions of students and their learning do teachers have at different points in time, from the beginning of the ACP program to the beginning of their second year as full-time teachers? 2) What conceptions of assessment do teachers possess at different times from the beginning of their post-baccalaureate program to the beginning of their second year as full-time teachers? 3) In what ways do their experiences in the ACP and teaching influence the change in understanding of students as learners over time from the beginning of the program into their first two years of teaching? 4) In what ways do their experiences in the ACP and teaching influence the change in knowledge of assessment of student learning over time, from the beginning of the program into their first two years of teaching? and 5) In what ways does the knowledge of learners interact with the knowledge of assessment throughout this process?

In this chapter I will include a summary of the findings as they pertain to each of the sub-questions, a comparison of these findings as they relate to the literature on the relevant topics as discussed in Chapter Two, the implications of the findings for teacher preparation and policy, recommendations for teacher preparation and policy, and finally conclusions.

Summary of Findings

Sub-question One:

What conceptions of students as learners do ACP-track teaching interns have at different points in time, from the beginning of the ACP to the beginning of their second year as full-time teachers?

This question sought a description of participants' knowledge of students and their learning at different points in time throughout the investigation. At the beginning of the program, all four participants had clear teacher-centered views of students as learners. They initially viewed their students as blank slates and focused primarily on lecturing as the primary way of achieving their goals. Activities that they considered student-centered, such as hands-on, experimental work, consisted mostly of cook-book style labs and activities that served to confirm material presented to students in lectures. Alice and Danielle consistently emphasized the importance of providing students with the appropriate foundational knowledge before leading them into hands-on activities. These notions were found consistently throughout the various data collection exercises in the investigation. However, all participants showed, at various points alternate, albeit unconsolidated, views on student learning. Alice, Beatrice and Catherine emphasized, during the interviews, the importance of students interacting among themselves and sharing ideas during group work. However, the activities they planned and carried out provided little, if any, space for such interactions. The activities planned were mostly confirmatory and followed prescribed procedures allowing for little discussion on the part of the students. Moreover, in some cases, as with Beatrice, they would occasionally serve as motivation/entertainment exercises. All participants at some point or other during their first year in the program stated the importance of student prior knowledge in learning; however, the idea seemed to gradually return to the direction of their initial perception that relating content to student experiences would help convey content that, due to its abstract nature, was difficult for students to understand. Their concepts of prior knowledge were mostly prevalent at the time when they were simultaneously teaching and attending classes at ASTEP. While prior knowledge became an afterthought after the participants completed their ASTEP coursework, questions on this subject were elicited again in the Exit Task. This suggests that the different views existed in their mental schema as alternative yet inapplicable views of learning.

Sub-question Two:

What conceptions of assessment do ACP-track teaching interns have at different times, from the beginning of ACP to the beginning of their second year as full-time teachers?

Unlike their view of students at the beginning of the program, all participants showed no structured views on assessment. None of them planned any form of assessment in their lessons and, upon being asked, all except Danielle defaulted to informal questioning as a way of gauging the learning that took place in their classes. After completing their first courses, participants showed an increased awareness of the importance of gauging student learning. Moreover Alice, Beatrice and Danielle eventually distinguished informal and formal methods of assessment quite clearly, while Catherine found it harder to view informal assessment as a valid form of gauging student learning. During their participation in ASTEP courses and internships, the combination of experiences allowed the participants to develop coherent personal views of assessment. However, save for occasional exceptions, assessment, as a part of lesson planning, remained an afterthought. This was especially true when it came to formal assessment. Nevertheless, upon prompting, Alice, Beatrice and Danielle would consider the use of student products that resulted from their planned activities as ways to determine student learning during their activities. Participants also showed a shift in views regarding assessment as they transitioned from interns to teachers. As interns Alice, Catherine and Danielle tried to incorporate both formal and informal assessments formatively; however, as they moved into teaching formative assessment became almost exclusively informal while formal assessment became primarily quizzes and tests.

Sub-question Three:

In what ways do the experiences in the ACP and teaching influence teaching interns' conceptions of students as learners over time, from the beginning of the program and into their second year as full-time teachers?

All participants began the program with teacher-centered notions of students and learning that were based primarily from their personal experiences as K-16 students. The ASTEP program provided them with experiences that exposed them to situations in which their views of learning were challenged by an alternative view that, to the participants, seemed to be quite at odds with their preconceived notions. As they struggled to reconcile both schemas, participants incorporated some components of the views presented in ASTEP by virtue of how strongly they resonated with their pre-existing notions resulting in them showing awareness of different views of learning but prioritizing one of them. For example Beatrice was a strong believer in the importance of group work and, during her first summer semester and her internships, she highlighted the group work aspects of the ASTEP courses. However, she consistently highlighted the role of these activities in increasing student motivation rather than fostering the exchange of ideas or challenging pre-existing conceptions students might have. Alice and Danielle also highlighted the importance of hands-on approaches, as presented in ASTEP, in helping students develop an understanding of the concepts being addressed. However, rather than viewing it from the 5E perspective, in which these activities could be used either to challenge pre-existing conceptions or to elaborate on newly presented ideas, both participants used activities as confirmation of content delivered by lecture and note-taking – an approach that resonated with their initial views of learning. Moreover, in the cases of Alice, Beatrice and Danielle, the teacher-centered approach they observed in their mentor teachers further reinforced the validity of their own views. This resulted in reconciled views that gave priority to their initial views while setting aside those presented by ASTEP. This reconciliation was acknowledged by them when discussing their perception that the 5E approach might not be something applicable to all students or that it only worked under the controlled conditions presented in their ASTEP class activities. Essentially when developing their understanding of students and learning, participants would question their initial views only as far as contradicting evidence was present in their immediate environment, such as the ASTEP classroom, mentorships, etc. They would focus on what they perceived as the most relevant model of learning based on the context in which they found themselves. They would then reconcile different views by prioritizing those that aligned with their own initial views while setting aside, but not entirely discarding, alternative views presented in their coursework.

Over time the mental models that constituted the PCK of the participants showed evidence of shift based on their interpretation of experiences that either challenged or supported their views of learning. In most cases, the ASTEP coursework challenged their initial views of learning in a manner that caused dissatisfaction with their existing mental schema. However the ASTEP views were not always consistent with the participants' experiences later in the program. In fact many of the experiences the participants encountered as teachers would support their initial mental model thus resulting in the apparent shift back to the initial views. However claiming that such back and forth shift existed would assume that the initial observation actually resulted in a substantive change in the initial model. This would imply that the epistemological commitments and overall belief systems had re-arranged into a new schema (Posner et al., 1982). The data from this investigation does not support this, rather the participants would still be evaluating the potential of the new framework to provide support for their perceptions and experiences on teaching and learning.

Sub-question Four:

In what ways do their experiences in the ACP and teaching influence teaching interns' conceptions of assessment over time from, from the beginning of the program and into their second year as full-time teachers?

Of the two components of PCK addressed in this investigation, assessment was showed as the least important initial structure as far as views and connections to the various aspects of teaching were concerned. From the beginning to the end, assessment was mostly an afterthought when it came to lesson planning, be it summer data collection or classroom observations. Participants organized their initial views of assessment on those views presented by the ASTEP coursework. However, like with their views of students and learning, the pre-existing notions served an important role in the way in which the views of assessment were organized. Beatrice and Catherine showed clear examples of this when using the terminology employed in their coursework to explain their views of assessment, redefining the terminology employed in class to explain their views. While the nomenclature and classification of assessment types and approaches was used comfortably by all participants except Catherine, the views of the application of assessment were shaped not only by the ASTEP coursework but also by both the internship and teaching contexts. Unlike the case of students and learning, where participants had a preconceived notion of learning, in the case of assessment, ideas were shaped by rough initial views based on the context in which the participants were placed and according to their own methods of processing these experiences. The context experienced by the participants shifted from a combination of ASTEP coursework and internship to full time classroom responsibilities. In a manner similar to the development of their knowledge of students and learning, participants emphasized the aspects of assessment that resonated with their initial views. While no participants considered assessment in their initial planning task, Alice, Beatrice and Catherine all suggested informal questioning as a way to gauge student learning. Throughout the ASTEP coursework, students were exposed to the use of both formal and informal approaches to formative assessment. In this case, all participants were comfortable addressing the use of informal and formal approaches in formative assessment. However, as they experience teaching full time, their view of assessment was influenced less by their coursework and more by their institutional context. Furthermore, in the case of Alice and Catherine even state prescribed objectives were considered when discussing their personal assessment objectives. This shift results in a re-categorization of ideas whereby formal assessment is viewed almost exclusively as summative assessment and oriented by institutional goals while formative assessment is carried out informally and usually unplanned. In this case, the school context resonated more with the initial views where assessment was considered an external consideration and for the most part disconnected from the learning process save to verify the achievement of institutional goals.

In contrast to what was observed with the participants' views on learners and learning, when it came to their views of assessment, the participants had a less organized mental schema. This schema was based on their general understanding of assessment, mostly summative, as opposed to learning-oriented assessment. As such their perceived limitation, and thus dissatisfaction with their mode, was triggered with the first ASTEP courses. This resulted in the re-organization of their schema early in the program in a way that allowed them to construct a new framework to explain the role of assessment in the learning process. However this initial accommodation of the schema (Vosniadu, 1994) to include the notions of assessment provided by ASTEP was based almost exclusively on the incorporation of new terminology to explain their initial views. In a manner similar to that observed with their conceptions of students as learners, participants experiences later in the program tended to support their initial conceptions of assessment. However in contrast with what was observed with their knowledge of learners and learning the use of the terminology for assessment, albeit adapted to their personal definitions of assessment, clearly became a part of their re-arranged schemas.

Sub-question Five:

In what ways do the conceptions of students as learners held by ACP-track teaching interns interact with their conceptions of assessment throughout the ACP and into their second year as full-time teachers?

The preceding summaries focused on the fact that coherency with either pre-existing notions or contextual situations dealing with either prior or current experiences facilitated or limited the incorporation of knowledge presented to participants into their understanding of teaching and learning. Personal experience was the most influential factor as far as this is concerned. Another factor was the complexity and internal coherency of existing conceptions. For example participants' views on students and learning stemmed from years of experience as K-16 learners and were backed by this. As such while their experience with 5E learning, as presented by ASTEP, was convincing enough to make them consider it, exposure to a context which, accidentally or purposefully, provided them with experiences that resonated with their experiences as students led them to revalue their original views. However, the alternative views ASTEP views on assessment were not discarded but rather held as inapplicable to the situations they were exposed to when teaching. However, this was not limited to aspects within one component of PCK, but also across components. Evidence suggested that views of learning and assessment also influenced each other and coherency among these views also influenced the incorporation of ideas. While participants were not asked to make a direct connection with this, their focus on the assessment of prior knowledge in a formal or informal manner was observed and discussed almost exclusively at the times when they were either exposed to ASTEP coursework and assignments or during the Exit Task interview. This suggests that coherency when reconciling views might be not only within a particular aspect of PCK but could also extend across component knowledge bases.

What this means, in terms of conceptual change, is that, when attempting to reconcile information that contradicts their mental models, participants consider not only the explanatory potential of the new conceptions, but also how these interrelate with each other. In essence, the different knowledge categories that make up PCK are evaluated as an integrated schema, rather than as isolated components.

Discussion

The findings of this investigation, as far as the development of PCK components relevant to Students as Learners and Assessment is concerned, is consistent with those discussed in the literature review. I found that whatever pre-existing conceptions the participants had at the onset of the investigation was shaped by their experiences as students, a finding which proved to be consistent with the findings of Duran, McArthur and van Hook (2004), Friedrichsen et al. (2009), Koballa et al., (2005), and Roehrig and Luft (2006) who claimed that learning experiences shaped individuals' views of teaching and learning. All participants had been exposed to teacher-centered experiences as K-16 learners and recalled these as sources of their understanding. This quite likely influenced the fact that all participants showed student-centered views at the beginning of the investigation. However, at the end of their teacher preparation programs, both student-centered and teacher-centered views of teaching and learning co-existed. Nevertheless, they interpreted their approaches and those of their mentors as student centered. This was consistent with the claims made by Simmons et al. (1999), Bryan (2003), Luft, Roehrig and Patterson (2003) and Crawford (2007). Furthermore, the disconnect between co-existing conceptions such as the 5E inquiry model and lecture-based approaches that was manifest in the participants echoed the results of investigations by Hewson et al. (1999a, 1999b), Marion et al. (1999), Tabachnick & Zeichner (1999), Meyer et al. (1999) and Lemberger et al. (1999). On specific aspects of knowledge of learners and learning, Alice, Beatrice, Catherine and Danielle all believed that students would find it easier to understand topics that could be related to their every day experiences. Moreover, while they became aware of the notion of prior knowledge, including misconceptions, as part of their ASTEP coursework, their attempts to incorporate this coherently in their lesson planning was consistent with the findings of de Jong et al. (1999) and Simmons et al. (1999).

While participants initially showed little awareness of possible student difficulties, in time, Alice, Catherine and Danielle would consider the abstract nature of content or content that could not easily be visualized as aspects that students would have difficulty with. This is consistent with the findings of van Driel et al. (2002) and de Jong and van Driel (2001), who reported that pre-service teachers would barely mention the possibility of students having difficulties with topics to be addressed. On the topic of misconceptions, and in a manner consistent with the findings of Halim and Meera (2002) and Berg and Bower (1999), none of the participants initially showed any understanding of the notion of misconceptions. While all participants showed awareness of misconceptions after their initial coursework in ASTEP, at no point did this translate into an important aspect of their lesson plans. This was consistent with the findings reported by Gomez-Zweip (2008) and Berg and Bower (1991).

When it came to knowledge of assessment, this study found that participants initially had no structured views of assessment. Participants initially inclined themselves towards informal questioning as a manner of gauging student learning rather than using written assessment. This was consistent with the findings of de Jong et al. (1999), de Jong et al. (1999), Friedrichsen et al. (2009), and Luft et al. (2003). As far as the interplay between their views of assessment and their views of students and learning, the participants in this study showed a clear connection between their teacher-centered views of learning and their views of assessment; formative assessment was unplanned and essentially informal whereas formal assessment was essentially summative. This alignment of goals was consistent with the findings of Duffy and Aikenhead (1992) and Gearheart and Osmundson (2009). Moreover, and in a manner similar to the participants of the investigation by Morrison and Lederman (2003), the participants in this investigation, despite showing an awareness of prior knowledge during their internship, rarely planned to assess it.

As far as the development of pre-service teachers' views on students and assessment, this investigation determined that, while during the program students showed some commitment to student-centered practices, this all but disappeared upon completing the program. This is only partially consistent with the findings of Simmons et al. (1999), who did not report this perceived backtracking in thought. However the way in which Alice, Beatrice and Danielle developed their views of assessment in conjunction with their views of students learning, shifting from teacher-centered to a conflict situation and back to teacher centered, was consistent with the findings reported by Geddis and Roberts (1998) that suggested that commitment to educational beliefs would influence views of learning and thus in the need to assess (or not) student prior knowledge. In a manner similar to this investigation, the aforementioned participants, showed some concern for prior knowledge during their internship, but it all but disappeared once they started full-time teaching responsibilities.

This investigation found that the participants reconciled conflicting views on the different aspects of student learning and assessment based on the coherency that their experiences had in direct relationship with their pre-existing notions both within and across PCK components. This suggests that it is possible that more than one path can be taken as a teacher develops his or her understanding of teaching. This reconciliation was mediated by the existing framework of ideas held by the individual and thus any form of accommodation was likely to occur in a personal, subjective manner. Thus, one contribution of this study is to provide an explanatory framework for the findings reported by Crawford (2007) and Geddis and Roberts (1998). Moreover it provided an explanatory framework for not only the disconnect observed between views of learning and assessment and practice (Bol & Strage, 1996, Otero & Nathan, 2008) but also that which is observed between awareness of prior knowledge and assessment reported by Morrison and Lederman (2003).

This reconciliation of ideas can be explained clearly under the lens of a conceptual change framework more so than by using the PCK model alone. What was observed was that the mental models (Vosniadu, 1994) the participants held were initially challenged in a manner that was enough to create dissatisfaction on part of the participants (Posner et al., 1982). As part of their coursework, participants were provided with ideas that were intelligible to them. These ideas were considered, based on their ASTEP experiences, as plausible (Posner et al. 1982; Strike and Posner, 1992) by the participants and thus were deemed to be capable of providing the foundation for the reconsideration of the schema as a whole. However, experiences later in the program challenged the capability of these new conceptions to be fruitful (Hewson, 1996; Posner et al., 1982). This occurred because, as the influence of ASTEP was removed from the context of the participants' development, the experiences that became their reality could be explained and addressed with their initial conceptual framework thus no need to re-conceptualize was necessary. Rather than that, the participants would, as expected, assimilate whatever notions would fit to improve their mental models (primarily the definitions and applications of assessment) while retaining the alternative notions provided by ASTEP as plausible yet non-fruitful alternatives.

This study also contributes to the literature by providing, within a single scenario, evidence that supports the PCK learning progressions proposed by Schneider and Plasman (2011). Moreover the analysis of the relationship within and between the components of PCK studied provided an explanation to the fact that Schneider and Plasman delineated, on a few occasions, learning progressions in PCK development that followed alternative pathways. In addition to this, the study supports and explains Schneider and Plasman's claim that some of these proposed alternative pathways were based on the experiences teachers would have (secondary vs. primary teachers for example). In addition to this, the findings of this investigation suggest that the generalized paths that were determined by Schneider and Plasman's meta-analysis are both nonlinear and nonexclusive with the possibility of individuals skipping or even shifting back and forth between stages based on the various experiences that shaped their understanding of learners and assessment.

What can be learned from this study

The determining factors in which the components of PCK were developed by pre-service teachers in this ACP were: 1) Coherence with pre-existing notions on a specific PCK component; 2) Coherence with other PCK components that are closely related; and 3) Coherence with the contextual goals and objectives as perceived by the teacher. The predominating aspect of the decision making process within each individual was his or her personal experiences. In essence, new experiences that the participants were exposed to were considered under the light of their pre-existing notions on the topic and incorporated into their schema or set aside as alternative albeit inapplicable knowledge. This process was continuous and nonlinear, that is, individuals will, given sufficient reinforcing evidence, revert to views that could have been assumed to have changed upon completing their teacher preparation programs.

Implications

For Teacher Education Research

Since the introduction of the notion of PCK by Shulman in 1986, the prevailing definition of the concept has gone through several modifications. Focus has been placed on additions, such as the notion of orientations to science teaching, as well as a diminished emphasis on certain aspects as far as development is concerned, such as the notion of syntactic and substantive knowledge of content. Some of these additions, as in the case of orientations, present a plethora of issues as far as their definition is concerned

(Friedrichsen et al., 2011). This case is especially important given that, in order to impact the development of PCK for prospective teachers, it is paramount to understand the role of the factors that influence this change. In the Magnusson et al. (1999) model, the one most commonly cited in the literature, this role is assigned to the aforementioned orientations. This study suggests that it is likely that the shaping of PCK occurs based on the reconciliation of experience, coming from the context (academic or otherwise) in which the person develops and the pre-existing notions they might have. However the interplay among the different components is dynamic, complex and rarely linear as participants continuously reassess and prioritize coherency both within knowledge components and among them in order to make a personal decision. In this process, new ideas might be retained for a while and co-exist with others yet are not influential in the schema that organizes each individual's understanding of teaching and learning. The ways in which the ideas interplay coherently with each other constitute each individual's PCK and serve the function of filtering new knowledge. This suggests that there is both a cognitive component that is fact based and one that is value based. These together constitute more than simply a knowledge base; they are a belief system. If we believe that PCK encompasses the knowledge that is developed by teachers, the value based component, which is the interplay that occurs within each individual based on his or her own experiences, cannot be removed from it. Isolating this value based component with an unclear definition is likely to lead us to believe that it is an isolated component that needs to be addressed before changes in the fact-based knowledge structure can occur. Results from this investigation suggest that it is the coherency within and among the components that determines the shift or lack thereof in prospective teachers. And this coherency is constantly reevaluated based on the context, academic or otherwise, to which the prospective teachers and beginning teachers are exposed. Given that research on teacher beliefs has identified their roles in teacher learning (Borko & Putnam, 1997; Kagan, 1992), and given that this investigation established a clear link for PCK development based on the existing structure of the construct defined as PCK, I believe it is necessary to reconsider the PCK model in the light of belief-based models that explain the development of teacher understanding for teaching. This is because it is possible that much can be improved if unnecessary duplication resulting from the isolation of research fields can be avoided. In essence I believe that the construct defined as ‘goals and orientations to science teaching’ by Magnusson et al. (1999) is an unnecessary, confusing and, to a certain extent, oversimplified proxy for the value-laden interactions that take place as PCK is shaped over time. Considering this limitation of the model, we have the alternative of simplifying it in order to allow us to plug-in the aspect of knowledge development is likely to improve the usefulness of PCK as a dynamic developmental model or to consider other frameworks as additional interpretive lenses when studying PCK.

For Teacher Education Policy

It is clear from the findings of this investigation that pre-service teachers might develop, based on their coursework, an awareness of reform-based practices. However, it was also found that they may not be provided with the experiences that consolidate them into the schema that guides their practice. This suggests that the perception that, regardless of their nature, teacher preparation programs of limited duration are unlikely to produce, on their own, the high quality teachers that are being called for. The results of this investigation, coupled with the current research we have on the issues, suggests that what our teacher preparation programs seem to be capable of accomplishing is the development of an awareness of reform-based views and practices yet rarely, if ever, a fully developed personal understanding of what these mean. In fact we seem to succeed, as far as the development of PCK is concerned, at providing beginning teachers with a potential alternative explanatory framework that is, for the most part, disconnected from their personal beliefs. Whether or not this alternative conception eventually establishes itself as the primary views of teaching and learning is based mostly on the experiences each individual goes through as he or she experiences classroom teaching. As such the context in which they develop themselves becomes as important, if not more important, than the reform-based notions pre-service teacher have been exposed to. The interesting aspect of the setup is that the people responsible for their teacher preparation programs are usually not a part of their ongoing professional development. This role is taken up by the context of the school in which they are placed—the beginning of their professional community outside their alma mater, which may or may not continue to be an influence, and other teacher organizations such as the National Science Teachers Association (NSTA). Thus the individuals responsible for the certification of high quality teachers are merely certifying that an individual has been exposed to the current best practices in education, yet they can hardly claim that he or she has developed these to the point of being capable of competently carrying them out. In terms of policies on teacher preparation, we should reconsider the meaning of our certification process. If what we seek to certify is highly quality teachers, then our existing programs, be it traditional or alternative, would seem to be woefully short in terms of the development of teacher knowledge for teaching. While the completion of such program is not without value in terms of laying the foundation for a future teacher, it does little to guarantee that this foundation will lead to a fruitful career as the new context in which a teacher develops. Given this, I believe we should also reconsider the role of the different actors in the process of teacher development. The first area of concern is the role of higher education institutions and their faculty, who are responsible for the teacher certification process. As the major actors in the development of the best practice in teaching, their involvement in teacher preparation exists in a limited time frame with little, if any, accountability. In the case of this investigation, the direct involvement of ASTEP instructors with all participants was limited in such a manner that participants, such as Beatrice and Catherine, viewed the principles presented in their courses as not applicable to their perceived realities as classroom teachers. This would suggest the need for either a lengthier certification process with supervision from program faculty or a shift of the certification process to specialized departments within higher education or professional institutions capable of providing this supervision. This argument is further supported by the fact that most of the development of a teachers' understanding of teaching seems to takes place after they have completed the prescribed coursework and experiences. This is further supported by the evidence that it is perfectly possible that their views of teaching and learning will be the same as the ones they had before participating in their teacher preparation program.

Recommendations for future research

This study, while useful in understanding the development of domain specific PCK and providing us with an initial understanding of the processes that mediate the development of PCK, did not manage to find and explain the later stages in the development of PCK as suggested by Scheider and Plasman (2011). Investigating a larger number of individuals over a longer time period might yield greater insight not only into the learning progressions as proposed by Schneider and Plasman, but also allow us to see if, despite the potential for multiple pathways, we can generalize enough of them to determine a route to facilitate the development of PCK.

The conspicuous role of value-laden cognitive aspects that can be related to belief systems and their impact on teacher learning suggests that a meta-analysis of research in the light of a clearly defined version of PCK would help us bring together aspects of teacher professionalism that are organized, at times, in different categories clarifying the literature in the field of teacher professional development. Furthermore, as noted in the discussion on experiences and prior knowledge, it is possible that certain categories or subcategories of PCK, such as beliefs of student learning, views on the purposes of assessment and others, might act as foundations for the development of PCK – in essence acting as cornerstones for the coherent mental schema that defines an individual's PCK. These categories could possibly be related to a stronger subjective component making them not only the most resistant to change, but also the ones whose change can lead to radical rearrangement of ideas – and addressing them could enhance the effectiveness of teacher preparation programs, traditional or not. Determining if such cornerstone beliefs exist and what they are could be important in helping teacher educators develop the most appropriate programs and experiences to achieve the goals of the teacher preparation programs.

Given the variety in teacher preparation programs, especially in ACPs and the importance of teacher experiences in the development of PCK, a need exists to conduct more studies that compare different ACP approaches as well as certification levels and areas. Furthermore, this investigation was limited by the selection of only two aspects of PCK; however, it was clear that the interplay among different components plays an important role in the acceptance or rejection of ideas; hence, including aspects such as curricular goals which, from these findings clearly guide assessment would be important. In removing the topic specific PCK from the analysis, mostly due to the constraints in data collection, this investigation managed to gain an overarching, albeit still rough, view of the overall development of teacher knowledge for teaching. This suggests that rather focusing on topic specific PCK, a definition closer to Shulman's (1986) presentation of PCK might not be as important as developing a better understanding of the overall development of teaching knowledge.

Another limitation of this investigation was it reliance primarily on the analysis of interview data. While classroom observations were conducted, their purpose was to provide experiential support to participant reflection during the interview. While observer reflections and notes occasionally referred to observed classroom practices, the data was insufficient to provide strong evidence to support more in-depth analysis than was presented in this investigation. A similar methodology coupled with detailed analysis of classroom practices could yield data that would allow analysis that could yield further insight into the intricacies of the development of teacher knowledge for teaching, allowing us to establish clearer relationships between espoused beliefs and classroom practice as teachers develop from novices to experts.

The use of conceptual change to provide an explanatory framework to the otherwise static PCK model allowed me to clarify the manner in which the components of PCK that were analyzed changed over time. This manner of addressing the limitations of the PCK model allowed a closer look at the complex nature of the processes that influence the change in views of pre-service teachers over time. It is thus possible that many shortcomings of our investigations are because of the fragmentation and lack of synthesis in our research models. It is possible we are at a stage in which more research is needed seeking to synthesize knowledge, rather than to further fragment it. Such a synthesis would surely yield more comprehensive results with a greater potential for application.

Conclusion

This investigation was based on the need to develop a more efficient way to address the shortages and limitations of the current education system in the USA. I investigated an ACP seeking to understand the development of teacher knowledge for teaching and the processes that facilitate or hinder it. The participants in this study were exposed to reform-based practices during their teacher preparation program as well as teaching internships that sought to provide them with first hand teaching experiences as well as an opportunity to use their knowledge in classroom settings. As they progressed through the ACP and into their fledgling teaching careers, they gained understanding of different aspects of teaching. Based on their experiences, both prior, during, and after the ACP, these teachers developed their views of teaching and learning by seeking coherency between factual knowledge and experiences. They contrasted the views of their ACP instructors, their mentors and peers with their personal experiences as students and in the field as interns first and as teachers later. It was clear that the predominant context at any given time provided them with the most worthwhile evidence of what works and what does not. This resulted in an initial challenge to their teacher-centered approach to instruction as presented by the ACP program. However, the initial structure, based on the 5E model proposed in the ACP, would find little support from most mentors and would show itself to be incompatible with the views of teaching and assessment goals that were prevalent in the institutions they worked at. This resulted in the participants disregarding the reform-based approaches in favor of those that, in their minds, not only had a more coherent structure among their component parts, but also aligned clearly with the expectations and dynamics of the classroom experience where they taught. If the goal of our ACPs is to promote reform based on student centered practices, it is clear that the programs themselves, while capable of providing beginning teachers with alternative views of teaching and learning, are not capable of generating the changes that we believe are necessary for the development of high quality teachers.

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APPENDIX A

Biology Lesson Planning Task

Background information: We know that students enter the SMAR^{2}T program with ideas about how to teach science. To help us better understand your ideas about teaching, we are asking you to design some science instruction. Don't worry. There are many different ways to complete the following task. We're interested in finding out your ideas about teaching and learning.

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

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

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

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

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

1 What do you want the students to learn?

2 Describe what will happen during the beginning, middle, and end of each class. What will you do? What will the students do?

3 Describe what will be needed for these two class periods.

4 Prepare any handouts or overhead transparencies that you plan to use.

APPENDIX B

Lesson Planning Task Interview

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

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

Talking Through the Plan

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

Begin with this question:

1. What did you think about as you were designing this lesson?

Then ask the participant to walk you through their plan by asking:

2. Walk me through your plan. How did you start the first day? Continue to ask clarifying questions; your task is to be able to really understand what the participant intended for each part of the plan. Possible clarifying prompts:

    a. What did you mean when you wrote _______________?
    b. Could you clarify what the students are doing during this part?
    c. Could you clarify what you are doing during this part?
    d. Could you tell me why you decided to do that?

Probing Participant's Knowledge

Subject Matter Knowledge (SMK/CKT)

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

3. What are your previous experiences with the topic of heritable variation within species?

    a. How well do you think you know (this topic)?
    b. Where did you learn about heritable variation within species?
    c. Have you taught (this topic) previously?

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

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

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

Knowledge of Students

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

7. What do you think students will already know about this topic?
   a. Why do you think that they may know that?
   b. Where do you think they may have learned this?

8. Do you expect students to have difficulty with anything that you have planned?
9. Why do you think they will have difficulty with that?

Knowledge of Instructional Strategies

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

10. From your plan, it appears that you chose to organize the class as ___________________ (i.e., lecture, experiment, investigation). Talk to me about making that decision.
   a. Where did you learn about how to teach this way?
   b. Did you consider organizing the classes in a different way? Why/why not?
   c. IF NO TO THE LAST QUESTION: Teachers often develop a range of ways to think about organizing their class; why do you think that you just have one way to think about it?

11. I noticed that you used a picture (graph, equation, analogy…) in your plan. Tell me why you used that _____________ at that point in your plan.
   a. How do you think this (picture, graph, equation, analogy) helps students learn about heritable variation within species?
   b. Did you consider representing that idea another way?

Knowledge of Curriculum

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

12. Where did you get your ideas for these two days of class?
    a. If you had access to other resources, what would you like them to be?
13. Tell me about the materials (handouts, transparencies) you prepared.
    a. Where did you get the ideas for these materials?
    b. How do you think these materials will help or hinder achieving the purpose your plan?

Knowledge of Assessment

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

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

Is there anything else about your plans that you want us to know?
Thank you again for participating in this interview.

APPENDIX C

Activity III – Video Analysis

PART A

1. Picture your best day of teaching Biology. Describe what makes it the best day.

RESPOND HERE:

2. What would you need to know, or learn, to accomplish your best day of teaching Biology?

RESPOND HERE:

PART B

You will watch a short video of an 11/12th grade physics classroom. The students have just completed a unit on optics. After you view the video, you will be asked to respond to the questions below. You will have 20 minutes to compose your responses. You may take notes about the video in the space provided. Then, following the written portion, there will be an audio taped discussion with your peers about what you watched.

Notes from the video.

TAKE NOTES HERE:

Please respond clearly, concisely, and thoughtfully.

1. What things did you see in the video that concerned you?
RESPOND HERE:

2. What aspects of the video represented good teaching?
RESPOND HERE:

3. What do you think of the teacher's use of the "design an eye" project? How does this compare to your best day teaching Biology?
RESPOND HERE:

4. What do you think of the teacher's use of small groups and oral presentations? How does this compare to your best day teaching Biology?
RESPOND HERE:

5. If you were to teach this class:
a. What aspects would you keep? Why?
RESPOND HERE:

b. What aspects would you change? Why?
RESPOND HERE:

c. What aspects would you eliminate? Why?
RESPOND HERE:

APPENDIX D

End of Summer Interview

Purpose: To review the lesson plan from the beginning of the summer, ask about changes participants would make in their lesson plans, and probe for why they would make the changes. NOTE: this interview is "lightly" structured by this protocol. The interviewer needs to be responsive to participants' lead on changes they would make in their plans from earlier in the summer.

Instructions:

1 Review the plan and the interview for each preservice teacher you plan to contact for the end of summer interview.

2 Contact your preservice teachers and make an appointment for an interview.

3 Send the plan and ask him/her to review it before the interview.

4 If you are doing this as a phone interview, then test the recording device before you make the call.

Begin the interview by saying: "I'm curious about what you think of the plan you wrote at the beginning of the summer, now that you have 'survived' the first 8 weeks of classes. When I contacted you, I asked you to review your plan and now I would like you to talk to me about what you like about your plan and what you would like to change." Follow the lead of the interviewee through one change at a time by asking questions such as:

1 Why are you considering this change?

2 What influenced you to consider this change? (we want to know where they learned what they said in previous question.

3 Was there something from this summer that promoted you to make this change?

4 In what ways are you thinking differently about this now than you were at the beginning of the summer?

5 Do you know of resources you could use to help you?

6 What did you learn about secondary students this summer that might affect your plan?

> Keep in mind the categories of knowledge we are investigating: knowledge of students; knowledge of instructional strategies; knowledge of curriculum; subject matter knowledge; and knowledge of assessment

> Look for changes in the following categories:

7. Purpose of the lesson,

8. Instructional style (e.g. teacher-directed to exploratory),

9. Instructional strategies (examples/activities/tasks),

10. Assessment of student learning, If your preservice teacher does not suggest changes to the lesson plan, then ask more leading questions:

11. Would you make changes to the purpose of the lesson? Why/why not?

12. Would you make changes to the instructional style of the lesson (e.g. more exploratory, more teacher-directed?)? Why/why not?

13. Would you make changes to the instructional strategies, such as examples used, activities, or tasks in the lesson? Why/why not?

14. Would you make changes to the ways that you assess for student learning? Why/why not?

APPENDIX E

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

The purpose of this research study is to investigate how your learning develops during the first two years following your acceptance into the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T) program. The research study will begin in Summer of 2006 and conclude in the Spring of 2008.

INFORMATION
You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to your grades in the SMAR^{2}T program classes. If you decide to participate, you may withdraw from the study at any time without penalty. Your course grades will not be affected by your decision to participate or to decline participation in the study. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION
If you decide to participate, you will agree to:

1. Participate in a pre interview (Summer 2006) and post interview (Spring 2008) in which you will be asked questions about lesson planning. We anticipate that each interview will last approximately 3 hours.
2. Participate in an interview at the end of the Summer 2006 in which you will be asked questions about the lesson planning that you completed at the beginning of the summer.
3. Allow the research team to observe you teaching one class on two consecutive days. These observations will occur each fall and spring for the next two years (Fall 2006, Spring 2007, Fall 2007, and Spring 2008). The process for the observations will include:
(a) The development of a written lesson plan
(b) An interview prior to the lesson in which we will ask you some questions about the lesson
(c) Observation and videotaping of the lessons
(d) A post observation interview following each observation in which you will be asked to watch the video and respond to questions about the lesson
(e) A final written reflection We estimate that each observation cycle will require approximately 8 hours of your time.
4. Allow the research team to display video clips at professional research conferences and other professional meetings. (Your image may appear in these clips.)

BENEFITS

Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for prospective teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated with up to $1000 per year (approximately 25 hours at $40 per hour) for your degree of participation in the research to be distributed at the end of each academic year (May). These activities will require no more than 25 hours of your time each year.

CONFIDENTIALITY

Your identity will be kept strictly confidential. Only members of the project team will know your identity. The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a pseudonym. You may view the videotapes on the University of Missouri campus and request that certain video segments not be used. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT Please read the consent statement below and place an “x” next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

________________ I hereby **agree** to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself. I agree to allow my classroom instruction to be videotaped as part of my participation in this study.

________________ I **do not agree** to participate in this research study.

Signed: ____ Date: _________________

Printed Name: ____

APPENDIX F

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

The purpose of this research study is to investigate how your learning continues to develop following the completion of the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T) program. The research study will begin in the Fall 2008 and conclude in the Spring 2010.

INFORMATION
You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to your grades in the SMAR2T program classes. If you decide to participate, you may withdraw from the study at any time without penalty. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION
If you decide to participate, you will agree to:

1. Allow the research team to observe you teaching one class each semester. These observations will occur each fall and spring for the next two years (Fall 2008, Spring 2009, Fall 2009, and Spring 2010). The process for the observations will include:
   (a) The development of a written lesson plan
   (b) An interview prior to the lesson in which we will ask you some questions about the lesson
   (c) Observation and videotaping of the lessons
   (d) A post observation interview following each observation in which you will be asked to watch the video and respond to questions about the lesson
   (e) A final written reflection

   We estimate that each observation cycle will require approximately 10 hours of your time.
2. Allow the research team to display video clips at professional research conferences and other professional meetings. (Your image may appear in these clips.)

BENEFITS
Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for beginning teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated up to $1000 per year for your degree of participation in the research; compensation will be distributed at the end of each academic year (May). The activities associated with your participation in this research study will require no more than 20 hours of your time each year.

CONFIDENTIALITY
Your identity will be kept strictly confidential. Only members of the project team will know your identity.

The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a pseudonym. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT

Please read the consent statement below and place an "x" next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

________________ I hereby agree to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself. I agree to allow my classroom instruction to be videotaped as part of my participation in this study.

________________ I do not agree to participate in this research study.

Signed: ____ Date: _________________

Printed Name: ____

Thank you. If you have questions at any time, please call Sandra Abell, Lead Project Investigator, at the University of Missouri at (573) 884-9033.

APPENDIX G

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

This letter is to follow up on our recent phone conversation about the SMAR^{2}T program and the “Researching Science and Mathematics Teacher Learning” project. Attached is an information sheet that summarizes the components of the project that we discussed.

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

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

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

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

________ No, I do not give my permission.

School

____

Signature ____ Date ____________

Printed Name ________________________________ Title ____________________

APPENDIX H

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

The purpose of this research study is to investigate your perspective on the learning of your intern in the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR^{2}T) program. This research study began in the Summer of 2006 and will conclude in Spring of 2007.

INFORMATION
You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence to you. If you decide to participate, you may withdraw from the study at any time without penalty. Only members of our research team will know the identity of individuals who choose to participate in the study.

PARTICIPATION
If you decide to participate, you will agree to:

1 Participate in an interview (approximately 1.5 hours) once in the fall and spring regarding your perceptions of your SMAR^{2}T intern's learning.
2 Have informal conversations with the research team about your SMAR^{2}T intern's learning during scheduled school visits to observe the intern's teaching.

BENEFITS
Your participation in this research study will improve the design of alternative certification programs and provide insight into the challenges and supports needed for prospective teachers in these programs. The information gained in this study may be useful to designers of alternative certification programs and guide state and national policymakers regarding the guidelines for alternative certification programs. The information gained in this study may be published and may also be useful to mathematics teacher educators at other universities and colleges.

You will be compensated with up to $500 per year (approximately 10 hours at $50 per hour) for your degree of participation in the research to be distributed at the end of each academic year (May).

CONFIDENTIALITY
Your identity will be kept strictly confidential. Only members of the project team will know your identity. The data collected during the study will be stored in a secure area in Townsend Hall. In reporting the findings of this study, your name will be replaced with a pseudonym. You may choose to end your participation at any time during the study, and your data will be destroyed. Data will be stored for three (3) years beyond the completion of the study and at that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

CONSENT Please read the consent statement below and place an "x" next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_______________ I hereby **agree** to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself.

_______________ I **do not agree** to participate in this research study.

Signed: ____ Date: ________________

Printed Name: ____

APPENDIX I

STUDENT RELEASE FORM:
Researching Science and Mathematics Teacher Learning in Alternative Certification Models

We are investigating how teacher learning develops for individuals in the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T) program. The research team is interested how various factors influence teacher learning. Your child's image may be captured on videotape as a result of his/her presence in a classroom in the study. We seek your permission to analyze the content of the videotapes in which your child's image is captured. . **Information:** Your participation/release is voluntary; you may choose that your child not participate and there will be no penalty or consequence. You may view the videotapes on the University of Missouri campus and request that certain video segments not be used.

If you sign yes on this form, you give permission for the research team to:
1 Capture your child's image on videotape, and analyze the content of the videotapes for research purposes.
2 Display clips at professional research conferences and other professional meetings. (Your child's image may appear in these clips.)

Privacy: No names or identifying information will be used in reporting the research findings on written documents. However, your child's image may appear in a video clip displayed at professional research conferences and other professional meetings.

Risks: This project does not involve any risks greater than those encountered in everyday life.

This project has been reviewed and approved by the University of Missouri-Columbia Human Subject Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585.

Consent: I have received and read a copy of this form. I understand the above information.
______ Yes, I agree to participate. I understand that I can change my mind and withdraw from the project at any time. I understand that I may request that certain information not be used.

______ No, I will not participate. If your child's image is captured on video while in the classroom, it will not be displayed or analyzed for research purposes.

Student Signature __________________ Date_________________

Child's Name ______________________
Please Print.
Parent Signature ________________ Date _________________

APPENDIX J

Pre-observation Interview Protocol

Prior to first observation: *Researcher role: Our role is to assume a stance of empathic neutrality. That is, we empathize with the participant and care about him/her. However, our role is to UNDERSTAND, not to Evaluate or Teach. Please keep these ideas in mind during your visit.*

<u>Pre-Observation Interview</u> (*purpose: to clarify the plans and uncover the intern's CKT and PCK*)

Opening Questions

1. Update us about what is going to occur over the next 2 days we are observing.
a.What will we see in Day 1? In Day 2?
b.What will you be doing?
c.What will the students be doing?
d.What are your purposes and goals for these 2 days?
e.How did you decide on these purposes and goals?
f. Why are these purposes and goals important to you?

Subject Matter Knowledge (SMK/CKT)

Say to the participant: One area that we are interested in is what we call content knowledge. In your case, we mean your own understandings of the science/math that you will be teaching.

2. What are your previous experiences with (this topic)?
a. How well do you think you know (this topic)?
b. Where did you learn about (this topic)?
c. Have you taught (this topic) previously?

3. What do you think is important for students to know about (this topic)?
a. Why do you think that is important?
b. Tell me about where and how you learned these things.
c. What else do you know about (this topic) that students might not need to know?

4. How do the science/mathematical ideas in (this topic) relate to other science/mathematical ideas?

Knowledge of Students

Say to the participant: Another part of what a teacher knows has to do with how students think about mathematics/science. The next questions are designed to probe what you know about how students might think about (this topic).

5. Tell me about the students in this class, in terms of science/mathematics.
a. Tell me more about your students' attitudes about science/mathematics.
b. Tell me about your students' science/mathematical abilities.
c. How do you think this particular group of students learn math/science best? Why do you think that?
d. How have your experiences with these students influenced the way you teach?

6. What do you think students will already know about this topic?
a. Why do you think that they may know that?
b. Where do you think they may have learned this?

7. Do you expect students to have difficulty with anything that you have planned?
a. Why do you think they will have difficulty with that?

Knowledge of Instructional Strategies

Say to the participant: We want to know more about how you organized the instruction during these two days. The next questions will help us better understand your decisions about what and how to teach (this topic).

8. Talk to me about how your plan addresses the important mathematical/science ideas you talked about earlier *(Probe for specifics based on the plan).*
9. From your plan, it appears that you chose to organize the class as __________________ (i.e., lecture, experiment, investigation). Talk to me about making that decision.
a. Where did you learn about how to teach this way?
b. Did you consider organizing the classes in a different way? Why/why not?
c. What other factors influenced your planning decisions?
10. I noticed that you used a picture (graph, equation, analogy…) in your plan. Tell me why you used that ____________ at that point in your plan.
a. How do you think this (picture, graph, equation, analogy) helps students learn about (this topic)?
b. Did you consider representing that idea another way?

Knowledge of Curriculum

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

11. Where did you get your ideas for teaching (this topic)?
a. Tell me about the materials (handout, transparencies) you prepared. Where did you get the ideas for these materials?
b. How did you modify these materials for your instruction?
c. Why did you make those modifications? What was difficult about your planning?
d. How do you think these materials will help or hinder achieving the purpose of your plans?

12. I have some questions for you related to how these plans relate to other topics that you might teach.
a. How do you see these 2 days of instruction as related?
b. How do these 2 days of instruction fit into the unit you currently are teaching?
c. How does that math/science fit into the bigger picture of what students learn in this class?
d. How does (this topic) fit into the "big picture" of what students learn about math/science in middle school/high school?

Knowledge of Assessment

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

13. During the 2 days of instruction, what are you going to focus on when assessing students?
14. How do you plan to assess these (things)?
a. Describe how you will know if students learned what you intended? Why do you think that it important to assess?
b. Are there other ways that you might know what your students learn in class on these two days?
c. Where did you learn about those strategies for finding out about what students learned?

Is there anything else about your plans that you want us to know?
Thank you again for participating in this interview.

APPENDIX K

Stimulated Recall Interview Protocol

During the Observation

The observer(s) will have selected 3-5 interesting instances to discuss. What constitutes an interesting instance?

Knowledge of Students

Student making a profound comment and the teacher does or doesn't recognize it or misinterprets what the student says or does. Student makes a comment that demonstrates confusion, and the teacher does or doesn't recognize or misinterprets why the student is confused? Teacher explicitly recognizes potential student difficulties.

Knowledge of Instruction

The teacher makes an instructional decision that alters the flow of the classroom by asking a question or directing students to perform a particular task. The teacher uses an example or analogy or representation to clarify an idea.

Knowledge of Curriculum

A particular task is chosen that may or may not elicit the student thinking that was intended. The teacher modifies the plan "on the fly" based on what occurs in the classroom. Teacher refers to math/science content in other parts of the course/curriculum (vertical or horizontal curriculum alignment).

Knowledge of Assessment

Teacher implements assessment to ascertain student prior knowledge. The teacher recognizes that the students are having difficulty with a particular idea. The teacher uses a low-level assessment strategy such as providing an "exit slip" that requires students to define rather than explain or synthesize.

SMK

Teacher demonstrates particularly strong SMK.
Teacher demonstrates inaccurate SMK.

After each observation:

<u>Stimulated recall interview</u> (*purpose: to have the intern immediately reflect on the instruction as a window into CKT and PCK and connect to pre-interview).*

Stimulated Recall Interview

1 How do you think the lesson went? In what ways was the lesson I observed different than other periods you taught it? Different from your plans?

2 We have selected some parts of the instruction we found particularly interesting. We want to watch them together and ask you some questions about them.

Let’s watch this part (interviewer asks questions starting in one of the following categories based on the reason for selecting the specific interesting instance).

a. What were you thinking when this was occurring? Tell me more about what was happening when you __________.

b. **[K of Students]** What do you think the student was thinking? Why do you think the student was having difficulty at that point? What knowledge about students did you use to make instructional decisions? In what ways, did students influence your teaching decisions today?

c. **[K of Instruction]** Tell me about that (example/analogy/activity/lab)? Why did you decide to use that? How did this teaching strategy help you achieve your overall goals? Where did that idea come from? How did the students respond? How did that influence what you did next?

d. **[K of Curriculum]** Did the activities achieve the purpose you intended? Why do you think that? How did your curriculum materials support or hinder you in implementing your plan?

e. **[K of Assessment]** What do you think students got out of the lesson? How do you know? Tell me about how you found out about student learning. Why did you decide to do that? Where did that idea come from? How do you think it worked?

3. Was there a time during the instruction when you changed your plan? Tell me about that.

4. Based on what happened today, what do you plan to do tomorrow? Will you change anything from your original plans?

5. [**Orientations**]. In general, how would you describe your teaching style? To what degree, did your instruction reflect your preferred teaching style? Explain.

a. What do you think is the teacher's role in a typical lesson?

b. What do you think is the students' role?

c. Now think of yourself as a math/science learner, how do you best learn math/science concepts?

d. How does your teaching style compare to your mentor's teaching style? Explain.

e. Compare your teaching style to what you're learning in your SMART courses?

f. In what ways have your ideas about teaching changed since you entered the SMART program?

Probe for sources of these changes.

APPENDIX L

Interview with Mentor Teachers

Say to participant: Thank you again for participating today. We are interested in the knowledge development of beginning teachers as they move through the SMAR^{2}T program. In particular, we are interested in what SMAR2T students learn through their experiences in their (internship or teaching experience). In addition, we would like to better understand how their interactions with you impact the learning of [insert name]. During this interview, I will ask you questions about your goals for your SMAR^{2}T intern [insert name].

Start the audio-recorder. Say to the participant: This is **_______** (Graduate Student), interviewing **_____________** on **_____________** (date). Do I have your permission to audio record this interview? (Wait for positive response)

Probing Instructions Views of Intern Learning

1. What are some things you think [insert name] has learned during his/her time in your classroom? (about the students, science/math teaching, other). Probe for specific examples.
2. What do you think [insert name] has learned <u>about the students</u> during his/her internship? (intentions)
a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
b. How has [insert name]'s knowledge of students changed since he/she began the internship? (outcome)
c. What else about learners have you shared with [insert name]? (Probe participants for all the goals they had for knowledge of learners using the sequence of probes above.)
d. If you were to explain to [insert name] how your students best learn math/science, what would you say? Would your answer change for the different types of courses you teach? Probe: Why?

5. What do you think [insert name] has learned <u>about teaching methods</u> from your mentoring during his/her internship? (intentions)
a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
b. How has [insert name]'s knowledge of teaching methods changed since he/she began the internship? (outcome)
c. What other teaching methods do you want [insert name] to learn? (Probe participants for all the goals they had for instructional strategies using the sequence of probes above.)
d. Why do you think these methods are important? (orientations)

6. What do you think [insert name] has learned <u>about curriculum</u> (for example, standards, scope and sequence curriculum materials) from your mentoring during his/her internship? (intentions)
a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
b. How has [insert name]'s knowledge of curriculum changed since he/she began the internship? (outcome)

c. What else about curriculum have you shared with [insert name]? (Probe participants for all the goals they had for curriculum using the sequence of probes above.)
d. How do you think curriculum materials help or hinder achieving your instructional purposes and goals? (orientations)
e. If you were to give advice to [insert name] about how to decide which subject matter to teach, what would you say? (orientations)

7. What do you think [insert name] has learned about assessment from your mentoring during his/her internship? (intentions)
a. Tell me about an example where you saw gains in [insert name]'s knowledge. (actions)
b. How has [insert name]'s knowledge of assessment changed since he/she began the internship? (outcome)
c. What else about assessment have you shared with [insert name]? (Probe participants for all the goals they had for assessment using the sequence of probes above.)
d. If you were to explain to [insert name] the reasons why assessment is important, what would you say? (orientations)
e. Tell me about the assessments that are used in the classes that (insert name) is in. (orientations)

8. What do you think [insert name] has learned about math/science subject matter from your mentoring during his/her internship? (intentions)
a. Tell me about an example where you saw gains in [insert name]'s math/science knowledge. (actions)
b. How has [insert name]'s math/science subject matter knowledge changed since he/she began the internship? (outcome)
c. What else about math/science subject matter have you shared with [insert name]? (Probe participants for all the goals they had for knowledge of subject matter using the sequence of probes above.)

Vita

Enrique Manuel Pareja

Permanent Address: None

The author Enrique Manuel Pareja was born in Lima, Peru in 1970. He attended the Universidad Peruana Cayetano Heredia from 1987 to 1994 and received a Bachelor of Science in Biology in 1994. He began work toward a Master of Arts in Education at the University of Bath, England in 2000 and completed it in 2004. He began work toward a Doctor of Philosophy in Learning Teaching and Curriculum at the University of Missouri in 2004 and completed it in 2014.

As can been seen from the preceding paragraph, he is a man defined by trips in a context that defines us by destinations. His major research interest is anything that falls his way and that has the potential to open his mind to new views and experiences outside mainstreams thoughts and beliefs. He currently entertains himself as an educational mercenary and, thanks to the technology available to us nowadays, research consultant/trainer.