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**SCIENCE TEACHER CANDIDATES DEVELOPING PROFESSIONAL PEDAGOGICAL
VISION AROUND AMBITIOUS SCIENCE TEACHING PRACTICES**

A Dissertation in
Curriculum and Instruction

by

Arzu Tanis Ozcelik

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The dissertation of Arzu Tanis Ozcelik was reviewed and approved* by the following:

Scott P. McDonald
Associate Professor of Science Education
Dissertation Advisor
Chair of Committee

Gregory J. Kelly
Professor of Science Education
Associate Dean for Research, Outreach, and Technology

Julia Plummer
Associate Professor of Science Education

Stephanie Knight
Professor of Education (Educational Psychology)
Associate Dean for Undergraduate and Graduate Studies

William S. Carlsen
Professor of Science Education
Chair of Graduate Program

*Signatures are on file in the Graduate School

ABSTRACT

This study examines how science teacher candidates negotiate ambitious science teaching practices and how they develop professional pedagogical vision during a science teaching methods course. Specifically, the following research questions are investigated: 1) How do teacher candidates negotiate and make meaning of ambitious science teaching practices when they engage in discussions in the first five weeks of methods course? 2) How does the professional pedagogical vision of science teacher candidates develop around teaching practices related to student ideas in a semester-long secondary science teaching methods course? Ambitious science teaching practices are used as part of the curriculum of the science teaching methods course. Using case study design and grounded theory for analysis, the research study investigated six TCs and their instructor during a science teaching methods course. Through using Studiocode video analysis, creating event maps, and applying interactional discourse analysis, I answered the two research questions. Analysis of how TCs negotiate meaning of ambitious science teaching practices yielded three themes: TCs negotiated agency: who is responsible for generating the scientific explanations, what counted as an explanation along with focusing on certain aspects of scientific explanations, and what counted as a phenomenon in the lesson and its relation to the content storyline of the lesson. Analysis of how TCs develop professional pedagogical vision provided four claims: TCs initially identified a small set of important practices and over time identified additional practices, as well as becoming more sophisticated about all of the practices; thus they developed a professional pedagogical vision increasingly aligned with ambitious science teaching. TCs develop professional pedagogical vision through in-the-moment and over-time negotiations of the teaching practices. Findings also showed that material representations of decompositions of teaching practice were important in supporting the negotiation of professional pedagogical vision. TCs negotiate professional pedagogical vision

more intensely in the context of local examples of practice than in distal exemplars of practice.

Study implications for the preservice teacher education context are discussed.



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Chapter 1

INTRODUCTION

This study examines how science teacher candidates negotiate ambitious science teaching practices in their discussions and how they develop professional pedagogical vision during a science teaching methods course. Ambitious science teaching practices are used as part of the curriculum of the science teaching methods course. Using case study design and grounded theory for analysis, the research approach considers the ways that teacher candidates learn to see teaching practices. The study has implications for teacher education. In this first chapter, I briefly describe the problem of practice in teacher education, suggested frameworks, ambitious teaching practices in science and math education, professional vision, and provide the research argument and research questions.

Problems of Practice in Teacher Education

Teacher candidates and beginning teachers face several challenges in learning how to teach science effectively (Appleton, 2006; Darling-Hammond & Bransford, 2005; Davis, Petish, & Smithey, 2006). These challenges include developing knowledge and understanding related to science content, practices and nature of science, learners, and instructional strategies, learning environments and professionalism (Davis et al., 2006).

These challenges could also be framed as problems of practice (Mikeska et al., 2009). The problem of practice occurs when there is a mismatch between methods courses, where a teacher educator provides teacher candidates with reform-based ideas about science teaching, and the field placement or student teaching classroom where teacher candidates are expected to

implement those ideas into their teaching in classrooms with a different orientation. Teacher candidates struggle to translate the theories and ideas they have discussed in methods courses into actual teaching in their field placement or student teaching. One of the reasons for the disconnect between the teacher education community and the teacher candidates' field experiences is that these communities do not talk effectively to each other and do not share similar visions generally. Thus, teacher candidates may not be capable of building coherent teaching repertoires for themselves.

Recent science education reform documents (NRC, 2007; 2011) and *Next Generation Science Standards* (Achieve Lead States, 2013) emphasize participating in science practices and discourses for students to be proficient in science learning. These new proficiencies in science education call for teachers to provide learning environments that promote engaging students in core ideas, scientific practices and discourses and crosscutting concepts. Some of the science practices that students should be engaged in involve constructing explanations based on evidence, using argumentation, asking meaningful questions, obtaining, evaluating and communicating information, and planning and carrying out investigations (NRC, 2011). Science teaching needs to provide opportunities for students to engage in the practices and discourses of science to improve students' science learning. Teacher candidates are expected to teach reform-based science teaching. However, in their placement schools, the teaching they observe in their mentors' classes may not demonstrate the ideas advocated in the reform documents.

One of the problems with teaching practices is a lack of attending to students' ideas during instruction (Mikeska et al., 2009; Davis et al., 2006). Prior research has demonstrated that science teacher candidates tend to have very limited ideas about what to do with student ideas while teaching (Mikeska et al., 2009; Davis et al., 2006). Teacher candidates also tend not to consider students or student learning very extensively, very carefully, or in very sophisticated ways (Abell, Bryan, & Anderson, 1998). Abell et al. (1998) have found teachers' reflections on

student learning to be primarily focused on students' interests and motivation. Levin, Hammer, and Coffey (2009) investigated teacher candidates' attention to students' ideas in their teaching and provided evidence of novice science teachers attending to student thinking from their earliest experiences in the classroom. Thus, it is important to understand how teacher candidates develop pedagogical discourses to understand student thinking and how they think they orchestrate students' ideas and what they focus on related to student ideas.

Suggested Models and Frameworks in Teacher Education

Researchers in teacher education recommend a model of teacher education grounded in the practices of teaching (Ball & Cohen, 1999; Ball & Forzani, 2009; Grossman & McDonald, 2008) in order to support teacher candidates to overcome aforementioned challenges. If there is coherence between their experiences in the methods course and in their placements, teacher candidates will improve science-teaching practices, assuming that TCs have better experiences in their methods courses. They need to develop teaching repertoires (Feiman-Nemser, 2001) that can foster professional pedagogical vision about effective science teaching (Hammerness, Darling-Hammond, & Bransford, 2005). There has been limited research that introduced efforts to collaborate with practicing teachers to build coherence among discourse communities (e.g. Zemba-Saul, 2009). Even though the research indicates success in methods courses, this success does not necessarily translate into practice (Clift & Brady, 2005).

Grossman and McDonald (2009) offered a framework with three dimensions for analyzing the preparation of teacher candidates in a university setting. They identified three key concepts for understanding the pedagogical approaches used in professional education: representations of, decomposition of, and approximations of practice. "Representations of practice comprise different ways that practice is represented in professional education and what these various representations make visible to novices. Decomposition of practice involves

breaking down practice into its constituent parts for the purposes of teaching and learning” (p. 2058). Approximations of practice refer to the degree to which the learning opportunities provided to novices resemble the authentic practices they will be expected to enact. These elements could play out in teacher education programs where teacher educators could demonstrate or model new forms of instructional discourse either live or on video, create environments to collectively analyze teaching practices, and provide opportunities for teacher candidates to approximate these practices in front of their peers as well as use tools to support their learning to teach.

While these pedagogical approaches are for the practices of teacher educators recommended for the teacher education classrooms, there are practices of teaching recommended for the TCs and novice teachers to learn and adapt in their classrooms. The curriculum of teacher education classrooms is becoming increasingly focused on specific practices of teaching for teacher candidates to try through different scaffolded opportunities and pedagogies of enactment.

Teaching Practices in Teacher Education

In recent years, a growing area of research has focused on teachers’ learning of core or high-leverage practices of teaching (Ball & Forzani, 2009; McDonald, Kazemi, & Kavanagh, 2013). Research and development projects in secondary English language arts (e.g., Grossman et al., 2009), secondary science (e.g., Windschitl, Thompson, Braaten, & Stroupe, 2012), and elementary mathematics (e.g., Lampert, Beasley, Ghouseini, Kazemi, & Franke, 2010) have begun to put the concept of core practices into action in teacher education with the aim of improving educational opportunities for all students. Researchers working in this area have identified and defined teaching practices that are essential for TCs and novice teachers to become capable of implementing before they go into the classrooms.

Grossman et al. (2009a) identified a list of criteria for core practices:

- Practices that occur with high frequency in teaching;
- Practices that novices can enact in classrooms across different curricula or instructional approaches;
- Practices that novices can actually begin to master;
- Practices that allow novices to learn more about students and about teaching;
- Practices that preserve the integrity and complexity of teaching, and
- Practices that are research-based and have the potential to improve student achievement. (p. 277)

Examples of core practices that meet these criteria include eliciting and responding to students' ideas, setting and maintaining expectations, and leading particular types of discussions as they come to life in particular content areas (Lampert et al., 2013; Ball & Forzani, 2009; Grossman, 2013). Researchers in science and math education include some of these core practices into ambitious views of instruction in which students are seen as sense makers and provided equitable access to rigorous academic work.

Ambitious Science Teaching Practices

In science education, Windschitl and his colleagues argue for deliberate practices (Ericsson, 2002; 2006; 2008) and developing a set of science teaching repertoires for TCs. They argue for these practices to assist TCs in overcoming the challenges they face and also to provide a common language for teaching practices for the teacher education community. According to Ericsson (2006), deliberate practice is not just repeated doing but cycles of repetition with feedback, which facilitates a balance between the conceptual and the practical learning.

Windschitl, Thompson, and Braaten (2009) considered and questioned which practices are more fundamental and worth learning for beginning teachers. They suggested that teaching practices should be grounded in important learning goals for all K-12 students, the literature on how students learn, and emerging longitudinal research about how novices learn the craft of teaching. They also suggested specific practices that could be tied to student thinking, and they

proposed high-leverage practices (HLPs) as the core repertoire of ambitious teaching. According to the authors, “ambitious teaching deliberately aims to get students of all racial, ethnic, class, and gender categories to understand science ideas, participate in the discourses of the discipline, and solve authentic problems” (p.4). They argue that this kind of pedagogy is both adaptive to students’ needs and thinking and maintains high standards of achievement for all learners.

Windschitl, Thompson, Braaten, and Stroupe (2012) identified four core-teaching practices for science education including constructing the big idea, eliciting student ideas, making sense of material activities and pressing for evidence based explanations. I describe details of these practices in the literature review chapter.

Teaching Practices in Mathematics Education

In mathematics education, some scholars (e.g. Lampert, 2010) discuss teaching practices in terms of core practices and others use the term high-leverage practices. Even though researchers named practices differently as core and high-leverage, they share similar meanings because they define practices as components of instruction that are accessible to novice teachers and use students’ ideas as the starting point of instruction.

National Council of Teachers of Mathematics’ (2014) publication *Principles to Actions: Ensuring Mathematical Success for All* describes specific research-informed teaching practices that are essential for a high-quality mathematics education for all students. The document identified eight mathematics teaching practices that research indicates need to be consistent components of every mathematics lesson. These practices include establishing mathematics goals to focus learning, implementing tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, posing

purposeful questions, building procedural fluency from conceptual understanding, supporting productive struggle in learning mathematics, and eliciting and using evidence of student thinking.

Unlike the teaching practices identified in math or science education, researchers at the University of Michigan identified high-leverage practices in elementary education across content areas. They argue that these high-leverage practices are content neutral and can be used across subject areas, grade levels or contexts. They came up with 19 teaching practices that are in different grain sizes and some of them are being entailed in other practices (Teaching Works, 2013). Some of these practices include leading a group discussion, explaining and modeling content, practices, and strategies in the disciplines, eliciting and interpreting individual students' thinking, diagnosing particular common patterns of student thinking and development in a subject-matter domain, implementing norms and routines for classroom discourse and work, coordinating and adjusting instruction during a lesson.

Making Sense of Ambitious Teaching Practices in Science and Mathematics Education

Both in math education and science education, ambitious teaching practices share similar principles including

“treating students as sense-makers, designing instruction for all children to have equitable access to rigorous academic work in school, referring to clear instructional goals to guide interaction, being responsive to the requirements of the school environment while wrestling with the need to improve schools as institutions in a democracy, and attending to students as individuals and learners” (Lampert, 2013, p. 228).

Ambitious teaching practices support high levels of student participation, value the knowledge and resources that students bring to the classroom, and maintain high levels of academic rigor. Ambitious teaching practices can only be developed through *deliberate practice* (Ericsson, 2002, 2008). Ericsson (2008) explains deliberate practice as not just repeated doing but

cycles of repetition with feedback, where the feedback can bring conceptual elements to influence specific problems. Through deliberative practice, TCs can associate conceptual understandings and practical problems as they gain constant feedback from teacher educators and peers.

Even though ambitious teaching practices share similar visions and principles in math and science education, it seems that the grain size of those practices is different in science and math classrooms. While the ambitious science teaching practices may include one or multiple class sections to only elicit students' ideas and thinking, ambitious math teaching practices may include multiple practices for example posing purposeful questions, using and connecting mathematical representations, and eliciting and using evidence of student thinking in one lesson. It seems that required time to implement these practices in the classrooms is different in science and math instruction. That difference may be related to differences in the big ideas, planned tasks and phenomena under investigation in science and math education in a given lesson.

There are, however, some similarities in the planning and enactment practices. Even though the math education literature does not explicitly specify that some of the practices are planning practices and some of them are enactment practices, it looks like establishing mathematics goals to focus learning and implementing tasks that promote reasoning and problem solving fall more into the planning phase of the instruction. Using and connecting mathematical representations, facilitating meaningful mathematical discourse, or eliciting, and using evidence of student thinking fall into the enactment phase of instruction. Thus, there are similarities in the way some of the practices are related to planning phase and some of them are related to enactment phase of instruction.

Researchers working on practices of teaching express their concerns that a “move toward core practices in teacher education risks becoming fad-like, resulting in a proliferation of

approaches driven more by the trend than by a deep understanding of how people learn to enact ambitious professional practice” (Lampert et al., 2013, p.379). Thus it is important to understand how novice teachers learn to enact ambitious practices. Researchers also urge continual dialogue within the field and among scholars over how to conceptualize aspects of practice that support practitioner learning of high-quality instruction (McDonald et al., 2013). Thus, researchers encourage “a continual examination not just of mechanistic implementation of a set of practices, but the meanings that are imbued within certain enactments and the kinds of learning environments that can be designed for students and teachers to thrive” (McDonald et al., 2013, p.381). Thus, the current research regarding how TCs negotiate meanings of ambitious science teaching practices in science teaching methods course is important and provides contribution and implications for research into learning ambitious/high-leverage/core practices.

One of the ways that teacher educators can support and investigate TCs’ making sense of teaching practices is through research around TCs’ analysis of teaching practices. Thus, investigating the development of TCs’ beginning expertise can help teacher educators gain knowledge of TCs’ learning to identify and analyze ambitious science teaching practices. This expertise can be thought of in terms of TCs’ ability to notice or their professional vision.

Professional Vision and Noticing

Goodwin (1994) introduced the term *professional vision* to refer to how professionals learn to recognize and interpret phenomena in their area of expertise and how their practices of seeing become socially recognized. He defined professional vision as “socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (p. 606). The majority of the studies on professional vision in the field of education have been done in the field of mathematics teacher education using the concept of noticing.

Noticing is part of everyday life. In our daily lives we see and interpret based on our own goals and orientations. However, with noticing in teaching we notice things that are central to professional goals (Ball, 2011). “Groups of individuals who hold similar goals and experiences often display similar patterns of noticing and in fact learning to notice in specific ways can be considered part of developing expertise in a profession” (Sherin, Jacobs, and Philipp, 2011, p. xxv). “What teachers attend to as they teach is highly consequential” (Schoenfeld, 2011, p. 223). The notion of what teachers are noticing is similar to the literature on scientific observation. “To observe scientifically requires much more than sensory perception and using one’s senses. True scientific observation requires coordination of disciplinary knowledge, theory, practice, and habits of attention” (Eberbach and Crowley, 2009, p.40). It requires certain level of background knowledge and theory to “notice” relevant elements of the phenomena or situation. The noticing literature has focused primarily on the cognitive aspects of Goodwin’s (1994) framework for professional vision. There seems to be potential for using the broader framework to help understand teacher candidates’ developing expertise (e.g., McDonald, 2016).

Research Argument and Questions

Research on teacher expertise demonstrates what expert teachers are able to do and the stages of teacher development (Berliner, 1994). Teaching is a complex activity that involves developing expertise in understanding classroom events and being able to respond to those events. Teacher candidates need to develop expertise in order to notice and interpret key classroom events recognized by expert science teachers, and this can be thought of as a process of acculturation into the profession of science teaching. As part of this process, science teacher candidates and science teacher educators must negotiate meaning or make meaning through participation in discussions of teaching events during the semester. Watching, experiencing, and analyzing videos of science classrooms can help teacher candidates to build foundational

knowledge about teaching. In this way, they can investigate the complexity of teaching from different representations of practice as they experience different science lessons in the rehearsals. However, learning from representations of practice, on their own, presents challenges for novice teachers.

Through decomposing practice in the analysis of teaching events with the instructor, teacher candidates can learn to see and talk about classroom situations and therefore develop professional vision. Sherin and van Es (2009) have suggested that professional vision is a productive lens for investigating teacher learning during decomposition of practice via video. Through the analysis of teaching, teacher candidates can become reflective practitioners and be able to identify and interpret complex classroom situations by using evidence from the classroom video to support their claims about classroom events. Therefore, professional vision can be a way to conceptualize the acculturation of newcomers into the established practice of the community of science teaching. Even though it is difficult to identify what practices are important in science teaching, Windschitl and his colleagues (2012) identify a candidate set of core practices in teaching science. Thus, I consider their work as established practice of the community of science teaching. Teachers who have an ambitious view of instruction as a professional pedagogical vision could develop core practices in which they organize equitable and rigorous instruction for students where students are seen as sense makers.

While it is an important first step to identify some possible core practices in science teaching, we also need to document the development of teacher candidates' beginning practices in order to understand how and where they get ideas about teaching. In this study, teacher learning is considered as a socio-cultural and situated activity in which teacher candidates develop understandings and practices as they interact in discourse communities over time (Lave and Wenger, 1991; Vygotsky, 2012). Socio-cultural and situated lenses on teacher learning draw our attention to the nature of teachers' participation in activities (Putnam and Borko, 2000).

As teacher candidates interact with other community members of these discourse communities, I consider how they develop professional pedagogical vision about teaching and learning. By looking at their discussions of teaching events and discourse of the analysis of teaching, this study makes claims regarding how beginning teachers develop professional pedagogical visions and how they negotiate meaning of ambitious science teaching practices. Thus, this study follows teacher candidates in their early science teaching experiences when they are in the science teaching methods course as they make sense and build knowledge, practices and commitments regarding teaching science.

While the preservice teachers will be building these practices in their local community, no community is independent, so I need to consider the nested nature of these communities. Figure 1. 1 (below) represents layers of communities and practices for these communities. The Next Generation Science Standards (2014) recommends K-12 students to engage in scientific practices and discourses (e.g., constructing evidence based explanations). In order to help students engage in those practices, TCs and teachers use ambitious science teaching practices (e.g., pressing for evidence based explanations). In order to engage TCs in ambitious science teaching practices, teacher educators must develop pedagogies of practices (e.g., approximation of practice), aligned with these other practices as goals.

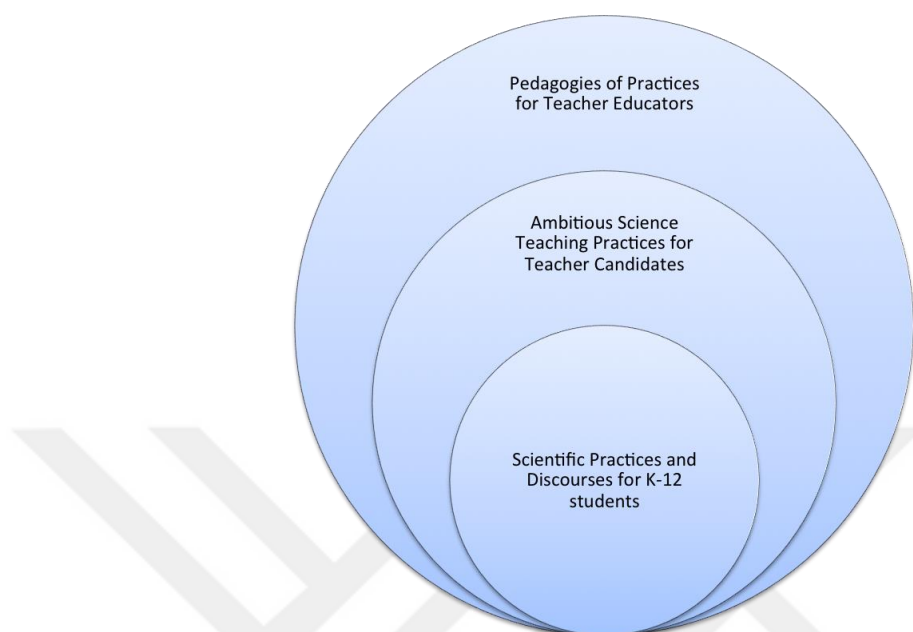


Figure 1-1: Layers of Communities and Practices.

The purpose of this study is to describe how science teacher candidates negotiate meanings of ambitious science teaching and how these teacher candidates' professional pedagogical vision develops. Specifically, I aim to answer the following research questions:

1. How do teacher candidates negotiate and make meaning of ambitious science teaching practices when they engage in discussions in the first five weeks of methods course?
2. How does the professional pedagogical vision of science teacher candidates develop around teaching practices related to student ideas in a semester-long secondary science teaching methods course?
 - What do they highlight and code in their discussions of teaching, and what material representations do they produce during the first five weeks of the science teaching methods course?

Overview of the Chapters

The dissertation includes six chapters, references and appendices. In Chapter 2, I present the situated and sociocultural learning theories that serve as the foundation for my theoretical framework, professional pedagogical vision as the core of my conceptual framework and review literature around ambitious science teaching practices, teacher candidate learning, and student ideas.

In chapter 3, I present the methodology of the research study including data collection and analysis methods, context and participants, and the curriculum materials from the methods course that was the context of the study. In chapter 4 and 5, I present my findings with evidence that address my two research questions, as well as a discussion of those sets of findings. Specifically, chapter 4 focuses on how TCs negotiate the meaning of ambitious science teaching practices and chapter 5 focuses on the development of TCs' professional pedagogical vision. Chapter 6 includes my discussion across the two sets of findings, conclusions for the study, and implications for science teacher education and future research suggestions.

Chapter 2

THEORETICAL FRAMEWORK and REVIEW of LITERATURE

In this chapter, I describe my theoretical framework drawing from both situated and socio-cultural views of learning. Then I describe professional vision as my conceptual framework for understanding science teacher candidates' learning of science teaching practices. Finally, I characterize existing empirical studies about professional vision, challenges in science teacher learning, tools and models in teacher education, ambitious science teaching practices, as well as literature around attention to students' ideas.

Socio-cultural Theory and Situated Learning

Historically documented epistemological shifts in learning theories have influenced the ways in which educational research has conceptualized teacher learning and teacher education. Paradigm shifts more specifically from behaviorist, to cognitive, to situated, social and distributed views of human cognition have also changed the research questions asked in teaching and teacher education research (Putnam & Borko 2000; Borko, Whitcomb, & Byrnes, 2008; Cochran-Smith & Demers, 2008; Grossman & McDonald, 2008).

This study defines learning by drawing on ideas from both situated and socio-cultural theories of learning. Learning can be seen as the legitimate peripheral participation in communities of practice (Lave & Wenger, 1991) and thus as a process of acculturation into the social-historical activities within a community. Legitimate peripheral participation is defined as “a descriptor of engagement in social practice that entails learning as an integral constituent” (Lave & Wenger, 1991, p. 35). Lave and Wenger (2005) describe learning as “socio-cultural

transformation with the changing relations between newcomers and old-timers in the context of a changing shared practice” (p. 150).

Lave and Wenger (1991) define “community of practice” as “a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice” (p. 98). The idea of “increasing participation” implies that there is directionality over time from more peripheral to more full participation and membership in communities of practice. Therefore, the framework has a process orientation. As newcomers integrate into a community of practice, they simultaneously change and are changed by that community. This “reproduction” is essential to understanding communities of practice and participation in them (Lave & Wegner, 1991).

As science teacher candidates enter the science teaching methods course they begin to read and have discussions about science education, teaching, students’ ideas and how to incorporate them in their teaching. At the beginning of these experiences, they are not fully aware of the things they need to pay attention to, but as they have discussions with peers and course instructors about teaching, they begin to develop ideas about teaching. For example, I watched two preservice teachers’ peer teaching their first lesson that they will eventually teach to the middle school students. They talked about the activities they planned to do, but it was not clear how they would incorporate students in the teaching. As we talked about that, they decided to ask students to first predict what will happen when they get temperatures from different parts of the body, and then discuss possible results before they collect data. As preservice teachers participate in these discussions and teaching events with peers and students, they will gain more experience and increasing participation in the science teaching communities of activities such as incorporating student ideas, responding to students’ ideas, assessing students’ ideas. Just becoming aware of things that they should be paying attention to should be important for them.

Lave and Wenger (1991) argue that by focusing on legitimate peripheral participation

they aim to broaden the analysis of learning from the individual learner to the participation in the social world, and from the concept of cognitive process to the more complete view of social practice. Thus, legitimate peripheral participation in communities of practice implies interconnections in historical terms, through time and across cultures. Lave and Wenger (1991) state that the transformation of communities of practice happens as they develop through iterations of newcomer to old-timer interactions.

Situative theorists propose that learning cannot be separated from the activity or the system in which it takes place - and that “there is no activity that is not situated” (Lave & Wenger, 1991, p. 33). It is not just the individual’s learning but his or her interactions within a social system and the sense making within that setting which is valued from this perspective (Greeno, 1997). Putnam and Borko (2000) explain that situative theorists oppose the knowledge acquisition perspective of learning and assert that:

... the physical and social contexts in which an activity takes place are an integral part of the activity, and that the activity is an integral part of the learning that takes place within it. How a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned (Putnam & Borko, 2000, p. 4).

Situated theories of learning focus on the process and take the activity or the event as the unit of analysis to show the interdependence of the social world and individuals. A focus on the situated nature of knowing and learning suggests that preservice science teacher learning should be grounded in increasing participation in practice and analysis of teaching. Preservice teachers’ practice and analysis of teaching are some of the activities they engage in during the teacher education program, specifically during the second teaching methods course.

Similarly, socio-cultural approaches view learning as occurring in social environments and describe socially mediated activity as the fundamental principle for development (Vygotsky, 1986; 2012). A socio-cultural perspective focuses on socio-cultural activities as the essential processes through which human cognition is formed. There is also an emphasis on the

importance of social, cultural, and historical artifacts that are associated with these activities. A socio-cultural perspective seeks “to explicate the relationship between human mental functioning, on the one hand, and the cultural, institutional, and historical situations in which this functioning occurs, on the other” (Wertsch, Rio, & Alvarez, 1995, p. 3).

In socio-cultural theory, “human activity is always and everywhere mediated” (Lantolf, 1994, p. 418). Mediation occurs through the use of language and other semiotic tools for meaning making. Meaning involves conceptual and contextual understanding, so meaning results from the tension between concept and sense, and it is continually negotiated through participation in context with others (Vygotsky, 2012). This suggests that meaning does not exist within language itself but rather is constructed through the social group’s use of language. Socio-cultural theory insists on the crucial role of social history and the primacy of tool mediators in development.

Language plays a special role in human thought and is a psychological tool. According to Wertsch et al. (1995), “individuals have access to psychological tools and practices by virtue of being part of a socio-cultural milieu in which those tools and practices have been and continue to be culturally transmitted” (p. 141). Thus, in the socio-cultural perspective, language is used to make sense of experiences and to transform those experiences into cultural knowledge and understandings through the interactions with others. Hence, the study of discourse is important to understand those experiences and learning.

Vygotsky (2012) sees psychological development as a cultural process rather than an individual process. Development continues along the lifespan, dependent upon experiences and access to cultural artifacts. Consequently, according to Vygotsky (2012), cognitive development is an interactive process, mediated by culture, context, language, and social interaction. Thus, Vygotsky (2012) proposes word meaning as the unit of analysis and activity as the explanatory principle for understanding the objects of the human mind.

Vygotsky (2012) introduced the idea of spontaneous and scientific concepts when explaining concept formation in socio-cultural theory. According to him, spontaneous concepts are direct experiences gained from everyday life in the world. These concepts are “strong in what concerns the situational, empirical and practical” (p. 206). Scientific concepts are learned from structured school experiences through systematic and abstract organization of concepts. He says, “The strength of scientific concepts lies in their conscious and deliberate character” (p. 206). Spontaneous and scientific concepts exist in a dialectical relation; the spontaneous provides the foundation in the everyday world to anchor the scientific concept, but at the same time the scientific concept transforms how we understand the everyday world. In our case, we can also think of preservice science teachers’ notions of teaching and learning science in terms of spontaneous and scientific concepts. Teacher candidates come to the profession or teacher education programs with spontaneous concepts regarding teaching through their everyday and past experiences (in previous classes as students). As they participate in the science teaching methods courses in which they learn scientific concepts regarding teaching, they begin to develop scientific concepts of teaching science that transform how they understand teaching in the classrooms.

Teacher candidates engage in multiple communities as they move forward in their teacher education. If we think of teacher candidates in a science teaching methods course, they are in a small community of peers and the instructor. When they are in the schools for field experiences, they are in the community of mentor teachers, students, principles and other colleagues. There is also a larger discourse community surrounding these communities. This larger community includes science and reform community, science education community, next generation science standards, and the international research community. Thus, teacher candidates are in different and multiple layers of discourse communities and they are exposed to different values, ideas and visions from these discourse communities. All of these communities communicate their own

values about what good science teaching is. It is important to understand what teacher candidates are taking up and are not taking up from these communities, and how these communities shape teacher candidates' learning to teach trajectory. In this study, I explore their experiences when they were in a science teaching methods course.

Attention to Discourse in Science Education

Research in science classrooms demonstrates the importance of discourse (Kelly, 2010; Kelly & Crawford, 1997; Lemke, 1990; Roth, 2005). Discourse is a fundamental component of participation in a community (Lemke, 1990). Lemke (1990) described how complex meanings of science content are constructed through interactions within the science classrooms. Discourse is defined as the “ways of being in the world... forms of life which integrate words, acts, values, beliefs, attitudes, and social identities as well as gestures, glances, bodily positions, and clothes” (Gee 2001, p. 526). Kelly (2007) described how it is important to see educational events through language and social processes:

(1) Teaching and learning occur through discursive and interactional processes. (2) Students' access to science is accomplished through engagement in the social and symbolic worlds comprising the knowledge and practices of specialized communities. Issues of understanding, appropriating, affiliating, and developing identities for participation in the knowledge and practices of the sciences can be understood through the study of discourse processes. (3) Disciplinary knowledge is constructed, framed, portrayed, communicated, and assessed through language, and thus understanding the epistemological base of science and inquiry requires attention to the uses of language (p. 443).

Cazden's (2001) book highlighted the importance of examining classroom discourse in order to understand the norms and practices of classrooms. Similarly, Wickman and Ostman (2002) used socio-cultural theories for understanding the meaning making in science classroom talk and action. They discussed learning on a discursive level by identifying how discourse

changes and how participants become participants in new practices. This sort of detailed analysis with the discourse practices of preservice science teachers in learning to teach context is not common. Previous research on science classroom discourse (e.g. Cazden, 2001; Wickman & Ostman, 2002; Kelly & Crawford, 1997) and how it can be supported could provide guidance to thinking about ways to support and understand the discursive practices of teacher education.

In research intended to understand students' learning of science, attention has been paid to how discourses and practices develop in classrooms. This suggests it may be productive for researchers in teacher education to investigate TCs' discourse events during their discussions of teaching in order to understand their learning in teacher education classrooms. Investigating the classroom discourse of TCs during the methods courses could provide insight into how they learn to see and interpret teaching events, as they develop discourse and practices around teaching science.

Goodwin's Definition of Professional Vision

Goodwin (1994) introduced the term *professional vision* to refer to how professionals learn to recognize and interpret phenomena in their area of expertise and how their practices of seeing become socially recognized. He defines professional vision as “socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (p. 606). He exemplified professional vision with cases of apprentice archaeologists learning how to conduct fieldwork and expert police witness testimony in a criminal trial.

Furthermore, Goodwin (1994) emphasized three discursive practices that define how members of a profession learn to identify the relevant features of a situation and interpret it according to the shared values and interests of the group. These practices are *coding schemes*, the use of established categories and codes to describe and construct the object of inquiry (e.g., color

schemes for classifying shades of dirt); *highlighting*, marking what is important in a way that foregrounds the information (e.g., drawing on the ground with a trowel to demarcate changes in coloration); and *producing material representations* (e.g., creating a map of the excavation).

Goodwin (1994) suggests that the, “ability to see a meaningful event is not transparent, psychological process but is instead a socially situated activity accomplished through the deployment of a range of historically constituted discursive practices” (p. 607). He argues that vision is perspectival and located within the communities of practice. Goodwin uses the scenario of an archeology student working with their instructor in the field to identify the change in slope. The task of the instructor setting the problem of finding an example category in the material she is looking at for *coding* and the solution of the student circling on the dirt with her hand to *highlight* function together in the *production of relevant graphic representation*. So, in the example the instructor’s problem of finding the category includes the coding task and student’s marking of the dirt includes the highlighting and as a result producing the map is the material representation.

Based on this example, the following scenario can be possible in the science teaching methods course in terms of how professional pedagogical vision can occur. In the discussions of teaching events during the science teaching methods course, the instructor gives the coding tasks through orienting TCs to focus on certain practices of teaching, and then the TCs describe what the teacher or the student is doing or saying through highlighting in the videos or the experienced teaching events. Through the negotiated patterns of highlighting and coding practices, TCs and the instructor come to an agreement about coding certain teaching practices under discussion in a given teaching event.

Teacher candidates are engaged in a process of acculturation into the profession of teaching. As part of this process, science teacher candidates and science teacher educators must negotiate meaning through participation in discussions of teaching events during the semester.

Teacher candidates learn to see, in Goodwin's sense of the word, the complex classroom interactions as indicated in reform documents through interactions with the instructor. They can develop professional vision, a shared interpretation of activity, as they engage in activities such as watching and analyzing video records of teaching. Therefore, teacher candidates' learning and the development of professional vision are situated in the episodes of teaching they experience and watch and, in particular, as they engage in discourse about teaching with other preservice teachers and science educators in the classroom through the discursive practices Goodwin (1994) identified. While professional vision is the view that TCs develop as they participate in these discursive practices, core practices of science instruction is the entity and content of their vision. What I meant by entity or content of their vision is that TCs could develop professional pedagogical vision aligned with the core practices.

Science teacher candidates are novice to the teaching profession. Their experiences of seeing classroom events are grounded in the student perspective they developed during their own experience as science students. Thus, we can think of their early conceptions of science teaching and learning as spontaneous concepts, and through discussions with a more knowledgeable other (the course instructor) they can develop scientific concepts related to teaching and learning science. The instructor of the course (an old-timer) engages preservice teachers (newcomers) within the community of science teaching practice. Therefore, taking the perspective of socio-cultural learning theories, this study recognizes the importance of discourse and cultural historical practices in the analytical discussions of teaching events and the acculturation of teacher candidates that happens as a result.

TCs can develop professional vision, a shared interpretation of activity, as they engage in activities such as watching and analyzing video records of teaching. In this way, they can investigate the complexity of teaching from different representations of practice as they experience different science lessons in the rehearsals events. However, learning from

representations of practice, on their own, presents challenges for novice teachers. Through decomposing practice in the analysis of teaching events about working with student ideas and orchestrating classroom discourse with the instructor, and integrating different practices in their lessons in the rehearsal teachings, preservice teachers can learn to see and talk about classroom situations and therefore develop professional pedagogical vision to guide their practices. In addition, this could improve the quality of teaching and thus affect the learning of their students.

Theoretical Foundations of Noticing and its Relationship to Professional Vision

Teachers develop professional vision as they move from novice to expert pedagogy in many areas (Sherin, 2001). In mathematics teacher education, a growing number of scholars (e.g. Sherin, Jacobs, & Philipp, 2011) have drawn on professional vision and have focused their attention on noticing. A recently published book, *Mathematics Teacher Noticing: Seeing Through Teacher's Eyes* (Sherin et al., 2011), is evidence of the growing popularity of noticing as a frame in mathematics teacher education. Some of the authors of this book were inspired by Goodwin's (1994) studies, Mason's (2002) book on the discipline of noticing, and the research on expertise in which noticing play a large role. Noticing has been theorized in a way that has tremendous overlap with professional vision, but in some cases scholars take up only part of the framework, or they include additional components, such as decision-making.

Examining what teachers notice is not new, and Erickson (2011) reports his observational study results conducted in early 1980s related to what elementary teachers paid attention to while they taught. Based on extensive observations, he proposes that teacher noticing is an active, multidimensional, and selective process that draws on teachers' prior experiences of teaching. He also argues that teacher noticing is instrumental, meaning it is opportunistic in that teachers notice in order to take action. He further elaborates that noticing interpretations differ along the lines of

differing “pedagogical commitments” held by different teachers, which implies that each teacher has different subjective worlds as he or she engages in real-time conduct of noticing while teaching. It was clear that due to the time period of the research, when the cognitive paradigm was popular, his results imply for teacher decision making, beliefs and teacher perception rather than contextual, historical and cultural meanings of teachers’ noticing.

Erickson (2011) describes Dewey’s essay (written in 1904), “The relation of theory to practice in education”, related to teachers’ interpretation of students’ behaviors. According to Dewey, it is pedagogically important, especially for novice teachers, to be able to interpret the students’ attention and interest through looking at only student behaviors. Erickson (2011) resurfaces the idea of how to pay attention to what and how teachers notice. He reminds us that if teachers do not learn to reflect critically on their understandings of student behavior, they may keep misreading students’ behavior and make judgments on the surface level. He argues that in order to improve teaching practice, pedagogical experiences require reflection within action.

In addition, Mason (2011) argues that roots of “the discipline of noticing” are potentially intentional rather than a random act. He emphasizes the idea of “acting freshly rather than automatically out of habit” (p.35) to train oneself to “notice-in-the-moment”.

Similarly, Miller (2011) describes “situation awareness in teaching”, the sort of “skilled viewing” drawing from different disciplines such as sports and aviation, and emphasizes that expert noticing is distinguished not only by that to which experts attend but also by that to which they choose not to attend. With the term “situation awareness”, Miller implies a theory of noticing and considers the cognitive and perceptual work of teachers. Teachers need to be aware of what is going on in their classrooms that is relevant to student learning. According to Miller, teachers’ situation awareness should involve learning to react to what is important and ignore what is not.

Unlike other authors, Ball (2011) argues that noticing is not only natural attention, but a culturally shaped perception. Sherin, Jacobs, and Philipp (2011) state, “Groups of individuals who hold similar goals and experiences often display similar patterns of noticing and, in fact, learning to notice in specific ways can be considered part of developing expertise in a profession” (p. xxv). Through discussions of teaching in the methods course, science teacher candidates can also begin to develop similar patterns of noticing or culturally shaped perception and thus develop expertise in the profession.

Empirical Studies of Professional Vision and Noticing

I present an overview of how authors conceptualize noticing and what methods and instructional settings they used in Sherin et al.’s (2011) book. Some authors (Sherin et al., 2011; Star et al., 2011) conceptualize noticing only as that to which teachers attend. Some other authors (e.g. Jacobs, Lamb, Philipp, & Schappelle, 2011; van Es, 2011) argue that noticing involves two processes, attending to particular events and making sense of these events. However, how the researchers make sense of these events also varies among them, with some (van Es, 2011; Goldsmith & Seago, 2011) focusing only on interpretations of these events, and others (Jacobs et al., 2011; Kazemi, Elliott, Mumme, Carroll, Lesseig, & Kelley-Petersen, 2011) focusing both on interpretations and on deciding how to respond to these events. The researchers (Goldsmith & Seago, 2011) looked at interpretation of details or evidence the teachers provide when they are identifying and examining the student artifacts for student thinking rather than just evaluating student artifacts. The facilitators in the video discussions directed teachers to provide evidence in what they are attending and making sense of the events.

In addition, authors differ in terms of whether they pay attention to the variety of what teachers notice or to teachers’ expertise when noticing through a specific lens such as students’

mathematical thinking or specific mathematical content. In these studies, the instructional settings the authors studied also differ, ranging from classroom discussions to one-on-one conversations to examinations of written student work. Sometimes these instructional settings were presented on video, and at other times they involved live interactions. Finally, the authors collected data regarding teachers' noticing in two main ways: by collecting video recordings of discussions or by requesting written responses to prompts. Given the scope of the book, it is evident that in mathematics teacher education, noticing has been conceptualized and used in varying instructional settings that use different methods.

Sherin and her colleagues have conducted research on the applications of noticing in teacher learning, particularly mathematics teacher learning. Most of their studies include analyzing what participants notice and how they reason about it in video clubs or professional development settings through viewing and discussing video-recorded excerpts of classroom practice (e.g. Sherin & Han, 2004; Sherin, 2007; van Es & Sherin, 2008; Sherin & van Es, 2009). For example, Sherin and van Es (2009) investigated the effects of video club participation on teachers' professional vision. They explored whether teachers develop professional vision, the ability to notice and interpret significant features of classroom interactions, as they participate in a video club. They designed video clubs to help teachers learn to identify and specifically interpret the ideas students raise about mathematics. Their study consists of two year-long video clubs in which teachers met monthly to watch and discuss video excerpts from each others' classrooms. They explored how the conversations change over time in the video clubs and also examined the influence of the video club experience on teachers' thinking outside of the video club. Thus, they examined teachers' comments in interviews before and after the series of video club meetings.

In addition, Sherin and van Es (2009) investigated how teachers' experiences in the video club influence their subsequent teaching practices. They video recorded the club meetings and

classroom observations, took field notes in the classrooms, and conducted pre-post noticing interviews with teachers. Noticing interviews include showing three short video clips from mathematics classes that show instances in which student mathematical thinking was visible, and questions to describe what he or she noticed in the video. In the analysis, they code for selective attention and knowledge based reasoning for the components of professional vision. They identified dimensions of analysis as actors and topics that teachers attend and stance and strategies used to explore student math thinking as in the knowledge based reasoning.

Sherin and van Es (2009) examined what the teachers attend to. Researchers paid close attention to topics (student, teacher or other actors, management, climate, pedagogy or math thinking), the stances teachers take (describe, evaluate and interpret) and the strategies they use to explore student thinking (restating student ideas, investigating meaning of student ideas, and generalizing and synthesizing across student ideas). The researchers found that when teachers described what they noticed, they would provide an account focused on observable features of the activity in the video; evaluating included judgments about the quality of the interactions in the video; and interpreting included inferences about what took place in the video.

Sherin and Van Es (2009) looked at the professional vision in terms of two components, selective attention and knowledge based reasoning. Based on the analysis of the video clubs, they found that teachers had come to pay more attention to student thinking as well as to engage in detailed analyses of students' ideas. They based their analysis on the number of teacher-initiated idea units for each topic as well as the comparison of the total time spent in discussions of student thinking in the first and the last video discussion meeting. They found that teachers' knowledge based reasoning developed as they saw the change in teachers' comments on video from describing or evaluating what took place to interpretations of what they noticed. Thus, they found that teachers came to discuss the issues in a new way. From the analysis of video club meetings,

of interviews outside of the video club meetings, and of the teachers' instructional practices, they found that participating in a video club influences the teachers' professional vision.

In Sherin and colleagues' studies, the conceptualization of teachers' professional vision includes two main sub-processes: (a) noticing or selective attention and (b) knowledge-based reasoning. In their previous study, van Es and Sherin (2002) proposed that noticing has three aspects: “(a) identifying what is important or noteworthy about a classroom situation; (b) making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent; and (c) using what one knows about the context to reason about classroom interactions” (p. 573).

The sub-processes of professional vision Sherin and colleagues used are similar to Goodwin's discursive practices for the facilitation of learning expert ways of seeing and interpreting. Noticing or selective attention is similar to highlighting, and knowledge-based reasoning is similar to coding schemes. However, building material representation does not have a correspondent point in the conceptualization of professional vision from Sherin and his colleagues. Another difference is in the studies of Sherin and her colleagues, they conceptualize professional vision in a linear pattern from highlighting to coding or from noticing to knowledge based reasoning, but in the Goodwin's study it is not a linear pattern. In Goodwin's study, the discursive practices of highlighting and coding do not always occur first highlighting and then coding schemes as in order, rather these practices may occur in the discourse of professions in an interwoven pattern.

The majority of the studies on professional vision and noticing have been conducted in the field of mathematics teacher education; however, there has been recent attention on the concept of professional vision in science teacher education. The majority of work in science education is conducted by German scholars, Seidel and Stürmer, however, their work takes a significantly different perspective on identifying and describing professional vision. They based

their studies on the literature on noticing specifically on Sherin and van Es's work and used a quantitative tool they developed to assess professional vision of teachers, specifically preservice teachers.

Blomberg, Stürmer, and Seidel (2011) investigated preservice teachers' professional vision as elicited by videos of different subjects. Their participants were preservice teachers majoring in science/mathematics and social sciences/humanities subjects. They found that preservice teachers majoring in different fields have different professional visions and concluded that beyond knowledge acquisition, subject-specific socialization may result in distinct sets of shared beliefs and values.

Seidel, Stürmer, Blomberg, Kobarg and Schwindt (2011) explored the effects of analyzing videos of one's own versus others' teaching on professional vision. Their participants were practicing secondary science teachers. They found no significant differences between teachers watching their own videos of teaching versus those of others with regard to professional vision. Teachers who watched their own videos noticed more relevant components of teaching and learning but were less self-reflective with regard to articulating critical incidents.

Similar to above studies, Seidel and Stürmer have multiple research studies using a quantitative tool, *Observer*, which Seidel and Stürmer (2014) created and validated to measure TCs' professional vision through quantitative methods. They took attending and knowledge based reasoning as two components of professional vision and divide the knowledge based reasoning part through description, explanation and prediction dimensions. They identified three categories as important part of effective teaching and learning: goal clarity, teacher support, and learning climate. Then, they developed items for these three categories using three dimensions of knowledge based reasoning in Likert scale scoring.

In various research studies, they showed their participants short video clips (2–4 min.), which function as item prompts. The clips feature three components of effective teaching and

learning, as they identified goal clarity, teacher support, and learning climate. Each clip is followed by standardized rating items tapping the three dimensions (description, explanation, prediction) of professional vision. In the tool, responses are given on a 4-point rating scale: 1 (*disagree*), 2 (*disagree somewhat*), 3 (*agree somewhat*), and 4 (*agree*). Items measuring *description* tap participants' ability to identify and differentiate between relevant events without making any further judgments (sample item: "in the excerpt that you saw: Does the teacher explain how the students are to carry out the tasks?"). Items tapping *explanation* focus on the link between an observed event and theoretical knowledge (sample item: "in the excerpt that you saw: Do you think that the students have the opportunity to see what is expected of them?"). Items assessing *prediction* assess participants' ability to predict the consequences of observed events for student motivation and learning (sample item: "based on what you saw: Will the students be able to experience themselves as self-directed learners?"). They used this observer tool to measure preservice teachers' professional vision in various research studies and I describe some of them below.

Stürmer, Seidel and Schafer (2013) investigated the impact of a combined practical and theoretical university-based term on preservice teachers' professional vision. They worked with 109 preservice teachers attending a five-month theory practice term guided through video-based courses about effective teaching and learning. At the university, they engaged preservice teachers in three consecutive video-based courses providing conceptual knowledge about effective teaching and learning components. In these courses, preservice teachers watched and analyzed videotaped classroom situations selected to represent the three components of goal clarity, teacher support, and learning climate. They also collected protocols of observed teaching lessons during the internship in the form of a portfolio to be handed in to the instructor at the end of the term. They analyzed preservice teachers' notes on lesson observations. They measured their changes in professional vision using the video-based tool *Observer*. They asked preservice teachers to

complete the *Observer* tool at the beginning and at the end of the semester as a pre-post test structure. They showed their participants six short video clips (2–4 min), which function as item prompts. Their findings show that preservice teachers positively change their professional vision during the theory practice term, especially if they show low entry levels at the beginning.

Stürmer, Konings and Seidel (2013) investigated how different university courses in teaching and learning impact the development of professional vision. They conducted pre-test–post-test with 53 preservice teachers about their declarative knowledge about teaching and learning and measured preservice teachers' professional vision with the online tool *Observer*. They found that teacher candidates in all three courses showed significant gains both in declarative knowledge and professional vision. A video-based course with a focus on effective teaching resulted in highest gains in prediction of the consequences of observed events for student learning processes, which is the highest level of knowledge transfer. They concluded that the development of professional vision is a strongly knowledge-guided process and university-based courses can enhance teaching-relevant knowledge for teacher candidates.

Stürmer, Konings and Seidel (2015) investigated which factors are related to preservice teachers' beginning professional vision and may constitute necessary conditions for development processes. They collected data through a questionnaire investigating their individual characteristics and opportunities used for learning and a video-based tool assessing their professional vision regarding generic pedagogical knowledge of teaching and learning from 55 preservice teachers. They conducted multiple regression analyses to identify relevant factors. They found that the number of attended courses on teaching and learning and the level of interest in the content are closely related to higher levels of professional vision. They found no relation with practical experience. It is concluded that professional vision is related to conditions of content-specific knowledge acquisition provided in formal teacher education programs.

Lefstein and Snell (2011) explored the political dimensions of teacher professional vision with primary school teachers in England. School teachers and academic researchers tend to look differently upon what happens in the classroom and often notice different phenomena and have different interpretations of observations of classroom actions. They explored what happens when these two different communities come together to talk about the recordings of classroom practices in professional development and called this the “politics of professional vision” (p. 505). They concluded that politics is critical to understanding the professional vision in the national policy context and in terms of power relations affecting what could be said and what was valued.

McDonald (2016) investigated differences between expert teachers’ (ETs) and teacher candidates’ (TCs) professional pedagogical vision for science teaching. He examined the ways ETs and TCs analyzed a 33-minute science lesson video from Trends In Mathematics and Science Study (TIMSS). The participants of the study were asked to highlight sections of the lesson they felt represented “inquiry science teaching” and provide reasoning for why they thought the instance to be an example of inquiry science teaching. McDonald (2016) found distinct differences in TCs’ and ETs’ professional pedagogical vision, in particular across four categories: actor focus, questions, grain size and enactment.

His results indicated that not only do the two groups largely attend to different surface level activities in a classroom, even when pre-service and in-service teachers attend to the same activities (e.g. questions), they have very different interpretations of those activities. His study indicates that when considering their own professional growth, teachers should be aware of the possibility of differences between colleagues in the way that they see and interpret classroom activity. McDonald (2016) suggests that a shift to evidence and explanations in analysis of classroom exemplars may help TCs to focus on students and their ideas, where TCs are asked to specifically indicate what activity in the classroom they are using as the basis for their judgments.

Much of the research around noticing and professional vision focuses on observation of

video recordings of teaching and attends to how preservice teachers or in-service teachers highlight and reason about the instances. The research primarily looked at individual teacher thinking, instead of how the discourse and practices changed over time for the collective group of teachers. In this respect, existing literature has missed an opportunity to take advantage of both the situative lens offered by professional vision, as well as ignoring one key part of Goodwin's framework, the production of material representations. Professional vision could be a way to conceptualize the acculturation of preservice science teachers into the established practice of the community of science teaching. Additionally, professional vision could allow for acculturation to happen in naturalistic ways in science teacher education classes.

Preservice Teachers' Challenges in Learning to Teach Contexts

Research on teacher learning and development has demonstrated the problems in learning to teach as the apprenticeship of observation, the problem of enactment, and the problem of complexity (complex classroom situations) (Hammerness, Darling-Hammond, Bransford, Berliner, Cochran-Smith, McDonald, & Zeichner, 2005). Davis, Petish, & Smithey (2006) reviewed several research articles in science education about preservice and new teachers and identified the challenges new teachers face. Their review demonstrates that preservice teachers at both the elementary and secondary levels face several challenges in learning to teach science effectively. Their results fell under five broad themes of challenges. The first theme is related to understanding the science content, scientific practices and discourses, and nature of science. The second theme includes understanding learners' strengths, needs and ways of knowing. The third theme involves understanding instructional techniques, strategies and approaches. The last two themes include understanding learning environments, and understanding professionalism. I summarize Davis et al (2006)'s results briefly.

First, preservice teachers do not demonstrate sophisticated knowledge of some science topics (e.g., Atwood & Atwood, 1996; Stofflett & Stoddart, 1994). In addition, beginning teachers tend to have unsophisticated beliefs about the nature of science (e.g., Abd-el-Khalick, 2001). Second, beginning teachers seem to want to engage, interest, motivate, and/or manage their students, though they also experience change in this focus (e.g., Abell, Bryan, & Anderson, 1998; Howes, 2002). Preservice teachers recognize that knowing about their students' ideas and backgrounds is important, but they do not know what to do with information they gather with regard to those ideas or backgrounds. Another common occurrence is that beginning teachers tend to emphasize the use of hands-on activities (toward the goal of engagement, interest, and motivation, as noted above; e.g. Abell et al., 1998) and emphasize the learning of science content (e.g. Geddis & Roberts, 1998). Beginning teachers sometimes have more sophisticated ideas about instruction than they are able to put into practice (e.g., Bryan & Abell, 1999). Finally, Davis et al. (2006) identified personal characteristics such as reflectiveness, identity, personal history, and self-efficacy that seem to influence one's development as a teacher (e.g., Czerniak & Shriver, 1994).

While Davis et al. (2006) grouped teachers' knowledge, beliefs, and practices into five broad areas, I focus on the problems with teaching practices. Research in teacher education has demonstrated a trajectory moving from investigations of teacher characteristics and behaviors to a focus on teacher thinking and decision making and research on teacher knowledge and beliefs (Grossman & McDonald, 2008). In the last three decades, there has been an emphasis on teachers' knowledge of specific subject matter, of learners, of assessment, and of curriculum after Shulman's (1986) conceptualization of pedagogical content knowledge (PCK). However, this research does not fully explain teachers' practices in their teaching. Thus, I focus on research related to teachers' teaching practices in the rest of this literature review.

The problem of enactment or the problem of practice is well documented in teacher

education literature (Crawford, 2007; Kennedy, 1999; Clift & Brady, 2005; Zembal-Saul, Krajcik, & Blumenfeld, 2002; Zembal-Saul, 2009). There is often a great disconnect between methods courses, where a teacher educator provides preservice teachers with reform-based ideas about science teaching, and the field placement or student teaching classroom where preservice teachers are expected to implement those ideas into their teaching. Unfortunately, in these field placement or student teaching classrooms, the cooperating teachers do not always have the same ideas about teaching science that were discussed in the methods courses or they are just not familiar with what is being taught in methods classes. Therefore, preservice teachers are faced with the problem of enactment, and thus they struggle to translate the theories and ideas they have discussed in methods courses into actual teaching in their field placement or student teaching. In other words, we as teacher educators often introduce the new ways preservice teachers should be teaching in methods course and then do not actually provide them with enough opportunities to start practicing how to teach in those ways until they are done with their coursework and are faced with figuring it out in less-supported environments with the pressures of real classrooms and of teaching real students. Magdalene Lampert (2001) describes this situation well when she says,

...learning about a method or learning to justify a method is not the same thing as learning to do the method with a class of students, just as learning about piano playing and musical theory is not learning to play the piano...(Lampert, 2001, p.35)

Likewise, Clift and Brady (2005) found that student teachers are themselves often challenged with contradictory ideas about students, teaching, and learning and are often confused with the contradictions and inconsistencies they encounter.

...the difficulty of enacting the practices recommended by methods courses and adopted by prospective teachers tells us that even when prospective teachers believe in teaching a certain way, they often do not know how to act on that desire or how to deal with difficulties they encounter. *Moving to action is more difficult than the intention to do so.*" (Clift & Brady, 2005, p. 322)

Mikeska, Anderson, and Schwarz (2009) identify three essential problems of practice that new teachers face when learning to teach science. These problems of practice include engaging students in scientific practices, organizing instruction and resources, and understanding students. Teacher education programs need to prepare new teachers for this challenging work. Davis et al. (2006) suggest that preservice teacher education must become more effective and efficient to meet the demand for highly qualified science teachers in order to support preservice science teachers to overcome these challenges. Research in teacher education recommends a model of teacher education grounded in the practices of teaching (Ball & Cohen, 1999; Ball & Forzani, 2009; Grossman et al., 2009; Grossman & McDonald, 2008):

To make practice the core of the curriculum of teacher education requires a shift from a focus on what teachers know and believe to a greater focus on what teachers do. This does not mean that knowledge and beliefs do not matter but, rather, that the knowledge that counts for practice is that entailed by the work. (Ball & Forzani, 2009, p. 503)

This approach has been referred to as *practice-based*, *practice-focused*, or *practice-centered* teacher education (Ball & Cohen, 1999). Even though there is an emphasis to practice based approach, it is not a new approach to teacher education. It has been studied by both behaviorist-oriented scholars (e.g., Gage & Winne, 1974) in 1970s and cognitive and behaviorist oriented scholars (e.g., Sykes, 2004) in 1990s (Zeichner, 2012). Although the efforts to explain the activities of teaching from these perspectives differ significantly, the idea behind the practice-based curriculum is that once the activities of teachers are identified, the teacher education programs should focus on developing teacher candidates' abilities to successfully enact these practices (Zeichner, 2012). Understanding the reasons for specific practices and identifying why they matter is part of the cognitive and current approaches, rather than the behaviorist perspectives. The current reform efforts in teacher education emphasize high-leverage teaching practices and routines that are believed to support high-quality student learning. Identifying the core teaching practices that should be included in teacher education curriculum has been an

ongoing reform effort in teacher education community (Zeichner, 2012). Some of the examples of instructional routines include posing problems, providing explanations, responding to student thinking, and leading class discussions (Ball et al., 2009; Grossman & McDonald, 2008). These routines have common features that they happen frequently, are fundamental to the practice of teaching, allow the learning of all students and are learnable by novices in teacher preparation programs (Ball et al., 2009; Grossman et al., 2009). One of the ways to identify core practices of teaching that should be included in teacher education curriculum is grounded in the teaching of certain subjects such as mathematics (e.g., Kazemi et al., 2009), science (e.g., Windschitl et al., 2011), and English language arts (Grossman et al., 2010) as well as the research that has identified specific teaching practices that are related to enhancing student learning (Zeichner, 2012).

Tools, Frameworks, and Models for Scaffolding Teacher Learning

Previous research suggests some strategies for effectively preparing preservice teachers for teaching science. Many research studies have developed tools, a beginning set of teaching practices or repertoires, conceptual frameworks, instructional models, strategies and other scaffolds to support preservice teachers in developing planning and teaching practices that meet these goals (Davis et al., 2006; Schwarz, 2009; Windschitl et al., 2009; Zembal-Saul, 2009; Grossman & McDonald, 2008).

One of the models described in teacher education is related to artifacts. Hiebert and Morris (2012) discussed the approaches taken in teacher education to improve teaching as recruiting talented people, improving the qualifications of teachers in the profession, and improving the instructional methods that are implemented in classrooms. They argue for improving artifacts to improve teaching as “artifacts or knowledge products survive individuals

and can be shared and improved over time” (Bereiter, 2002; Morris & Hiebert, 2011, cited in Hiebert and Morris, 2012, p. 93). They argue for preserving the knowledge in a format that can be shared among teachers and passed along to new teachers to support improvement in teaching. For these purposes they advocate the development of artifacts or instructional products that are public and shareable. Furthermore, they see these artifacts are in constant process as researchers and teachers create the artifacts, test them out, use the feedback from the trials to refine and revise them for future uses. Thus, the artifacts will be up to date and improved based on the feedback gained from the implementations. They proposed annotated lesson plans and common assessments as the instructional products. Their proposal is good in a sense that they propose a collective approach to knowledge building where knowledge is enacted in action not only by individual teachers but by groups of teachers working together with researchers, and collectively revising and annotating the lesson plans based on the feedback from each implementation for future use. These lesson plans and assessments could become the tools that support and be product of the knowledge for teaching. In the conceptualization of professional vision, Goodwin (1994) proposed building material representations as the third element that completes the coding and highlighting practices. Hiebert and Morris’s suggestion of annotated lesson plans and assessments would be one example of building material representations.

Grossman and McDonald (2009) offered a framework with three dimensions for analyzing the preparation of preservice teachers in the university setting. They identified three key concepts for understanding the pedagogical approaches used in professional education: representations, decomposition, and approximations of practice. Even though I discussed their framework above in the introduction; I want to elaborate on what they mean by these key concepts. Representations of practice comprise the different ways that practice is represented in professional education and what these various representations make visible to novices. Decomposition of practice involves breaking down practice into its constituent parts for the

purposes of teaching and learning. Approximations of practice refer to the degree to which the learning opportunities provided to novices resemble the authentic practices they will be expected to enact. They call these practices as pedagogies of practices for the teacher educators. These elements could play out in teacher education programs where teacher educators could demonstrate or model new forms of instructional discourse either live or on video, create environments to collectively analyze teaching practices, and provide opportunities for preservice teachers to approximate these practices in front of their peers as well as use tools to support their learning to teach.

Their framework seems to have potential, as it is readily applicable in terms of both helping teacher educators designing specific activities of teaching for the preparation of preservice science teachers and helping preservice science teachers learn to enact through repetitive and interactive cycles. One critical piece to applying this framework to teacher education, is a clearly defined set of practices for beginning teacher to learn. For science education, this set of practices can be characterized as ambitious science teaching practices.

Ambitious Science Teaching Practices

In science teacher education, Windschitl, Thompson, and Braaten (2009) went further and questioned which practices are more fundamental and worth learning for beginning teachers. They suggested that teaching practices should be grounded in important learning goals for all K-12 students, the literature on how students learn, and emerging longitudinal research about how novices learn the craft of teaching. They also suggested specific practices that could be tied to student thinking, and they proposed high-leverage practices (HLPs) as the core repertoire of ambitious teaching. According to the authors, “ambitious teaching deliberately aims to get students of all racial, ethnic, class, and gender categories to understand science ideas, participate

in the discourses of the discipline, and solve authentic problems” (p.4). They argue that this kind of pedagogy is both adaptive to students’ needs and thinking and maintains high standards of achievement for all learners.

Windschitl et al. (2011) investigated how novice teachers engage in the collegial analysis of student work artifacts and the development of tool systems to support this activity with novice teachers. They hypothesized that first-year teachers could take up forms of ambitious pedagogy under the following conditions: 1) that reform-based practices introduced in teacher preparation would be the focus of collaborative inquiry throughout the first year of teaching, 2) that participants use analyses of their students’ work as the basis of critique and change in practice, and 3) that special tools be employed that help participants hypothesize about relationships between instruction and student performance. In a qualitative multi-case study, they worked with eleven secondary science teachers engaged in tool-supported collegial analysis of their students’ work over two years in their pre-service and in-service contexts. Their data sources were video recordings of collaborative inquiry sessions with critical friends groups (CFG), classroom observations, student-created artifacts, interviews, and field notes. Their analyses include identifying patterns of participation across CFG sessions and changes in classroom practice during induction. They found that more than one third of the group developed elements of expert-like teaching, with the most gains made in pressing their students for evidence-based scientific explanations, a practice that was the focus of their regular examinations of student work. They suggested that for a majority of preservice teachers who initially held the most problematized images of the relationships between teaching and learning, the system of tools (rubrics and protocol) was critical in fostering deep analyses of students’ work and supporting a shared language among preservice teachers. They conclude that those who begin their careers with a problematized view of the relationships between teaching and learning are not only more likely to appropriate sophisticated practices early, but also to benefit from evidence-based collaborative

inquiry into practice. Their study highlights the role of tools in promoting ambitious pedagogy. They argue that novice teachers can develop a shared discourse to describe ambitious practices through the use of tools and participation in a community in which they engage in collaboratively analyzing students' work. Similar to Windschitl and et al, in this study the instructor of the studied course uses the ambitious science teaching practices as a curriculum for teacher candidates.

Windschitl, Thompson, Braaten and Stroupe (2012) proposed a set of subject specific high leverage practices. They identified four core practices and their associated tools. The first of those practices is a planning practice called constructing the big idea. Three of those practices are enactment practices, which they refer to as Discourses. Discourse 1 (D1) corresponds to eliciting students' ideas to adapt instruction, discourse 2 (D2) corresponds to helping students make sense of a material activity, and discourse 3 (D3) corresponds to pressing students for evidence-based explanations.

By "big ideas" they refer to relationships between concepts in the form of scientific models that help students understand, explain, and predict various phenomena in the natural world. They argue that without identifying the big idea for the unit of lessons, ambitious teaching cannot be initiated. During this process, teachers also select complex natural phenomenon or event representing the big ideas that students can relate to and teachers can develop a unit to help students develop explanatory models to explain the phenomenon under investigation. In this type of teaching, phenomena are events or processes that are observable by the senses or detectable by instruments. Phenomenon based teaching requires teachers to move away from a curriculum based on topics to a curriculum based on big ideas.

In the planning phase, teachers are expected to write a gapless explanation for the phenomenon and develop back-pocket questions to ask students as they move between groups to

help students develop explanatory models. By back-pocket questions, they mean questions that the teachers can use to elicit students' ideas during instruction and can literally put in their back pockets and look at as they move between the groups. By writing gapless explanations they refer to causal, rich explanations for the phenomenon through using abstract or unobservable characters, events, properties to form the explanation. Creating gapless explanation requires that they link many science ideas together and understand how evidence supports claims.

Discourse 1 (D1) practice, eliciting students' ideas, initiates the instruction and the goal is to elicit students' understandings of the phenomenon and adapt the instruction based on students' ideas. During discourse 1 (D1) practice, teachers are expected to enact sub-practices that help teacher elicit students' initial ideas including eliciting initial hypothesis about the phenomena, eliciting observations about phenomena, pressing for explanations and summarizing students' ideas. Teachers are expected to make instructional decisions based on the information they gathered in the lesson about students' partial understandings, students' alternative understandings, everyday language they use to describe the phenomenon, and everyday experiences they spontaneously use to make sense of the phenomenon. Looking at students' ideas in terms of these specific perspectives was part of the rapid student survey tools (RSST).

Discourse-2 (D2) practice, helping students make sense of material activity, includes laboratory work and readings with students' initial models to build content knowledge and advance students' conceptual understanding of the local phenomena. During making sense of material activity, teachers are expected to engage students in material activity and discourse around the material activity to help students make sense of the activity. In this phase, teachers make the students aware of the academic language associated with the science being studied and how it may be similar to or different from the everyday language that students used to talk about the phenomenon. There could be multiple material activities over the period of days that the

teacher uses to help students make sense of the phenomena within the unit.

Discourse-3 (D3) practice, pressing students for evidence-based explanations, aims to assist students in co-constructing evidence based explanatory models for the phenomena. In this practice, students are expected to draw on all the investigations and readings to finalize their explanatory models. This practice also extends to couple of class periods to help students complete their explanatory model.

In this study, these ambitious science-teaching practices are used as part of the curriculum of the investigated science teaching methods course as well as during the analysis of the data gathered through TCs' discussions of the teaching events.

Thompson, Windschitl and Braaten (2013) investigated developing practices of 26 preservice secondary science teachers as they moved between two communities with different contextual discourses, promoting contrasting visions of science teaching. They investigated a core set of four practices, selecting big ideas/models, working on student ideas, working with science ideas, and pressing for explanation. Thompson et al. (2013) argue that the core practices are generalizable across science teaching contexts and adjustable for various subject matter purposes. They investigated novices' trajectory of practice both influenced by their own developing pedagogical reasoning about teaching and learning, and their participation in multiple professional communities that may have contrasting visions and messages about good teaching. Therefore, their study investigates both individual and social aspect of pedagogical reasoning.

They also investigated how the tools and professional routines, used in different learning-to-teach settings, create opportunities and tensions for the early development of practice. They found three trajectories of practice—each with distinctive features for how novices engaged students intellectually. These trajectories are: integrating multiple ambitious practices,

compartmentalizing an ambitious practice, and appropriating talk without practice. They explained the differences by the communities with which teachers most closely identified, the degree to which teachers' discourses about student thinking were developed within these communities, and how teachers used tools from the communities to shape their practice.

One of the important components of ambitious science teaching is giving attention to students' ideas through eliciting and adapting instruction based on the elicited ideas.

Attention to Student Ideas

One of the problems with teaching practices is a lack of attending to students' ideas during instruction (Mikeska et al., 2009; Davis et al., 2006). Attending to students' ideas during instruction is one of the main components of ambitious instruction, but it was mainly emphasized especially during discourse 1, eliciting students' ideas practice. Research emphasizes the need for teachers to attend to student ideas (Ball, Lubienski, & Mewborn, 2001). It is important for teachers to "wait for and listen to" (p.155) student ideas in order to recognize important ideas in relation to the day's lesson (Fraivillig, Murphy, and Fuson (1999) cited in Sherin and van Es, 2009, p.22). When teachers pay close attention to students' thinking the opportunities for student learning increase (Franke, Carpenter, Levi, & Fennema, 2001). However, prior research has demonstrated that preservice science teachers tend to have very limited ideas about what to do with student ideas while teaching (Zemba-Saul et al., 2000; Mikeska et al., 2009; Davis et al., 2006). Preservice teachers also tend not to consider students or student learning very extensively, very carefully, or in very sophisticated ways (Abell, Bryan, & Anderson, 1998). Abell, Bryan, and Anderson (1998) have found teachers' reflections on student learning to be primarily focused on students' interests and motivation. Researchers engage teachers in identifying and interpreting

the ideas students raised in video clubs that are designed to help teachers learn to attend to student ideas (Sherin & van Es, 2009).

Zemba-Saul and colleagues (2000) investigated preservice elementary teachers' ability to structure and sequence interventions to appropriately address students' prior knowledge and their learning goals. In their study, the two preservice elementary teachers responded poorly to the students in their first cycle of planning, enacting, and reflecting on a lesson and did not gain an understanding of students' thinking while they were teaching. Their thinking and practices changed in the second cycle as they tried to account for learners' ideas in their planning and enactment. Through using pedagogical content knowledge (PCK) framework, Zemba-Saul et al. (2000) argue that preservice teachers tend to encounter problems when attempting to improvise in response to students' questions. However, they suggest that with time and experience, preservice teachers are able to improve their interactive teaching skills.

Similarly, Levin, Hammer, & Coffey (2009) investigated preservice teachers' attention to students' ideas. They analyzed classroom episodes to study how novice teachers attended to student thinking during instruction. In their design, student teachers examined records of practice primarily with respect to evidence of student reasoning, first drawing on existing examples and then collecting their own. Their assignments included the preparation of case studies from their classes, at least one of which had to include a video the preservice teacher selected and transcribed for presentation in a seminar. Levin et al. (2009) provide evidence of novice science teachers attending to student thinking from their earliest experiences in the classroom, and they argue against the stage-based perspective on student teachers' attention to students' thinking. The stage-based perspective claims the notion that novices must focus on themselves before they are ready to focus on student thinking. While previous work (Abell et al., 1998) has focused on identifying novice teachers' attention in their reflections, Levin et al. (2009) analyzed classroom episodes to show novice teachers attending to student thinking during instruction.

Thompson et al. (2013) investigated preservice secondary science teachers' practices as they moved between two communities with different contextual discourses. One of the practices they investigated is *working on student ideas*. In this practice, the teacher initiates instruction by eliciting and making students' ideas visible and uses these initial ideas to inform instructional decisions. The teacher foster meaning-making by connecting students' lived experiences and knowledge to scientific phenomena and by engaging students in sense-making discourse about how the activities connect to their developing scientific ideas. The teacher often assesses development of students' ideas through informal and formal means to provide feedback to students about their current thinking and to make decisions about future instruction (Coffey, Hammer, Levin, & Grant, 2011, cited in Thompson et al., 2013).

Thompson et al. (2013) provided novice teachers with a tool that outlined a routine for eliciting students' initial ideas. They found that preservice teachers' pedagogical discourses focused on eliciting students' ideas, and they also tried to understand how and under what conditions students' ideas changed over time. They argued that this finding is "more than a consequence of "interest" in student thinking and it encompassed more than a pedagogical stance about supporting students' scientific thinking" (p.603). They conclude that "by developing a critical pedagogical discourse focused on teasing apart students' ways of making sense of science and then engaging in principled experimentation about talk and tasks that could advance these ideas, these novice teachers positioned themselves to accelerate their learning as well as their students' learning" (p. 604).

Similar to Levin et al. (2009), Thompson et al. (2013) also do not think that beginners first concentrate attentional resources on their own performance, then later on students (Berliner, 2004). They found that two-thirds of the novice teachers in the study developed critical pedagogical discourses that were hybrids of a focus on teacher performance and on student learning. They argue that novice teachers are competent on attending to student thinking. In

addition, they offer that the reason they may not do so is that in shifting contexts from teacher preparation to school settings, they become subject to the constraining ideologies of classroom control and learning as fact acquisition (Kennedy, 1999). They also conclude that revising discourses around student thinking might not be possible as long as professional work takes place in a culture that conserves the status quo in terms of pedagogy, curriculum, and student expectations.

In this chapter, I described my theoretical framework drawing on sociocultural and situated theories of learning. These learning theories focus attention on the activities and the discourses TCs engage in during their learning environments. I also described professional pedagogical vision as my conceptual framework, drawing from Goodwin's (1994) definition of how professions see and interpret events in their area of expertise. I also described empirical studies of professional vision, challenges TCs face in learning to teach, research on ambitious science teaching practices, and literature on TCs' attention to students' ideas. This study aims to build on this foundation and contribute to the current literature on two areas. The first area is preservice teachers' learning and their social negotiation of the meaning of ambitious science teaching practices and how teacher educators can facilitate that learning. The second area is using professional vision as a complete framework to guide a more naturalistic examination of preservice teacher learning with specific consideration of the development of material representations as part of professional vision.

Chapter 3

METHODOLOGY

In this chapter I explain the design of the study, the context and participants as well as data collection and analysis methods. The purpose of this study is to describe how science teacher candidates negotiate meaning of ambitious science teaching and how their professional pedagogical vision develops as they engage in a science teaching methods course. Specifically, science teacher candidates enrolled in SCIED 412 course and concurrently in CI 495C within one semester during Fall 2013. I aim to answer the following research questions:

1. How do teacher candidates negotiate meaning of ambitious science teaching when they engage in discussions in the first five weeks of methods course?
2. How does the professional pedagogical vision (PPV) of science teacher candidates develop around ambitious science teaching practices in a semester-long secondary science teaching methods course?
 - a. How do science teacher candidates highlight and code teaching events in their discussions of teaching and what material representations do they produce?

The Design of the Study

Case Study Methodology

The research design of this study is a qualitative case study informed by ethnographic methods. Although case studies can include quantitative analysis and historical cases, in this study I use case study as a form of qualitative research that facilitates the exploration of a phenomenon within its real context with multiple sources of data. Case study shares similarities

with other forms of qualitative research (Merriam, 2009), including: the search for meaning and understanding, the researcher is treated as the primary instrument of data collection and analysis, use of an inductive process for investigation, and highly descriptive report of the results.

Merriam (2009) describes case study as a form of qualitative research and defines it as “an in-depth description and analysis of a bounded system” (p. 40). Yin (2009) proposes a two-fold definition: One part relates to the scope of the case study and the other part relates to the technical definition of case study. On the topic of the scope of case study, Yin proposes, “A case study is an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident” (p.18). The second part of the definition adds:

“The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result, relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result and benefits from the prior development of theoretical propositions to guide data collection and analysis” (p.18).

Some researchers referred to case study as strategies of inquiry and a method of qualitative research emphasizing the process (Yin, 2009; Merriam, 2009; Creswell, 2007), others referred it as a choice of what is to be studied rather than a methodology (Stake, 1995). I take Yin’s (2009) definition of case study and approach case study design from his perspective.

Deciding on the Case

Case study aims to construct rich descriptions of the events and understandings of the subjects in order to begin to make sense of the “messy complexity of human experience” and “to see what some phenomenon means as it is socially enacted within a particular case” (Dyson & Genishi, 2005, p. 3, 10). Dyson and Genishi (2005) stated, “Cases are constructed, not found, as researchers make decisions about how to angle their vision on places overflowing with potential

stories of human experience” (p. 2).

Identifying the case is an important step in order to draw the boundaries of the case and to decide on the research design. One of the features of case study is the unit of analysis, the case. Dyson and Genishi (2005) described case as “a small, naturalistic social unit (i.e., a social unit recognized as such by participants themselves)”, and “that unit becomes a case of *something*, of some phenomenon” (p. 2, 3, emphasis in original). According to these researchers, a case should be a bounded system. In order to understand the boundedness of the case, Merriam (2009) suggests asking about how finite the data collection would be, if there is a limit to the number of people who would be included, or if there is a finite time for observations. Researchers, including Stake (1995), have suggested placing boundaries on a case to see the scope of the study. Suggestions on how to bind a case include: a) by time and place (Creswell, 2003), b) by time and activity (Stake, 1995), and c) by definition and context (Miles & Huberman, 1994).

In this study, I examined a case of professional pedagogical visions of science teacher candidates who were enrolled in SCIED 412 course. The case is bounded by the larger context of the SCIED 412 and CI 495C courses. The first five weeks and the last four weeks of the semester teacher candidates have a shared meaning-making experience around ambitious science teaching in the SCIED 412 course. Then, when they go to the field experience for six weeks, the larger case branches out to individual cases as the context and participants in the community expand.

Types of Case Studies

Yin (2009) differentiates case studies between single, holistic, embedded, and multiple-case studies (see Figure 3-1). He argues that single case studies are common in doing case study research and identifies two variations, holistic designs and embedded units of analysis. I considered this study as a single embedded case study with multiple participants because the

larger context of the study included the Science Teaching Methods II (SCIED 412) and CI 495 C courses and the participants were bounded by these courses. Following Yin's (2009) identification, each participant was an embedded unit of analysis within the case. The case study design, bounded and rooted in the context of the Secondary Science Teaching II and CI 495C courses, was understood through multiple data sources and was analyzed using an interpretive lens. Even though there were multiple physical contexts when the teacher candidates (TCs) went to the schools for field experience, I considered the boundaries of the case to be students in the science teaching methods course with a field experience component. Thus, I examined how the professional pedagogical vision developed during the course and how TCs negotiated meaning of ambitious science teaching.

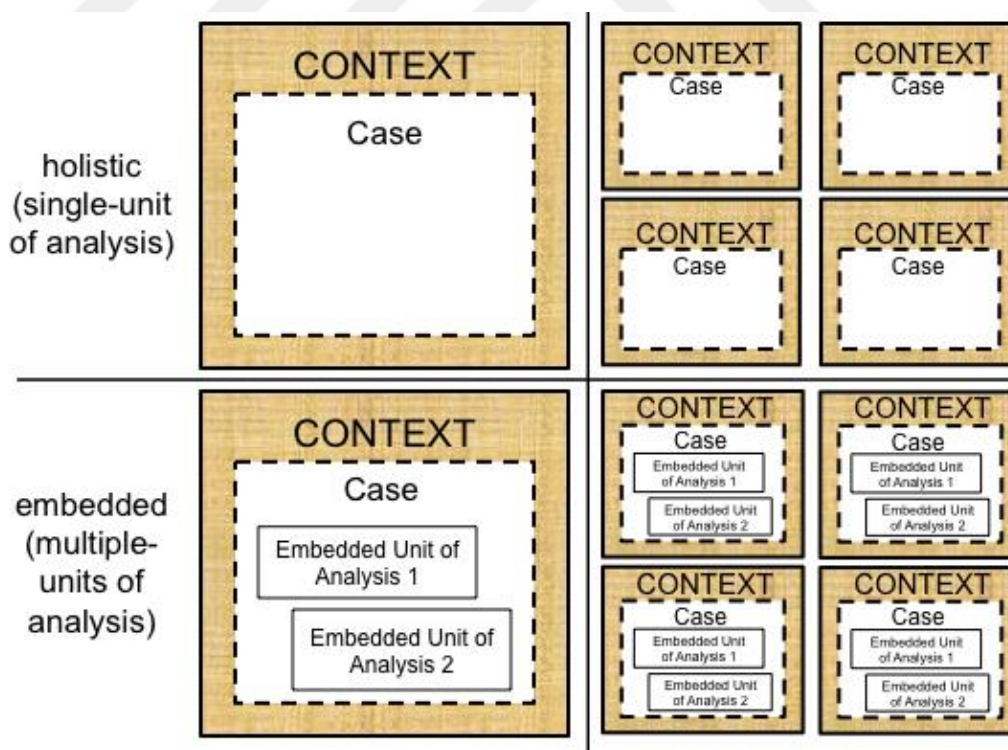


Figure 3-1: Types of Case Studies (Copied from Yin, 2009, p. 46).

Yin (2009) proposes five circumstances in which single case studies should be used.

These circumstances are “where the case represents a) a critical test of existing theory, b) a rare or

unique circumstance, c) a representative or typical case, or where the case serves a d) revelatory or e) longitudinal purpose” (p. 52). This study was a representative or typical case of science teaching methods course, which has a field placement component and includes peer-teaching rehearsals. However, it is also unique in the sense that it focuses on professional vision with ambitious science teaching practices. Including embedded subunits in the single case design allowed significant opportunities for extensive analysis and enhances the insights into the single case. However, Yin (2009) also urges researchers not to fall into analyzing at the individual level while ignoring the larger holistic aspect of the single case.

The difference between a holistic case study with embedded units and a multiple case study is that the context is different for each of the cases. While a holistic case study with embedded units only allows the researcher to understand one unique/extreme/critical case, in a multiple case study, the researcher examines several cases to understand the similarities and differences between the cases. I chose the design of the case study as the holistic case study with embedded units instead of the multiple case study design given the way I have defined the context.

Why case study is an appropriate methodology?

Yin (2009) discusses three conditions that should be checked in order to decide whether a case study is the appropriate method to use. These three conditions include the type of research questions posed, the extent of control the researcher has over the actual events and behaviors, and the degree of focus on contemporary rather than historical events. Thus, according to these conditions, Yin (2009) proposes that when *how* and *why* questions are being posed, when the investigator has no or little control over the actual phenomenon, and when the focus is on a contemporary phenomenon, case study methodology is relevant and appropriate.

Case study design is chosen as the appropriate research method for this study because first, the research questions include “how” questions that are explanatory in nature (Yin, 2009). This study asked how participants develop professional pedagogical visions about teaching and learning and how they negotiate meaning of ambitious science teaching in their discussions of teaching. In addition, case study design is aligned with the theoretical framework of the study. Drawing from socio-cultural and situated learning approaches, the science teaching methods course (SCIED 412), seminar course (CI 495 C) and field experience classrooms have their own culture that produce their own discourses through interaction between teacher candidates and the instructors, and between teacher candidates, mentor teachers and the course instructor, respectively. For this reason, this study investigates the contextual meaning of professional pedagogical vision of teacher candidates in their analysis and (reflective) practices of teaching as they negotiate meaning of ambitious science teaching. One of the other reasons that case study design is a relevant and appropriate method for this study is that the researcher has no control over the science teacher candidates’ professional pedagogical vision and their negotiations of the meaning of ambitious science teaching (Yin, 2009). The last reason that the case study is an appropriate method for the study includes that the focus of the research is a contemporary rather than a historical phenomenon (Yin, 2009).

Context of the Study

The context of this study included secondary science teaching methods course (SCIED 412: Secondary Science Teaching II), secondary education clinical application of instruction course (CI 495C), a seminar course the TCs are concurrently enrolled in, all occurring in a large mid-Atlantic university’s teacher education program, as well as the four secondary schools in two districts, where the TCs were in their field placements.

During Fall 2013, teacher candidates were in SCIED 412 course in the first five weeks and the last four weeks of the semester. They went to the secondary schools for the field experiences for the six weeks in the middle. Teacher candidates met for the CI 495C course during the first eleven weeks of the fall semester. After completing their field experience the seminar for the CI 495C course ended (see Table 3-1).

Table 3-1: Layout of the Courses in the Semester.

15 Week Course 08/27/13 - 12/12/13		
The first 5 weeks (08/27-09/30)	The next 6 weeks (09/30-11/11)	The last 4 weeks (11/11-12/12)
SCIED 412 on campus	Field Experience in the local schools	SCIED 412 on campus
CI 495C seminar on campus		No seminar for CI 495C

SCIED 412 was the science teacher candidates' second teaching methods course. Their prior teaching methods course (SCIED 411: Secondary Science Teaching I) focused on reformed science teaching, understanding students and lesson preparation and also required teacher candidates to engage in two microteaching activities with local middle school students. SCIED 412 focused on unit planning and the analysis of teaching through peer teaching rehearsals and video of teaching. Teacher candidates met for 3 hours two days a week and engaged in analysis of teaching, where they watched videos of teaching of model teachers from the University of Washington's website, <http://tools4teachingscience.org>, videos of their own enactment in teaching in the rehearsal events, and also engaged in curriculum planning. After SCIED 412, TCs enrolled in student teaching for their final semester.

The teacher candidates were concurrently enrolled in a field experience course (CI495C)

where they went to the schools for the field experience in the mornings for six weeks in the middle of the semester and met face to face weekly for 1.5 hour on campus during the first eleven weeks of the fall semester. In the seminar course, teacher candidates discussed educational issues they experienced in the high schools during the field experience. The course instructor was, at the same time, their supervisor in the field and went to the schools to observe and provide feedback on their teaching.

Participant Selection

Merriam (2009) discusses that in qualitative research, the most common sampling method chosen is non-probability sampling. The purposive (Chein, 1981, as cited in Merriam, 2009) or the purposeful sampling (Patton, 2002, as cited in Merriam, 2009), one of the most common methods among the non-probabilistic sampling methods (Merriam, 2009), is used in this study. Purposeful sampling is used when the researcher wants to learn and get deep insight and understanding from information-rich cases from which a great deal can be learned (Merriam, 2009).

Merriam (2009) discusses different types of purposeful sampling including typical, unique, maximum variation, convenience, and snowball or chain sampling. This study used a convenience-sampling method to select the participants. Merriam (2009) explains convenience sampling as when the researcher selects the sample based on time, money, location, availability of sites or respondents, and so on.

Participants

The participants in the study included all six teacher candidates (four female and two male) enrolled in the SCIED 412 and CI 495C courses concurrently, the SCIED 412 course instructor, and the CI 495C course instructor, and two of the mentor teachers. The background information about the participants is included in Table 3-2.

Table 3-2: ¹Background of the Participants.

Participants	Major	Previous Teaching Experience	Field Experience Placement Grade/Subject
Abby	Secondary Education Biology	SCIED 411 microteaching, previous field experience for one semester.	9 th Grade Biology class
Erika	Secondary Education Biology	Only in the SCIED 411 microteaching	7 th Grade integrated Science and 8 th Grade Physical Science
Debbie	Secondary Education Chemistry	Only in the SCIED 411 microteaching	11 th Grade Chemistry
Kayla	Secondary Education Biology	Only in the SCIED 411 microteaching	9 th Grade Biology class
Bryan	Secondary Education Physics	Only in the SCIED 411 microteaching	No Field Experience
Mark	Secondary Education Biology	SCIED 411 microteaching, tutoring, a university course assistant.	No Field Experience
Sean	Science	6 years K-12	SCIED 412 Course

¹ All the names included in the table are pseudonyms.

	Education Faculty	science/physics teaching and 10 years of science education faculty	
Neal	Supervisor, Biology Teacher	40 years of K-12 Science teaching, 6 years of college supervisor	CI 495C Course
Mr. Young	Chemistry teacher	40 years of teaching experience	11 th and 12 th grade honors and academic level chemistry
Mr. Hersey	Integrated Science Teacher	13 years of teaching experience	7 th grade life science and 8 th grade physical science

The teacher candidates were certified in biology (four of them), physics (one), and chemistry (one). Their previous teaching experience, for most of them, was limited to their teaching experiences in the previous science teaching methods course. Only Mark and Abby had other teaching experiences, Mark was a teaching assistant for a college level chemistry course, and Abby did her previous field experience in the schools before she was transferred to the current university.

At the beginning of the course six teacher candidates enrolled in the course; however, incidents occurred, and one teacher candidate (Mark) dropped the course when he was dismissed from the field experience. Therefore, I have data from Mark only in the first five weeks of the semester. Another teacher candidate (Bryan) did not get clearances to go to the schools due to personal circumstances, so he could not participate in the field experience. Thus, I do not have data from Bryan during the six weeks of the field experience.

The mentor teachers Mr. Young and Mr. Hersey were in the same school district. Mr. Young was chemistry teacher and had 40 years of teaching experience and Debbie's mentor

teacher. Mr. Hersey was the integrated science teacher in the middle school and had 13 years of teaching experience and Erika's mentor teacher.

Gaining Access and Recruitment of the Participants

I talked to the instructor of the SCIED 412 course and he agreed to participate in the study. He was also concurrently my advisor and dissertation committee chair. I contacted the CI 495C course instructor through email and he agreed to participate in the study and all six teacher candidates agreed to participate in the study.

For their field experience, the five teacher candidates were placed in two nearby school districts in four schools. I contacted the building principals via multiple emails and phone calls in September. The head principal of School District A where three of my participants were placed refused to participate in the study from the beginning. The building principals of the other two schools in the School District B where two of the teacher candidates placed in agreed to participate in the study. Then I met mentor teachers and visited their classrooms for three days and got their consent forms but we could not get enough consent forms from the parents.

Reflection on the Data Collection Process: what was planned and what actually happened

The data collection process for the first five weeks went smoothly, and I collected the associated proposed data. Due to challenges on the district level as well as with individual teacher candidates, the mentor teachers and the supervisor, I was not able to collect the proposed data when TCs went to field experience. I took fieldnotes for three days in each of the classrooms I observed when the mentor teachers were teaching. I had two pre-post interviews for Abby, and only one field experience interview for Kayla, Debbie and Erika. TCs were supposed to write six

lesson plans during the field experience. I was able to collect six lesson plans from only two TCs, and the other two TCs did not share their field experience lesson plans with me.

I think other contextual situations including two significant personal problems also contributed to this process. One of them was the small number of students enrolled in the SCIED 412 course, the other one was Bryan could not get the clearances to go the schools, and another problem was Mark was dismissed from the field experience due to some problems. Addition of all these contextual situations/issues impacted the data collection process. What I learned from this process was the importance of negotiating the roles and building trust and relationships with the participants. Also, other factors that impacted this process could be people's familiarity with the educational research and how much I, as the researcher, was able to translate those to my participants.

Researchers' Role

In this study, I was the primary investigator. I was responsible for data collection, analysis, had a participant observer role in the classroom and an interviewer. While I have these responsibilities and roles, I acknowledge my biases, and try to listen objectively and record information in the interviews and field notes. I attended all meetings of SCIED 412 and CI 495C with the teacher candidates.

I also have a personal interest working with teacher candidates that comes out of my own background. I went through a secondary education program with physics option in an integrated program where we receive both a master of education and a bachelor degree in a five-year program. I was one of the students who was good at school. During my last years of my college when I was taking two of my science teaching methods courses, while transitioning my role from being a student to becoming the teacher, I realized how much support I needed to create the

reform-based lesson plans. I remember the frustration that we did not see appropriate representations of practice either in the material form of lesson plans or the enactment of those lessons in representations of teaching. Seeing that mismatch in my methods courses led me to pursue a career in the academia to investigate how I can improve my own teaching and become a role model or provide better representations of practice for these difficult forms of teaching. This connection between the theory and practice of teaching is very important for my own learning and teaching. That's why I wanted to help teacher candidates see and recognize classroom events and become better teachers and to become teachers who care about teaching and want to improve their practice.

During my coursework both in masters and doctoral program, I tried to select science methods courses as the contexts for my course assignments. I have attended elementary science methods courses, some of the elementary science content courses, and both secondary science teaching methods courses (SCIED 411 and 412). I also have experience in analyzing data from teacher candidates' microteaching activities during my masters' thesis.

I attended the secondary science teaching methods course I (SCIED 411) during the semester when four of my participants were taking the course. I observed the class, took field notes from time to time, and collected course materials. The purpose of that observation included learning where teacher candidates are coming from in terms of the prior knowledge and experience in teaching, and what course materials/readings they had before coming to the SCIED 412 course, and making myself familiar to them and giving them the opportunity to know me.

Even though I talked with the course instructor before the study regularly, I did not have any influence on the curriculum of the course before the course started. As the semester proceeded, we had conversations about which case studies he wanted to include from the UW website to show teacher candidates as representations of practice. We decided to include an additional biology case study as most of the participants were biology majors. I wanted to have

teacher candidates analyze the chemistry case study twice - at the beginning and end of the semester; however, because of the number of students who dropped as the semester proceeded, the instructor of the course eliminated the second analysis.

Data Sources and Data Collection Methods

In July 2013, I applied to university's institute review board (IRB) (in Appendix A) to get permissions for the study. I received the approval for the study in August (in Appendix B). After I received the required permissions from the university's institute review board for the study, I contacted the supervisor to explain the study. Then on the first day of the SCIED 412 course, I explained the study to TCs and they all accepted to participate in the study and I received their consent forms and started collecting video recordings and fieldnotes in the course.

According to Merriam (2009), case study does not claim any specific data collection or analysis methods; from testing to interviewing, any methods of data collection as well as qualitative data analysis techniques can be used in case study. Case study focuses on holistic description and explanation. Yin (2009) stated, "Case study inquiry relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result, and benefits from the prior development of theoretical propositions to guide data collection and analysis" (p.18). Stake (1995) discusses observation, interviews, and document review as sources of data used in case study. Thus, these scholars agree that a variety of methods can be used in case study research.

I align the data collection stage of this study with Dyson and Genishi's (2005) ethnographic methods. Even though Dyson and Genishi do not call their study an ethnographic case study, they do use ethnographic methods. They rely especially on thick descriptions, field notes, and participant observations, as well as interviews. This study is not an ethnography, but I

used ethnographic field notes and participant observation to collect data. I did not engage in thick descriptions but coding.

I relied on multiple data sources to investigate how TCs develop professional vision and negotiate meaning of ambitious science teaching including ethnographic field notes (Emerson, Fretz, & Shaw, 1995) and participant observation (Spradley, 1980) of both courses, video recordings of the SCIED 412 course, interviews with TCs and instructors, and collected documents and artifacts from the assignments and course materials. Merriam (2009) writes that other types of qualitative studies such as ethnography could be combined with case study, since the defining characteristic of case study is the unit of analysis, the bounded system. Ethnographic methods were used for this study because case studies seek to understand the holistic nature of a bounded system and ethnographic methods allow the researcher to become immersed in the real-life experiences of her participants within the study context.

Therefore, in order to understand teacher candidates' professional pedagogical vision and their negotiation of meaning making for ambitious science teaching practices, I employed ethnographic data collection methods. Immersion in the sites as a participant observer, taking field notes, and recording videos of interactions in the classrooms enabled me to get insight into teacher candidates' practices. I also interviewed teacher candidates and their instructors, and collected any documents used in the courses to further my insights to answer the research questions. I describe each of these data collection methods in detail below.

The data collection for this study involves three time frames. The first encompasses the first five weeks of the semester when teacher candidates are concurrently in the SCIED 412 and CI 495C seminar, the second includes when teacher candidates are in the field placements in the school and concurrently in CI 495C course. The last includes the final four weeks of the semester, where TCs are only in the SCIED 412 course. Throughout all three time frames, I collected multiple forms of data (see Table 3-3).

Table 3-3: Data Sources in Different Steps.

SCIED 412: Secondary Science Teaching Methods Course (15 weeks)		
The first 5 weeks in the campus (5x6 hours in a week)	The next 6 weeks in the field experience- 09/30/13-11/08/13	The last 4 weeks in the campus (4x6 hours in a week)
• Video records of the SCIED 412 [30 hours from two angles-total 60 hours] • 2 Lesson plans for the rehearsals (20 min peer rehearsal) for each TC. • 2 Pre-post interviews around rehearsals for each TC. • Field notes of the SCIED 412. • Curriculum materials- given to TCs in the course. • Self-video Analysis of D1 practice. • Analysis of Model teacher (Bethany)'s teaching.	• 6 lesson plans (only from 2 TCs), • 3-day field notes (observation of two mentor teachers' teachings, not the TCs' teaching) • 1 interview with TCs regarding their experiences in the field experience. • 5 Rapid Student Survey Tools (RSSTs) for each TC.	• Video records of the SCIED 412 [18 hours from two angles] • Field notes of the SCIED 412. • Curriculum materials-documents used, given to TCs in the course. • Unit plans for each TC. • 1 Exit interviews for each TC.
CI 495C Field experience Pre-student teaching Seminar		
• Field notes of CI 495C • 1 Interview with the course instructor • 1 Video record of a feedback given to TCs from the supervisor • Collection of documents-course materials given to TCs.		No Classes

Participant Observation

Observation is a common source of data in case studies and leads the researcher toward a greater understanding of the case. Stake (1995) suggests that researchers give their readers a sense of “being there” to develop vicarious experiences by thoroughly describing the physical situation, as the physical place is fundamental to meanings for most researchers and most readers.

According to Yin (2009), observations can be *direct* or *participant*. Using direct observation, the researcher makes meaning about events, behaviors, physical environment, and so forth of the site during his or her visits. On the other hand, during participant observation, the researcher is involved in the context in different roles, such as being a part of the culture studied or being in interaction with the main participants of the research through meetings, interviews, and other interactions. In this study, I practiced participant observation by engaging in the context with the participants through interviews and social interactions within two courses. Through participant-observation, I tried to make sense of the events and behaviors as an “insider” (emic perspective). In the observation method, there are degrees of involvement in the practices of people under study. I describe these different levels of involvement below in detail.

Glesne and Peshkin (1992) explain:

Participant observation provides the opportunity for acquiring the status of “trusted person.” Through participant observation-through being a part of a social setting- you will learn firsthand how the actions of your others correspond to their words; see patterns of behavior; experience the unexpected, as well as the expected; and develop a quality of trust with your others that motivates them to tell you what otherwise they might not (p. 39, emphasis in original).

The authors emphasize the nature of being trusted in the research site so that the researcher is able to create close relationships with the participants. In the observation method, the degree of the researchers’ involvement in the culture and the practices of the observed group changes the quality and amount of the data that will be collected (Kawulich, 2005). Participant observation has a continuum, ranging from mostly participation to mostly observation. Kawulich (2005) describes how different scholars have approached and described this continuum. Kawulich (2005) uses the term “stances of the observer” when describing the varying levels of participation from one extreme level, complete participant, to the other extreme level, complete observer. She described the *complete participant* as “a member of the group being studied and who conceals his/her researcher role from the group to avoid disrupting normal activity” (p. 7). She described

the *participant as observer* stance as “the researcher is a member of the group being studied, and the group is aware of the research activity” (p. 7). The other stance in the continuum is *observer as participant*, and this stance “enables the researcher to participate in the group activities as desired, yet the main role of the researcher in this stance is to collect data, and the group being studied is aware of the researcher's observation activities” (p.7). The last stance she described is the *complete observer*, in which “the researcher is completely hidden from view while observing or when the researcher is in plain sight in a public setting, yet the public being studied is unaware of being observed” (p.7).

In this study, I have an *observer as participant* stance because I am not a member of the group of teacher candidates, but I was interested in participating as a means to conduct better observation and, hence, to generate a more complete understanding of their ideas during discussions of teachings and their participation in various classroom activities. I previously explained some of my involvement in the researcher's role section. Being an *observer as participant* also enables me to interpret the data I collected from other sources too. Glesne and Peshkin (1992) state that interview questions that are developed through participant observation will be connected to known behavior, and their answers can therefore be better interpreted. Thus, in my case, I used the observations I made to create the interview questions.

Record keeping is an important part of observation during case study research (Stake, 1995). According to Stake (1995), good record keeping “provide[s] a relatively *incontestable description* for further analysis and ultimate reporting” (p. 62). For this research, I used two ways to record how teacher candidates develop professional vision in the science teaching methods course (SCIED 412) and secondary education clinical application of instruction course (CI 495C). One way was taking field notes that helped to give the general picture of what is happening in the classroom and to capture the important aspects related to the study. The other way was video recording the observations, which provides a data source for details of the teacher candidates’

teaching practices and discussions of teaching in the science teaching methods course. I describe these methods in detail below.

Field Notes

During participant observation, I took field notes in all sections of SCIED 412 course, and CI495C course, and three days of visits in the mentor teachers' classrooms. First-hand participation in some initially unfamiliar social world and the production of written accounts of that world by drawing upon such participation are the core of ethnographic research (Emerson, Fretz, and Shaw, 1995). Emerson et al. (1995) discuss orienting yourself to see events and interactions as potential written records when participating in order to write. They suggest several points in the process of "jotting notes." One of these suggestions is to concentrate on a remembered scene more than on single words, which can narrow our attention to the entire scene after the fact. They also suggest recording as much detail as quickly as possible and to save evaluation and editing of the scene until we have written all the details we can remember. They also emphasize that our notes should be as spontaneous as the interactions we are observing.

Following Emerson et al.'s suggestions, I took field notes as I observed the SCIED 412 and CI 495C courses and two of the teacher candidates' mentor teachers' classrooms in one of the school district. Teacher candidates took the SCIED 412 course for 3 hours on Tuesdays and Thursdays, and the CI 495C course for 1 hour 15 min on Tuesdays. Teacher candidates were in the high schools for six weeks in the mornings. They observed their mentor teachers, and helped them in classroom activities such as taking attendance, grading assignments and they taught at least six lessons by themselves.

As Emerson et al. suggested, I tried to attend to the events I observed in a "microscopic" manner (Geertz, 1973, 20-23, as cited in Emerson et al., 1995) and wrote the field notes to tell

“what happened” in the classrooms in great detail. Because I was especially interested in the discussions of teaching, I took fieldnotes to report the interactions in the classroom in detail. In the interactions, I tried to capture the expressions of what the TCs and the instructor were saying in verbatim rather than summarized dialogs. An example page of fieldnotes is provided in Figure 3.2.

While jotting the fieldnotes in every class period for both courses, I cleaned and wrote more detailed fieldnotes every other day of the class period for the SCIED 412 course. As Emerson et al. (1995) explain timing of writing up fieldnotes is more important than how long the researcher spends in the field. I started cleaning and writing up fieldnotes for the CI 495C course at the beginning. However, later in the semester, I did not write up for those fieldnotes just because I did not see any discussion of teaching related to the research questions I am asking. I have fieldnotes in my notebook but not all of them are polished yet.

9/17/13 9:28 AM Created	
Title	
09.10.2013 3 rd Week	
1. day of teaching for teacher candidates	
The instructor says your job today is eliciting, pressing, probing, and using wait time. 20min of instruction.	
Kayla starts teaching her phenomenon, about cows. She shows pictures of cows with problems and she sets up her scenario and problem and asks, “what do we know about environment of these cows?”	
Then she breaks them into groups and Bryan asks where this is happening and Kayla explains.	
Kayla says draw your ideas to Debbie’s group.	
○ Then she visits Erika’s group. Kayla asks, “why are they having these problems?” And Groups are talking about water is used and grass is what they are eating. Then she asks, “How is it getting the cow’s system?” then they say, “They are digesting.”	
Kayla rephrases their answer “digested, can it get into their body in other ways?” Bryan says “breathing air”. Kayla says, these are good, expand on those ideas. What do we know about this. What happens... When you first breath where it goes, digested stomach.”	
Kayla goes to Debbie’s group	
“into water” “grass”, “What do we know about farm land?” basically what she says, cows eating digested	

Figure 3-2: A Snapshot of Fieldnotes.

Video Recordings

Routine social interaction is very complex and nuanced (Erickson, 2006), so fine-grained information about these actual interactions comes best through audiovisual recordings. Video records capture every detail of our observations, which might make analyzing data from them seem overwhelming; however, they are useful when we know what to look for on these video records. The videotape is not the actual data (Erickson, 2006), and the researcher needs a systematic method of analysis for the video research. In video research, where, when and to what the researcher gives attention determines the data of the study.

For this study, I video recorded all sections of the SCIED 412 course and this includes the instructor's teaching, each teacher candidate's teaching to their peers, the debrief sections of the teaching episodes that happened just after the rehearsal events, and their unit planning sections. I have 48 hours (8 weeks x 6 hours) of video records only from SCIED 412 course from one angle (96 hours from two angles). One of the class sessions in the last four weeks was canceled because the instructor was sick and the last session of the course was about the job search for TCs and it was an informal meeting so those two days I do not have recordings of these sessions of the course. Videos give me exact records of what teacher candidates engaged in during the course and how the teacher candidates used language when describing and analyzing the teaching episodes they experienced or observed. Video recordings also give the highlighting and coding-specifically what they attend and how they interpret events related to teaching practices. Video records helped me see the development of the discourse during the SCIED 412 course specifically during the analysis of teachings.

I used two video cameras in two angles; one was positioned in the back of the classroom and the other one was positioned at front section of the room. I manipulated and repositioned the cameras, when there was group work especially during the rehearsals, in order to capture the

discussions in the small groups. I zoomed in and out during the video recordings to capture what was written on the white board or presented in the smart board. The video recordings were offloaded each day after the class sessions and files were named and stored in various digital sources.

Interviews

Another data source is interviews, which have been suggested as an important data source in case studies since case study researchers seek multiple views on the world they are exploring (Stake, 1995; Yin, 2009; Dyson & Genishi, 2005). The ontological stance of using interviews is that “people’s knowledge, views, understandings, interpretations, experiences and interactions are meaningful properties of social reality” (Mason, 2002, p. 63). The notion that knowledge is co-constructed through the interaction between the interviewee and interviewer constitutes the epistemological stance of using interviews. Consequently,

The research interview is based on the conversations of daily life and is a professional conversation; it is an inter-view, where the knowledge is constructed in the inter-action between the interviewer and the interviewee. An interview is literally an *inter view*, and inter-change of views between two persons conversing about a theme of mutual interest (Kvale and Brinkmann, 2009, p. 2).

Interviews are useful because social explanations and arguments constructed in interviews can reveal “depth, nuance, complexity and roundedness” that other methods might not reveal (Mason, 2002, p. 65). Interviews can be in different formats according to how structured the questions are, i.e., structured, focused, and open-ended interviews (Yin, 2009). For case studies, it is suggested that interviews be open-ended and that the questions can be about the views, opinions, and ideas of the interviewees’ regarding the events. On this topic, Stake (1995) stated, “The purpose for the most part is not to get simple yes and no answers but description of an episode, a linkage, an explanation” (p. 65). The interview approach of this study has the

characteristics of ethnographic interviews used in ethnographic research as a supplementary method to clarify the interpretations from the observed data. In ethnographic interviews, “the interviewer and the interviewee already know each other and previously talked together. This gives rise to a different emotional climate between the two parties” (Kvale and Brinkmann, 2009, p. 191). By the time I started the interviews, I already attended and observed some of their first science teaching methods course in Spring 2013 and have been participating in both of the courses for this study, so I was familiar with the participants.

I conducted semi-structured interviews with the teacher candidates and the course instructors. The interview questions are included in the Appendix C. Through interviews I tried to learn what Seidman (2005) talks about as “the details of experience” and “the reflection on the meaning” about TCs’ experiences in the courses. I tried to ask follow-up and probing questions through interpreting what they said. Stake (1995) suggests that during the exchange, the interviewer needs most to listen, take few notes, as fits the occasion, but stay in control of the data collection. Following Stake’s (1995) suggestions, I tried to be silent to give them space to talk. I video recorded the interviews and took notes during the interviews.

The interviews with teacher candidates included four interviews, two of them were pre-post interviews related to each of their respective rehearsals and were conducted before and after each TC taught their lessons. The interviews lasted from 7 min to 34 min durations. The main focus of the interviews was how they plan to address student ideas and engage their students in scientific practices and how they handled student ideas and engaged students in scientific practices in their lessons, and if there was anything they want to change/improve for next teaching.

Another interview was conducted after their field experience before they come to the SCIED 412 course regarding their experiences in the schools and views about teaching they observed in mentor teachers’ classes. In order to understand how they negotiate the meaning of

science teaching in field experiences I also needed to understand their field experience culture. That's why I asked teacher candidates about how they think about the teaching they observed in the field experience experiences in their mentor teachers' classes. My original plan for the field experience interviews was to interview TCs before and after they taught their lessons in the field; however, not all of them were available to meet with me during the field experience, so I had two pre-post interviews with Abby about her two lessons she taught during field experience ranging from 35min to 45min. I had one interview with Debbie, Kayla, and Brooke about their field experience lasting approximately 47, 55, and 63 min respectively.

The last interview was conducted on the last day of the class as an exit interview to understand what they learned from the class, whether or not they will be using the ideas they learned from the class in their future teachings, and what they noticed from different representations of practice they saw during the class and the field experience. The duration of the interviews for five TCs ranged from 14 min to 40min.

I also conducted interviews with the course instructors. The interview with the SCIED 412 instructor happened when TCs were in the field experience around the 10th week of the semester and took 20 min. The interview with the CI 495C course instructor occurred on the last day of the seminar course and took 36 min. The interviews were about the general structure of the courses and how each of the instructors plans to press teacher candidates on the issues around student ideas and scientific practices.

Collection of Documents and Artifacts

Documents are another data source used frequently in case studies. Stake (1995) explains, "documents serve as substitutes for records of activity that the researcher could not observe directly" (p. 68). Public documents and personal documents are the two common categorizations

for types of documents (Whitt, 2001; Merriam, 2009). For the study, I collected personal documents, which for this research were teacher candidates' lesson plans, any written materials and video analysis developed during the analyses of the teachings, rapid student survey tools (RSSTs) filled during field experience, any tools and readings given to the teacher candidates in the courses and the video records of supervisor feedback given to them on their teaching of the first lesson in the field. I talk about the details of these artifacts in the following paragraphs.

Teacher candidates were supposed to submit their lesson plans in the course management website. I had access to that website and downloaded the lesson plans from there. If some of the assignments were not submitted, I then requested them from the instructor. I collected Discourse 1 (eliciting students' ideas) and Discourse 2 (helping students make sense of material activity) rehearsal lesson plans from all TCs, and the unit plans for fracking, consisting a total of 24 lesson plans from all TCs but Mark. TCs were supposed to use another management system, Taskstream (a web-based software program that can be used as an electronic portfolio and assessment management tool. It allows students to upload assignments of their course for evaluation.), in which the university requires them to upload their files created in the field experience. I requested TCs to share their lesson plans created in the field experience with me through this system so that I can also see their supervisor's feedback on their lesson plans, but not all of them shared their files with me. Lesson plans taught in the field experience classroom were collected only from Debbie and Abby.

I intended to use these documents to triangulate the data sources and to help me understand teacher candidates' professional pedagogical visions more completely. Building material representations, a component of professional vision, was investigated through document analysis. Personal documents "refer to any first person narrative that describes an individual's actions, experiences, and beliefs" (Bogdan and Biklen, 2007, p. 133). Because these materials are personal, they are very subjective and reflect the participants' perspectives (Merriam, 2009).

Thus, document analysis helped the researcher understand how teacher candidates think about science teaching practices and how their professional pedagogical vision is evident in their lesson plans.

I included the assignments related to video analysis of teachings from the SCIED 412 course in the document analysis because those are the artifacts that TCs created in some sort of material format, in this case Studiocode timelines and written notes within the timeline for specific instances. There are two assignments related to the video analysis, the first one includes analyzing representations of practice from the tools4science teaching website, a case study in chemistry teaching. We were going to ask them to analyze the same video at the beginning and at the end of the semester, but because one of the TCs dropped the course in the middle of the semester, the SCIED instructor did not want to ask them to analyze the video again, so I have their first analysis of chemistry teaching case. Teacher candidates were asked to find instances of good science teaching and take notes in Studiocode about why they think the instance is a good science teaching.

The second video assignment included analyzing their own Discourse 1 (eliciting students' ideas) lesson using Studiocode while they were eliciting students' ideas. They were asked to find instances when they employed the four sub-practices of eliciting students' ideas including eliciting students' initial hypothesis, eliciting students' initial observations, summarizing students' ideas, and pressing for explanations. Another practice that they decided to look at apart from these sub-practices includes looking at the instances of entering and exiting groups. Discussion about entering and exiting groups emerged as they were debriefing and reflecting on their D1 practices, so while looking at their practices in the videos, they decided to include that practice in their analysis of videos.

The last artifact that was collected during the course was the rapid student survey tool (RSST) that they filled out during the field experience. The TCs filled out these tools based on

their observations of student thinking in the field experience classrooms. TCs filled out these tools either when the mentor teacher was teaching or they themselves were teaching. They looked for evidence of students' partial understandings, alternative understandings, everyday language and everyday experiences with the phenomena being taught. I have six RSSTs from Erika and Abby and five RSSTs from Debbie and Kayla. TCs were asked complete six RSSTs, but some of them were not able to observe student thinking because their mentor teachers were not doing group work or labs, in which students' ideas were more visible, instead the classes were mostly lecture-based, and thus, the students' thinking was not visible for the TCs to complete the RSSTs. Overall, how much of each data I have for the study included in Table 3-4.

Table 3-4: Overall Data Sources and Their Quantity.

Data Sources	Duration (Quantity)
SCIED 412 Video	48 hours (total of 96 hours from two angles)
Interviews	24 pre-post, 4 field experience, 5 exit interviews for all TCs 1 interview with each instructor.
Field notes	16 class-sections of SCIED 412 and 11 class-sections of CI 495C.
Documents and artifacts	22 RSSTs for four TCs, 12 video analysis of TCs' own discourse 1 teaching (6) and of Bethany's teaching (6) for all TCs, 4 supervisor-feedback for four TCs. All class materials for SCIED 412 and CI 495C.

Data Analysis

I took a grounded theory approach (Corbin & Strauss, 2007) to analyze the data in this study starting with open coding, grouping the codes, and creating the coding categories. The

grounded theory approach requires theories and explanations to be grounded in data from the field, especially in the actions, interactions, and social processes of people.

While the grounded theory approach (Corbin & Strauss, 2007) was used because the codes emerged from and were grounded in the data, discourse analysis was used to determine the meaning-making and development of professional pedagogical vision from the social interactions happening and evident in the classroom discourse in the open coding process of grounded theory. So, grounded theory was the overarching approach, and discourse analysis was used under that approach, especially during the open coding process. While the video analysis and creating event maps constituted the macro level analysis of video records, the discourse analysis of the transcription of selected events constituted the micro level analysis of the study. Discourse analysis based on interactional sociolinguistics theory (Gee & Green, 1998; Gumperz, 2001) was used to determine the discourse analytic units. During the coding process, I wrote analytical memos to describe the episodes as well as chronologically keep track of emerging code descriptions and example episodes. Writing memos helped me group the episodes in certain codes and write explanations for the code descriptions.

For the analysis, I used constant comparative method, which is a type of grounded theory approach to generate theories through constant comparison. Glaser and Strauss (1967) described four stages of constant comparison in which the researcher continually sorts through the data collection, analyzes and codes the information, and reinforces theory generation through the process of theoretical sampling. The research begins with the raw data and through the constant comparison method a substantive theory will emerge (Glaser & Strauss, 1967). There are two main phases of analysis of video records, described in detail below.

Phases of the Analysis of Video Records

Phase 1: Video Analysis, Creation of Event maps and Choosing what to transcribe

Video recordings and fieldnotes constitute the primary data sources for the study. I outlined the main data sources to answer each research question in Table 3-5. I started with analysis of the video recordings of the SCIED 412 course in the first five weeks.

Table 3-5: Data Sources for Each Research Question.

Research Questions	Data Source	Data Analysis
How do teacher candidates negotiate the meaning of ambitious science teaching when they engage in discussions in the first five weeks of their methods course?	Video records of SCIED course in the first five weeks. Field notes of the SCIED 412	Discourse and Video Analysis of video records of SCIED 412.
How does the professional pedagogical vision of science teacher candidates develop around ambitious science teaching practices in a semester-long secondary science teaching methods course? • How do science teacher candidates highlight and code in their discussions of teaching and what material representations do they produce?	Video records of SCIED 412, Fieldnotes of SCIED 412, artifacts of video analysis assignments (both their own videos and the chemistry teacher's videos)	Discourse Analysis of transcripts of videos, Lesson plan analysis, Analysis of Studiocode timelines.

The data analyses for the video recordings include different levels of analytic scale including macro and micro level analysis. In my initial analysis of the video recordings, I used Studiocode ² (a Mac compatible video analysis software) to identify the events happening in each

² Studiocode is a software package that connects codes directly to segments of video, and also supports text documents such as transcripts. The central component of Studiocode is a

class, constituting the macro level analysis for the study. A bounded activity around a topic and purpose can constitute the event (e.g. curriculum planning, observing model teacher). The changes in the events can be determined through looking at the changes in purpose, type of activity, and topic (Kelly, 2004). Below is the Figure 3.3-code window that shows codes for the events I captured in the class. After coding videos for the events happening in the course, I created event maps at the macro level (Kelly & Chen, 1999; Kelly, Brown & Crawford, 2000; McDonald & Kelly, 2007) to see the structure of the lessons during the semester. I constructed event maps through my analysis of videos in the Studiocode timelines, shown in Figure 3-4, and reading the fieldnotes for each day. The event maps were constructed by looking at how time was spent, on what and for what purpose (Kelly, 2004). I provided a snapshot of a page of an event map in Figure 3-5 and provided three class sections of event mapping in the Appendix D. The event maps are organized around days of instruction and what assignments students were supposed to do for that day, the time stamps devoted for each event and the list of events. Then I made connections to the coding I have done, which will be described in the second phase of the analysis.

After identifying the events, I selected events where the class had discussions around science teaching as a form of purposeful sampling. Because the research questions I am interested in investigating are about teacher candidates' professional pedagogical visions around teaching practices, I did purposeful sampling and transcribed those events where there was discussion about teaching. Thus, macro level analysis also allowed me to select data that can help me answer the research questions. I transcribed the classroom discourse of those selected events, which are highlighted as yellow in the event maps, exemplified in Figure 3.5. Organization of the event

“timeline,” which provides graphical representation of all codes, descriptors, and narrative comments attached to a particular video. Coding the video directly will allow for a variety of verbal and visual cues to be considered—intonation, gesture, body position, written representation, and so on—to comprehensively capture the instances to answer the research questions.

maps is explained in the footnote 3 inserted in Figure 3.5. I did not transcribe other events, including some of the discussions about readings, the process of generating explanations for the tanker crush as the students of science, TCs' Internet search for phenomena, peer teaching rehearsals, the lesson/unit planning sections and all other logistics discussed in the class (e.g. grades, assignments). I transcribed only discussions around teaching. I completed Studiocode video analysis and created event maps and transcribed selected events for the first five weeks and the last four weeks of the SCIED course.

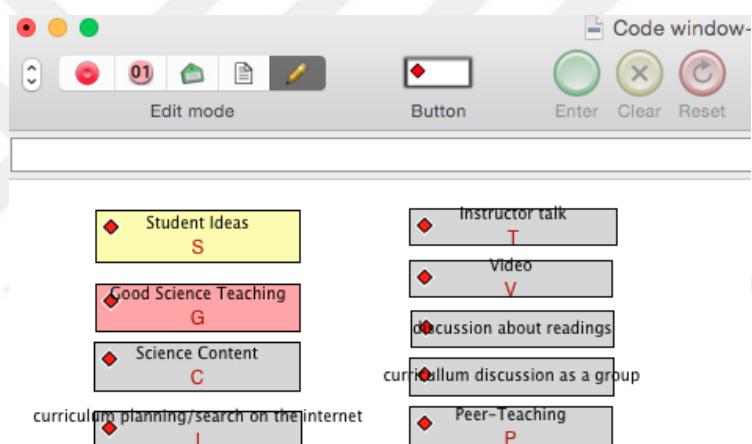


Figure 3-3: Studiocode Code Window.

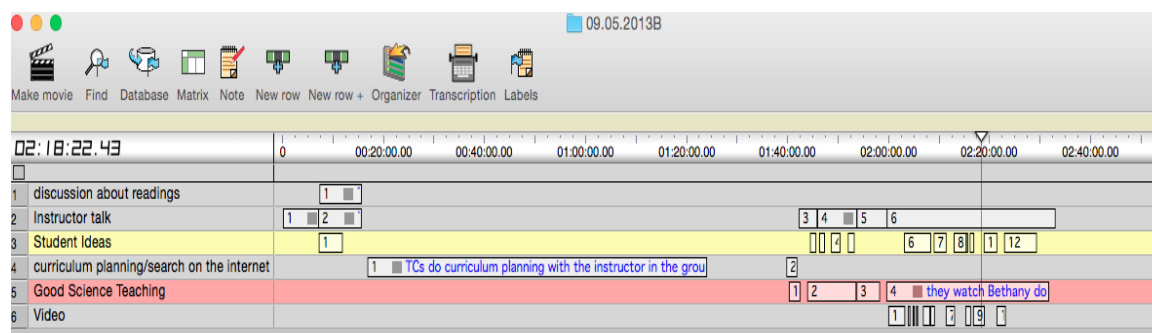


Figure 3-4: Example Studiocode Timeline.

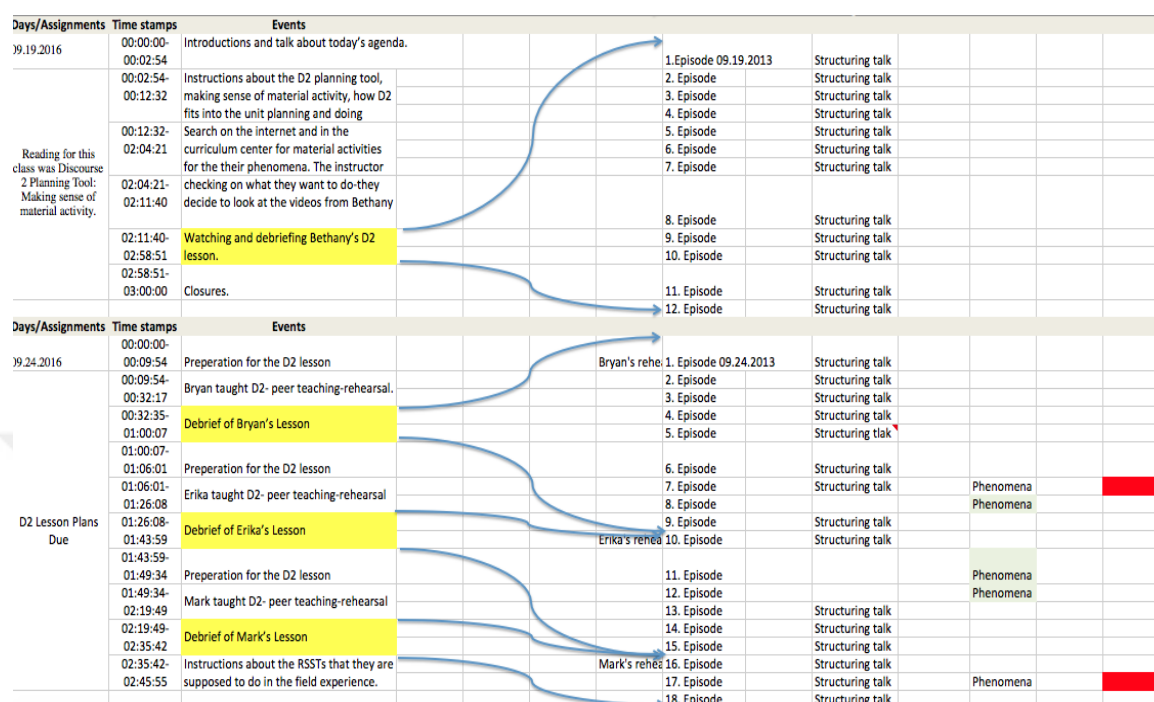


Figure 3-5: A Section of the Event Map Showing the Highlighted Transcribed Events³ and episodes within each event.

Phase 2: Coding, Coding Framework, Example Episodes

After transcribing the selected events, I took grounded theory approach (Corbin & Strauss, 2007) to analyze the transcripts, starting with open coding, then grouping the codes, and creating the categories of codes. Since I was interested in understanding the collective meaning-making of science teaching in the discussions of teaching, I coded for the group conversations including the instructor's input as part of the group. I started with open coding based on what they said in the discussions of teaching, and as the new codes emerged, I added them in the coding

³ The event mapping is organized around the major events happening in the classroom. I included days and time stamps for each event; assignments or readings TCs did for that day. Then I linked the episodes for the transcribed events. Yellow highlighted events are transcribed. I also included major code categories for each episode on left side of the event maps. The majority of the episodes includes codes related to structuring classroom talk codes, but some of the episodes include two code categories (either a combination of structuring talk and phenomena codes or student ideas codes) and they are highlighted in red.

framework table, where I have descriptions and episode numbers, provided in Table 3.6.

During the open coding process, discourse analysis based on interactional sociolinguistics theory (Gee & Green, 1998; Gumperz, 2001) was used to determine the discourse analytic units. While coding, I decided when the focus/content of the conversation changed I would treat it as the end of an instance, thus I chose the unit of analysis as episodes. Also, discourse markers (mostly from the instructor's discourse such as "okay", "so") and paying attention to the instructor's use of video segments to look at the practice of teaching also helped me determine the unit of analysis. Thus, episodes could consist of one or more turns of talk, which is similar to what other researchers (e.g. Kelly, 2004; Kelly, Crawford, & Green, 2001) identify as sequence units, cohesive thematically-tied interactions identified *post hoc* through semantic and contextual cues. Some episodes included multiple codes because the focus of the conversation was related or same, so I did not divide them to multiple episodes.

I coded the discourse of classroom members for three areas: structuring talk, phenomena, and students' ideas/role of prior knowledge. These three areas emerged after coding the first two days of the course at the beginning of the analysis process using open coding. Among structuring talk codes, I was using four different groups to code for structuring talk including codes related to structuring talk in teacher-student interaction, structuring talk in teacher-group interaction, structuring talk in peer-group interaction and structuring talk in teacher-whole class interaction. All these codes are related to their conversations in the science teaching methods course about teaching events. Under these groups (e.g. in teacher-student interaction), I had individual codes (e.g. pressing) and sub-codes (e.g. pressing to create external representations). These groupings helped me to focus on certain codes one at a time. The coding framework tables about structuring talk, phenomena and student ideas were provided in the Appendix E, Appendix F and Appendix G respectively.

Below are example episodes that show how I chose the unit of analysis and coded the episodes. I have given names to the episodes based on the days, such as **08.29. Episode 9** indicates the date and episode number as it appears in the document, so this episode will be the 9th episode on August 29.

The following episodes (**08.29. Episode 8 and 9**) are from the second class, and they are part of the discussion when TCs talk about the analysis they have done of Bethany's class, where Bethany was eliciting students' ideas. Bethany is one of the teachers they watched from the case studies from the University of Washington's website, <http://tools4teachingscience.org>. The TCs used Studiocode to analyze Bethany's chemistry lesson and the instructor collected and stacked their timelines, and in these episodes they were looking at those timelines.

08.29. Episode 8 and 9:

[They started watching Bethany's video, and they looked at the instances where it looks like everyone agrees that something happened in the instance based on TCs' analysis in the Studiocode timelines.]

[They watched the section of the video where everyone marked it as good science teaching]

Table 3-6: Example Episode 1.

Episodes	Transcription	Codes
08. 29. Episode 8:	Sean: So, you all agree that that was good teaching, so what is good about that? What is the principle you can draw from that?	
	Debbie: She initially summarized right you started it, she was receiving their initial thoughts.	Structuring talk/Teacher
	Sean: Okay.	Student/Summarizing Students' ideas and

		Eliciting hypothesis
08.29. Episode 9:	Debbie: and then she showed real life example there.	Phenomena/ Connecting to Real life example
	Erika: Yeah, I liked it because it was a real life example, she had the video, which actually happened, this is you know, it is like not, not from each students' life, but something that has actually happened.	
	Sean: So real thing.	
	Erika: Clearly, the kids all thought it was cool.	Phenomena/Student interest and attention
	Sean: Right, So, she picked something, well Mark and Bryan, why did you like this, because you marked this too?	
	Mark: I liked it because it was something that happened in real life, and gets students' attention.	
	Sean: Okay.	
	Bryan: I agree.	Phenomena/Easier to connect and remember for later
	Sean: Do you? So, why would you use something from real life?	
	Bryan: Well, you connect it to them; it is easier for the student to think about it. You know, instead of just saying here is the mass, this is pressure.	
	Erika: I also think, like, we need to use life examples like this, if the students in his class were tested on like the gas laws, I mean not only they do this activity but like just that exciting example they can, that's something "ohh gas law I remember seeing it where the tanker imploded", so it is easy for them to recall, [inaudible].	
	Sean: So, picking this thing that's sort of exciting helps them connect.	
	Erika: M-hm, and remember more.	

In these episodes, the instructor (Sean) asked them what they considered as good teaching and Debbie offered an utterance about teachers getting students' ideas and summarizing the ideas. And later, she offered another utterance on teachers bringing real life examples. While agreeing with Debbie's second utterance (as they start their sentences "yeah", "I agree"), other TCs offered comments related to real life example and how using a real life example gets students' interest and attention and helps students remember the concepts better. Thus, I considered that the focus of Debbie's first utterance (eliciting and summarizing students' ideas) about good science teaching was different than the focus of her second utterance (using real life examples), so I made them two episodes. The 8th episode was about eliciting students' ideas and summarizing those ideas and coded for both structuring talk/teacher-student interaction/eliciting, and summarizing ideas. The 9th episode was about how they as a class collectively negotiated and made sense of the meaning of good science teaching in terms of using/providing real life examples. Even though this is an episode, there are three codes within the episode about: phenomena being real, phenomena getting students' interest and attention, and phenomena helping students connect and remember concepts better for later. I did not divide this episode into three episodes to show only one code because the utterances from different TCs support each other's utterances and are meant to make sense of the interpretation of why using real life examples was an important part of good science teaching.

Below is another example from 09.19.2013, and on this day they were looking at Bethany's class to observe how she helped students do Discourse 2 (D2) practice: making sense of material activity.

Table 3-7: Example Episode 2.

Episodes	Transcription	Codes
09.19.	[They watched a section of Bethany's teaching]	

Episode 9:	Sean: Okay, so we are low on time. Any comments about this last bit? What is she doing here, what was she trying to accomplish?	
	Kayla: I think she brought back to whole class [inaudible]	Structuring talk/Teacher/ whole class/Bringing ideas together that are talked in individual groups
	Sean: Hmhm, she brought back to whole class, yeah, anything else?	
	Bryan: She remembered what students said in their groups, she asked to that guy, "what was that noise?" you know she is, "you are talking to this group, she is talking to them". So, that helps I think of that.	Structuring talk/Teacher/group/ formative assessment
	Sean: Yes, she is, another piece of formative assessment thing, she remembers what the groups did and also sort of forces them to talk about stuff they don't. Yeah, anything else? Do you think these variables that she asked them to test are chance?	

In this episode, stopping the video and the instructor's question about interpreting what was happening in the video initiated another unit of analysis and TCs (Kayla and Bryan with the instructor) collectively offered interpretation of what the teacher was doing (bringing students' ideas back together and doing formative assessment) in the video. Later, when the instructor asked, "Yeah, anything else? Do you think these variables that she asked them to test are chance?" I marked it another episode because the instructor changed the focus of the conversation with this question.

The two examples above were from the days when they observed video of Bethany's teaching to see how she used the discourse practices, so those days included watching, stopping

the video and talking about the instances they just watched. Thus, stopping the video and talking about the instance was usually accompanied with a question from the instructor. Thus, most of the times, the questions that the instructor asked after seeing the video constituted the beginning of one of the episodes, thus constituted as a signal for a new unit of analysis. For example, in the Episode 9 in 09.19 above, after watching the video, the instructor asked "... Any comments about this last bit? What is she doing here, what was she trying to accomplish?" and initiated a new episode as they watched a new instance (a new focus) from the video. However, in some of the instances of the instructor's questions immediately after the video did not constitute a new episode because sometimes they watched segments of videos to see evidence for whatever they have been talking in the episode. Thus, on those episodes the focus of the conversation did not change.

On the other hand, on the days TCs taught their rehearsals, they did not observe their own videos, so in the discussions of rehearsals they did not use the video to see the enactment of teaching again. In the discussion of the first couple of rehearsals, the discussions are initiated with the instructor's questions to the teacher (whoever is teaching during the rehearsals) and to the other TCs (acting as students) about how they felt and how the lesson went, but as the semester progressed, the TCs initiated the talk about how the lesson went without the instructor's initial prompts. TCs reflected on the lesson as teachers and students. Example episodes for these days are included in the findings chapter in detail.

Thus far, I explained how I chose the unit of analysis, and how I coded the episodes in different days, providing different types of examples. I completed this process for the first five weeks of the video data. After completing open coding, I put all the episodes that I coded with the same code and compiled them together. Then, I compiled all these episodes in the memo files and wrote a memo regarding each episode to summarize what is happening in each of them.

Compiling all the episodes and writing memos for each one of them helped me check the

accuracy/consistency of my coding and allowed me to group some of the similar codes. During this process, I realized a couple of missing codes for some of the episodes and added those codes too. Then, those memos helped me write a description of the codes and see the trends by looking at the episodes chronologically within each code. Concurrently, I created the final versions of the coding frameworks provided in Appendices 5, 6 and 7 with descriptions and example episodes from the transcripts. After open coding, I started putting codes in categories.

To form the report of the findings I started creating claims to capture findings of how TCs negotiated ambitious science teaching practices in the discourse. After multiple turns of this step, I reported three overarching themes in the findings section.

Analysis for the Professional Pedagogical Vision

I also used the grounded theory approach for the analysis of the second research question in the same way I described before. I started analysis for this question based on the episodes I already created for the first research question. As I explained earlier the episodes were determined based on the content of the discussion. When the content of the discussion changed it indicated a new episode. I also included the instructor's input as part of the classroom discourse and included all the conversations regarding teaching. For the analysis of professional vision, I still used an utterance or multiple turns of talk as the unit of analysis to code for highlighting and coding practices.

For the analysis of professional pedagogical vision, I needed to include multiple turns of talk similar to episodes, but sometimes episodes were not capturing all the talk around an instance of teaching, which I call an activity. The instance of teaching could be an observed teaching, a moment from the lived experiences in the rehearsals or the videos of the rehearsals or a hypothetical teaching scenario the instructor provided. Goodwin (1994) describes,

“an event being seen, a relevant **object of knowledge**, emerges through the interplay between a **domain of scrutiny** (a patch of dirt, the images made available by the King videotape, etc.) and a set of **discursive practices** (dividing the domain of scrutiny by highlighting a figure against a ground, applying specific coding schemes for the constitution and interpretation of relevant events, etc.) being deployed within a **specific activity** (arguing a legal case, mapping a site, planting crops, etc.) (p. 607).

So, based on Goodwin’s terms and definitions, TCs’ professional pedagogical vision (constituting a relevant object of knowledge) emerges through looking at the videos of instruction and their experiences in the lessons (constituting the domain of scrutiny), and a set of discursive practices (constituting highlighting, coding and building material representations) being deployed within a specific activity (an instance of teaching). Even though I coded for the highlighting and coding practices, I still included the larger chunks of turns of talk constituting the activity to report episodes of the professional vision analysis. Thus, sometimes I combined two episodes that were related to one teaching instance (an activity) and I considered the combination of those episodes as one episode.

The coding for this question included identifying the parts of talk as highlighting and coding and thinking about what counts as highlighting and coding and how highlighting and coding happened in the classroom discussions. I used Goodwin’s terms of *coding schemes*, *highlighting*, *using material representations* as I coded the episodes. So, he describes *highlighting* a figure against a ground. When TCs highlight or emphasize a piece of teacher or student talk or behavior from the observed teaching through restating or marking it, it means they highlighted it. When they apply a specific coding scheme, label or interpretation of the relevant events, it means coding. TCs code teaching events through describing the situation, or through connecting and comparing it to other teaching instances either in peers’ lessons or Bethany’s lesson (just like when the archeology student compared the dirt with the Munsell color chart) or through giving suggestions or alternatives for future implications. TCs create material representations through analyzing videos in Studiocode, or through developing lesson plans.

I did three passes of the analysis of data for this research question. In each pass, I clarified what I was coding as highlighting and coding and identified the activities I described above. I used analytical memos to describe activities and discursive practices happening in each activity. I tried to come up with patterns of discursive practices happening for each activity discussion. An example of my coding is provided below:

Table 3-8: Example Episode 3.

Episodes	Transcription	Code
08.29. Episode14:	Sean: Now, we can probably take a look and see what is she doing. So, let's see. She starts walking around and talking [The instructor is showing the video without sound to fast-forward to come to the instances that TCs marked] [They watched video]	
	Debbie: Pressing	Coding of the teacher's practice as Debbie interpreted and labeled the practice the teacher did.
	Sean: Hmm? Pressing?	The instructor revoiced her idea
	Debbie: Especially the kid in the jacket?	Highlighting of specific instance from the instruction that Debbie thought the teacher was pressing the student with the jacket.
	Sean: Yeah.	The instructor agreed
	Debbie: [Inaudible]	Debbie highlighted student idea in the video through restating what the student

		said in the video
	Sean: Yeah, "I don't know, I don't know". Definitely, yeah. Anything else she was doing?	The instructor revoiced what Debbie highlighted and he agreed. Then invited TCs to code more.
	Kayla: Probing	TC coding
	Bryan: Hm-hmm [Agreeing to Kayla]	Bryan agreed with Kayla's coding
	Sean: Probing? Where were the examples of probing?	The instructor wanted evidence of probing and wanted them to highlight an instance
	Kayla: [Inaudible] girl. oh no, (she is up the steam?)....	Kayla highlighted the student that the teacher probed on.
	Bryan: [Inaudible]	Inaudible
08.29. Episode 15:	Debbie: What did the first kid say?	Debbie highlighted another student
	Sean: Yeah it is really hard to hear.	
	Debbie: It is really hard to hear. I think he mentioned something about [inaudible] [They watch the video again]	Debbie highlighted student idea
	Sean: He says something about just exploding. It is really hard to hear.	The instructor highlighted
	Bryan: [Inaudible]	TC highlighted student's idea
	Sean: Like what?	The instructor asked clarifying question
	Bryan: "Like exploded because there is no more space, so it exploded."	TC highlighted through restating what the kid said.
	Sean: Ha, there is no more space, [the instructor ran the video again] Okay, so, is that	The instructor revoiced what Bryan highlighted

	probing that we were talking about? So, he says if Bryan were right, "there is no more space so, it exploded." so, she starts asking questions about what? What is she asking?	and pressed them whether or not it is probing. So he oriented them to code and oriented their attention to the questions the teacher asked.
	Kayla: "Why is it go in?"	Kayla highlighted the teacher's question.
	Sean: "Why is it go in?" Right? So, what is she doing there?	The instructor revoiced what Kayla said. Then asked TCs to code.
	Debbie: She's revoicing (word?) that something wrong on kind of reiterated, but ...	Debbie coded it as revoicing
	Sean: Well, she is not really revoicing exactly, she is not saying back to him what he said. But, she is asking him about a piece of what he said.	The instructor evaluated Debbie's coding and coded again.
	Debbie: Instead of saying you are wrong.	Debbie added to instructor's coding.
	Sean: Right, because he says it explodes and then she clearly knows that's not what happened. So, she is trying to get him to think about. So, she is saying, "ohh, it didn't explode it got crushed. Right? So, she is saying it did not do this [makes hand gesture of explosion], it did this [makes hand gesture of implosion].	The instructor agreed with Debbie and then highlighted the teacher's comments.
	Debbie: Yeah, she revoiced how a (Ideas for the purposes?)	Debbie agreed and coded.
	Sean: Yeah, so I don't know may be. It is hard to tell. It does not matter, We don't have to classify everything, but I do want you to think about how she is doing this because again not in a very short period of time, not	The instructor reminded them that they are going to do these practices themselves.

	next week but a week after, you are gonna be doing this with us. You are gonna have to pick a phenomenon and you are gonna have to sit and talk to us, do what I did with you with those models, right? [Teachers laugh]	
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In these two episodes, TCs discussed what the teacher, Bethany, did in the observed video instance. TCs and the instructor collectively coded teacher moves and questions, and students' ideas through labeling and interpreting the ideas, and highlighted parts of instruction through restating the teacher questions or identifying specific student or teacher action or idea. The instructor also facilitated their highlighting and coding through multiple discourse moves as well. I also coded the instructor's facilitation moves to understand how he helped TCs develop professional pedagogical vision, but the results of how the instructor facilitated conversations are not part of the dissertation. TCs and the instructor engaged in discursive practices of highlighting and coding in multiple turns of talk to describe a teaching activity observed in Bethany's class.

Analysis of Artifacts

Analysis of interviews and artifacts were supposed to be used for the triangulation purposes, thus the analysis started after themes were created for the analysis of video records. Video records constitute the main source of data. For the research question regarding how TCs negotiate meaning of ambitious science teaching in their discussions of teaching, I used only the video data. For the research question regarding professional pedagogical vision analysis, I used video records as well as the artifacts, such as Studiocode analysis of Bethany's and their self-analysis of Discourse 1 practice. I also looked at their lesson plans but I did not include lesson

plan analysis in the findings. One of the themes that emerged from the professional pedagogical vision analysis is related to the shared material representations. Their lesson plans are not shared material representations, that's why I did not include them for the findings of this research question. What I meant by shared material representations is material representations shared and analyzed among classroom members. The artifacts created in Studiocode were brought into the scrutiny of classroom members; TCs were able to look at each other's analysis of videos, re-watched the instances again and had conversations upon their analysis. However, lesson plans were not shared in a sense that enables analysis or critique of them. Analysis of RSSTs was going to be used especially to understand what they produce as material representations as an evidence of their professional pedagogical vision during field experience. However, I did not answer that research question in the dissertation. Thus, analysis of RSSTs are not included in the findings as well.

TCs completed two video analysis assignments, including analysis of Bethany's class and their own first rehearsal around discourse 1 (D1) practice, eliciting students' ideas. I analyzed 6 Studiocode timelines of TCs' analysis of Bethany's teaching as well as 6 Studiocode timelines of analysis of their own rehearsals. In Bethany's class analysis, they were looking at *good science teaching*. They identified instances of good science teaching and took notes in the comments to interpret why they think those instances were good science teaching. An example of their timelines and their comments is provided in Figure 3-6.

In their analysis of their own rehearsals, they looked at the instances of four sub-practices of eliciting students' ideas including eliciting students' initial hypothesis, eliciting students' initial observations, summarizing students' ideas, and pressing for explanations as well as an additional practice, entering and exiting groups. An example of the Studiocode timeline for their own rehearsals is provided in Figure 3-7. So, in the figure, TC Debbie taught her first rehearsal and she analyzed her own lesson for the sub-practices of eliciting students' ideas as the coding

schemes. She highlighted instances of her eliciting students' initial hypothesis, eliciting initial observations, etc.



Figure 3-6: Studiocode Timeline for the Analysis of Bethany's Teaching.

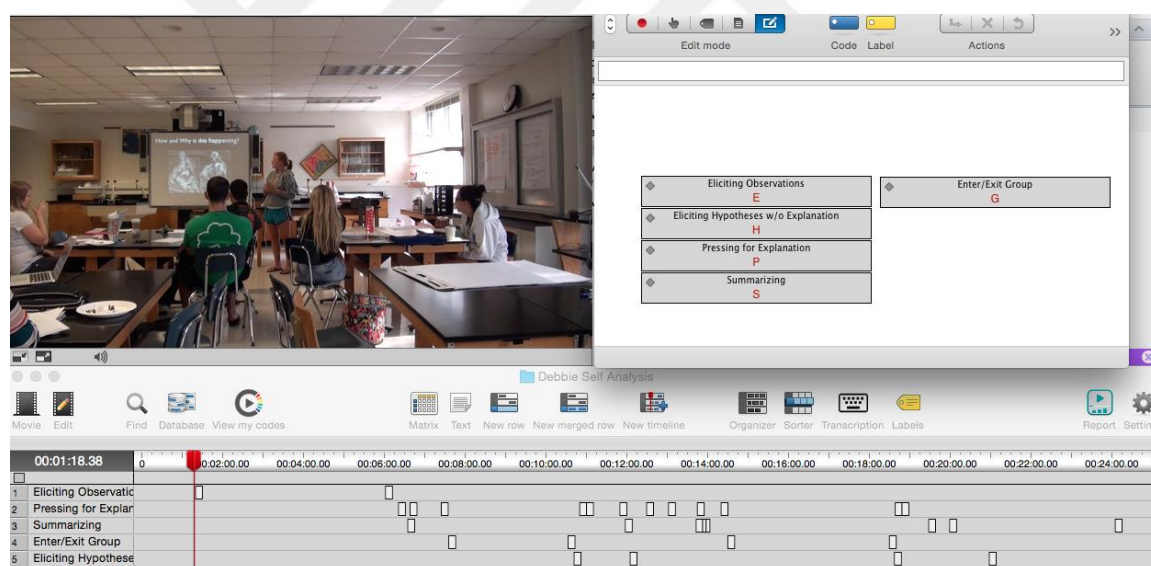


Figure 3-7: Studiocode Timeline for the Analysis of Their Own Discourse 1 Rehearsals.

TCs individually analyzed Bethany's teaching in the first day of the class (08.27. 2013) and they had discussions around the same teaching video on the days of 08.27.2013, 08.29.2013 and 09.05.2013. They individually analyzed their own rehearsals on the 09.17.2013 and they had discussions around their own analysis through watching the videos together on the same day. In order to triangulate the data sources, I used their material representations, in this case their analysis of Studiocode timelines, and I laid out the days they discussed their analysis and

observed the same videos that they already analyzed. I looked at how they analyzed those instances individually and how they later collectively talked about the same instances of videos. Figure 3-8 provides a snapshot of the window when I was using both their material representations and their videos of when they were looking at those material representations as a class. In Figure 3-8 there is stacked timeline where TCs analyzed Bethany's teaching individually. The instructor put those individual timelines together and stacked them and brought in the classroom and TCs observed again their analysis of Bethany's teaching through stacked timelines, shown in the smart board on the right side of the figure, indicated with the red arrows in figure 3-8. I looked at the stacked timeline of Studiocode (the Studiocode timeline on the right side in the figure, circled in red) to understand what/if they coded individually for those instances that they were observing collectively in the class together (the Studiocode timeline on the left side in the figure, circled in purple). Then I looked at the transcriptions of how they talked about those instances together. The transcripts came from my analysis of TCs' conversations in the captured instances in the purple-circled timeline in Figure 3-8. So, there are multiple instances of intertextuality in this Figure. The right videos and stacked timelines are TCs' analysis of Bethany's teaching, and left video shows the SCIED 412 class when they were observing their own analysis on the smart board and the bottom timeline is my analysis of SCIED 412 class on that day.

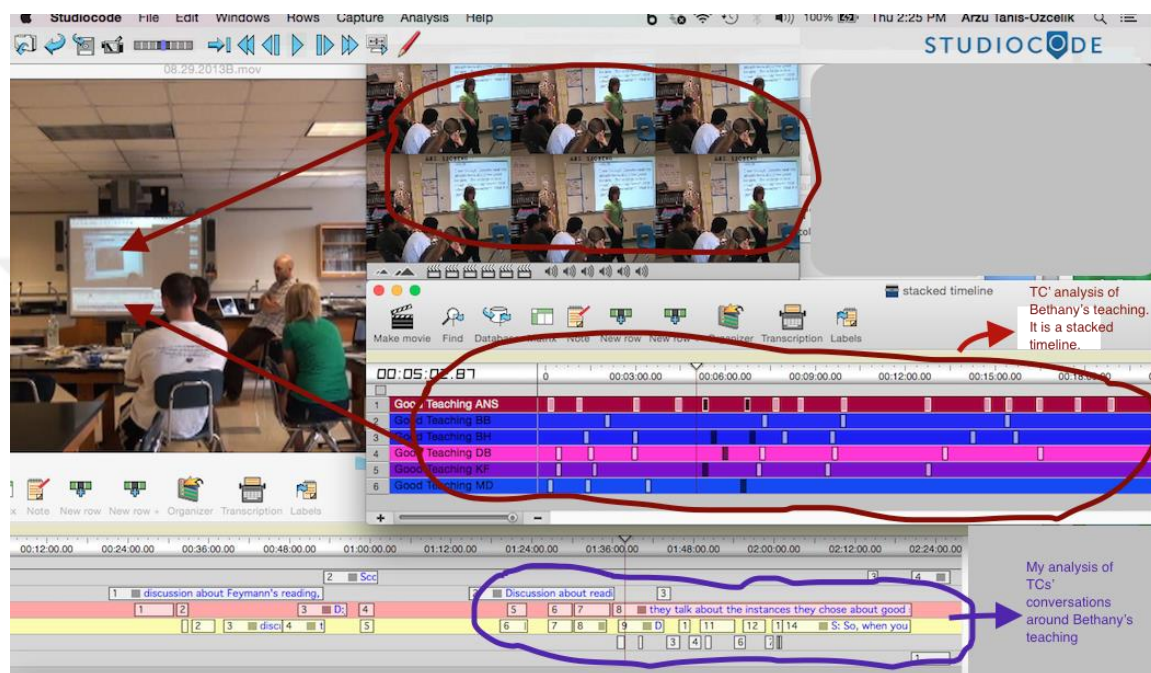


Figure 3-8: Studiocode Timelines for the Analysis of Material Representations and Collective Discussions Around the Same Material Representations.

Validity (Credibility) and Reliability (Dependability) of the Study

To ensure internal validity or credibility there are multiple strategies the researcher can use. One of the strategies is triangulation. I established the triangulation through the use of multiple methods. Data collection methods including video recordings, field notes, and document analysis were used to check for discrepancies and to help me triangulate these sources (Maxwell, 2012). The goal of obtaining triangulation is the enhancement of trustworthiness and validity (Glesne & Peshkin, 1992).

One of the strategies for ensuring internal validity or credibility is member checks through soliciting feedback on my emerging findings from some of my participants (Merriam, 2009). I had weekly meetings with my advisor who is the course instructor of the SCIED 412 to check my coding. The nature of those meetings included looking at the transcripts and the videos and discussing each instance and coming to consensus on the codes.

Another strategy for checking internal validity or credibility is called peer examination or peer review (Merriam, 2009). Throughout the coding process, I shared my analysis with an academic writing group, consisting of a math education graduate student and science education graduate students in our weekly meetings, and asked them whether or not they would agree with the way I coded. I also shared some of my analysis in the Penn State Discourse Analysis group. Also, my committee members' reading the findings and giving comments ensure to build peer review in the dissertation process.

I also had another science education grad student code ten percent of the video data. We met and talked about the coding framework (Appendix E), I explained what each code meant and how I was coding. Then one week later we met and discussed his coding. In his first coding, he only focused on what the TCs said in the discussions, so we went through a couple of examples of his coding and talked and came to consensus about how to code. He coded again including the instructor's turns as part of the data. We compared our coding using the percent agreement and found that inter rater reliability was 71 percent. He coded both in codes and sub-codes levels, but we compared on the codes level. Because I have many sub-codes, we thought it would be practical to compare on the codes level instead of sub-codes level. We discussed the codes that we did not agree on initially and came to consensus in the coding. He gave a couple of suggestions in the wording of my coding framework for structuring talk codes (in Appendix E) for readability and clarity.

Reliability or dependability means whether the results are consistent with the data collected. To ensure dependability, researchers suggest an audit trail. Throughout the analysis process, I kept memos and notes to keep track of how I collected the data, the decisions I made and how I coded and created the categories.

External validity or transferability can be ensured through sufficient descriptive data so that new researchers or readers can apply or do the transferability. The person who reads the study decides whether the findings can apply to their situation. Thus, I explained the description of the study and its context in detail to enable the reader to compare it to their situations.

Curriculum and the Classroom Activities for TCs

TCs are engaged in multiple activities during the course including observing representations of practice, decomposition of practice and approximations of practice, analyzing student artifacts, and constructing explanations for tanker crush phenomena, and all the rehearsal phenomena related to fracking as students of science. The syllabus of the course is included in Appendix H. Some of the readings they were provided were from the tools4teachingscience.org website, including a discourse primer, anchoring events, big idea primer, and tools for each discourse practice. TCs also read, “What is science?” (Feynman, 1999), and the NGGS Executive Summary (Achieve Lead States, 2013) to make them familiar with the new standards and three dimensions of learning,

Based on my analysis of fieldnotes, video records, and the event maps created, the activities they engaged can be organized into a structure represented by Figures 3-9 and 3-10. Figures 3-9 and 3-10 are structured around the cycle of activities they engaged in for D1: eliciting students’ ideas and D2: making sense of material activity practices in the first five weeks.

The first five weeks' activities

The activities TCs engaged in the first five weeks of the course are represented in Figure 3.9 and includes individually analyzing a model teacher's teaching when the teacher was eliciting students' ideas and then collectively (with the instructor) decomposing the same teaching through looking at their analysis. Then, TCs created explanations for the same phenomena that they saw the 9th grade students were trying to create explanation for in the observed teaching. In creating explanations activity, the TCs were the students and the course instructor was the teacher who was trying to elicit their ideas using different talk-moves in order to help them create explanations for the phenomena. These activities occurred in the first two days of the class.

Then, TCs engage in planning for the approximations of practice, which will be called rehearsals interchangeably in the dissertation. For planning their rehearsals, they chose a local phenomenon and big idea in science in order to engage their students in constructing explanations for that phenomenon. The local phenomenon they chose was fracking, and they all investigated different effects of fracking from biology, physics/earth science, and chemistry aspects. They spent an entire class searching, learning and planning for their phenomenon. They discussed and gave feedback to each other on their ideas for their planning in small groups and with the instructor, individually as well. The phenomena they chose related to fracking includes effects of acid rain on the statues (Debbie), the effects of acid rains on plants, soil and animals (fish) (Brooke), the effects of fracking fluids on the animals (cows) and their death (Kayla), the effects of fracking on the ecosystems and their recovery (Abby), the process of fracking and its effects on earthquakes (Bryan), and the effects of fracking on climate change (Mark).

During their planning sections, they were expected to write a gapless explanation for their phenomena and back-pocket questions to ask to the students during both small group and whole-class classroom discussions. The terms gapless explanations and back pocket questions came

from the ambitious science teaching practices (Windschitl, et al., 2012). By gapless explanations, Windschitl and colleagues mean very detailed and rich causal explanations of the phenomena by linking science ideas together and including how evidence supports the explanation. By back pocket questions, they mean questions that the teachers can use to elicit students' ideas during instruction and can literally put in their back pockets and look at as they move between the groups. Searching for information about the phenomena and lesson planning lasted for the third class period and part of the fourth class-period in addition to out of class time.

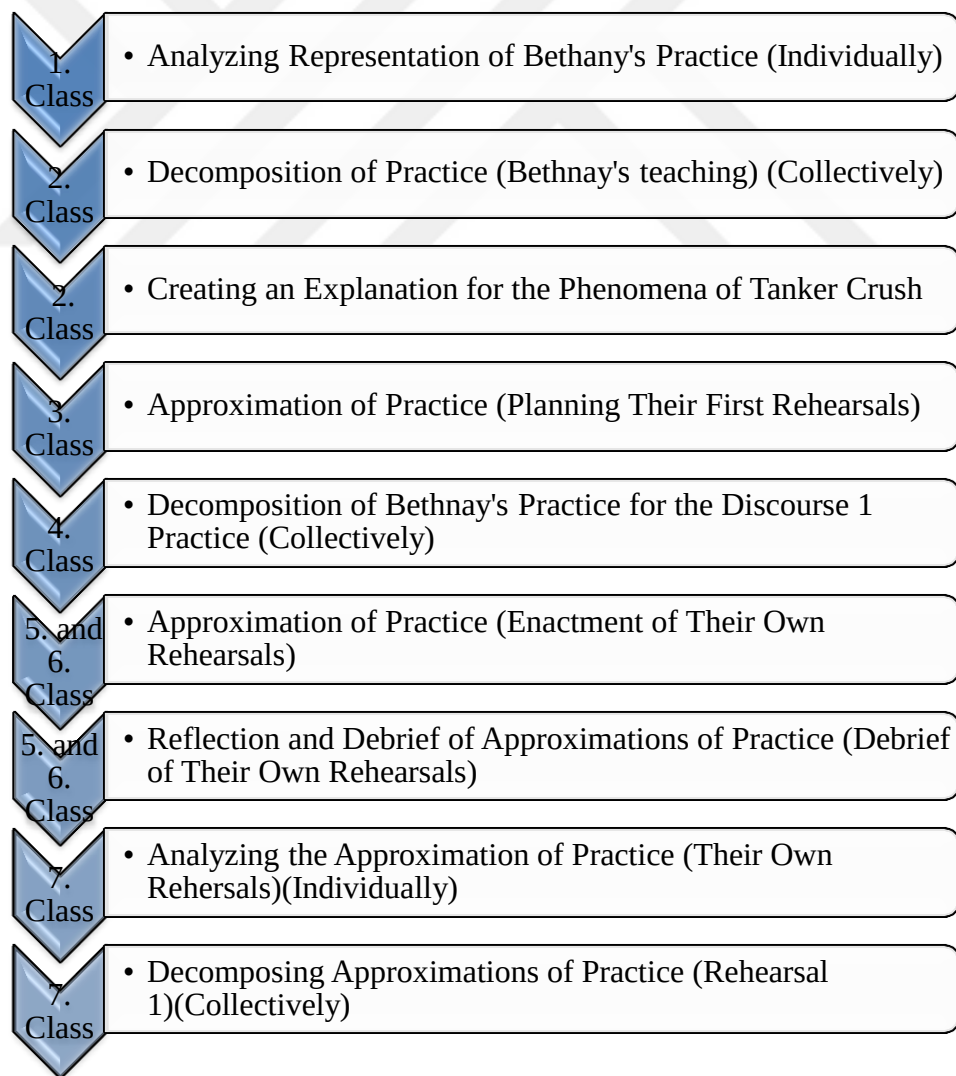


Figure 3-9: Cycle of Activities for D1 Practice: Eliciting Students' Ideas.

Later in the fourth class session, TCs engaged in a detailed decomposition of practice to look at how the model teacher, Bethany, elicited her students' ideas. In this decomposition, the instructor engaged them in observing and talking about the observed instances of teaching. The difference between the collective decomposition of practice happened on the second day of the course and this collective decomposition includes chosen instances and whether or not TCs initiated the pre-highlighting of the instances of teaching. More specifically, in the previous decomposition, the instructor played the instances in the video that most TCs already marked as good science teaching in their analysis, and TCs and the instructor talked about those instances. In this decomposition activity, the goal is more focused to look at how the model teacher elicited students' ideas and what sub-practices she used to elicit the ideas in order to help TCs see how the practice of eliciting student ideas is enacted. Eliciting student' ideas was the first practice they rehearsed in the next class.

Then in the fifth and sixth class sessions, they taught their first rehearsals for the purpose of eliciting their students' ideas about the phenomena they chose. The rehearsals lasted 20 minutes for each TC and the instructor of the course intervened whenever he saw an instance where he thought the TC could ask a different question, or when he saw an opportunity to help the TC in getting her/his students' ideas about the phenomena. During these rehearsals, the other TCs acted as students in the classroom. The typical classroom activities that TCs included in their rehearsals include engaging students in pictures of the phenomena or telling them a scenario to set up the phenomena and introduce the phenomena for the students and then dividing them into the groups. While the groups were working towards explaining the phenomena, the TCs circulated around the groups and asked them back-pocket questions to elicit their ideas to help them construct an explanation of the phenomena.

A reflection and a debrief section of the rehearsals followed the enactment of the rehearsals, lasting approximately 20 minutes for each TC. During the reflection and debrief section, the instructor asked them to reflect on the lesson, how they taught, and how the students felt during instruction. The TCs reflected on as the teacher and the students who were taught. The enactment and the reflection cycle continued for two days for each TC's first rehearsals. While they were enacting their rehearsals, they were video recorded.

After their rehearsals they were given their own videos and they analyzed their own teaching using Studiocode software on the seventh class session. They coded for instances whenever they were eliciting hypotheses without explanations, eliciting observations, summarizing ideas, pressing for explanations, and entering and exiting groups. The first four sub-practices are part of the discourse 1 tool: eliciting students' ideas. Paying attention to entering and exiting groups came up during debrief discussions in the previous days, and they decided to code for it during their analysis of the videos.

Then, they decomposed those analyses collectively with the instructor in the class. During this day, the instructor collected their timelines where TCs marked the instances of them eliciting students' ideas, and they observed a couple of instances from each TC's teaching and had discussions about those instances. All activities explained above were for the purpose of rehearsing Discourse 1 practice: eliciting students' ideas.

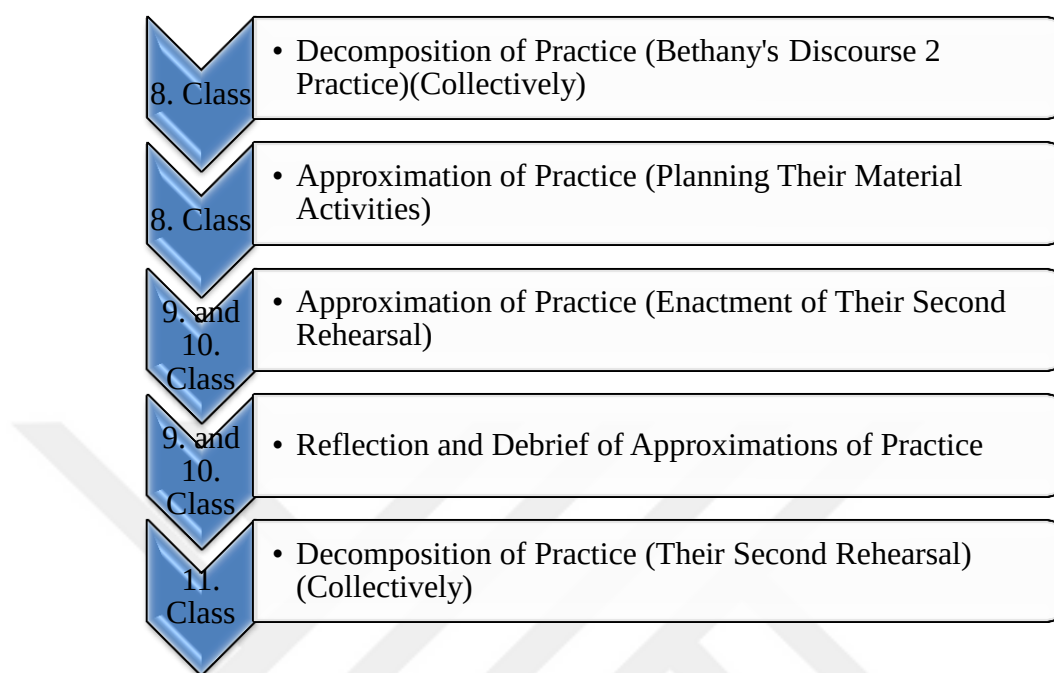


Figure 3-10: Cycle of Activities for the D2 Practice: Making Sense of Material Activity.

TCs continued a similar cycle of activities for the second rehearsal for Discourse 2 practice where they engaged students in a material activity, represented in Figure 3-10. Before the second rehearsal, they also decomposed a representation of practice where the same model teacher (Bethany) was engaging her students in a lab activity through discourse practices to make sense of the material activity. Then, TCs planned for their second rehearsals and enacted it with the same format, teaching 20 minutes to their peers and reflecting and debriefing on the lesson for approximately 20 minutes for each TC.

The material activities they chose related to effects of fracking includes a lab experiment where students look at different chemicals and their acid levels and how they affect the calcium carbonate (chalk) (Debbie), engaging students with data tables showing different levels of acids affecting the plants, the soil and the fish (Brooke), building a model of the lung and reasoning with questions to help students understand how chemicals go into the alveoli (Kayla), engaging students in designing food webs and scaffolding students through the process of (before, during,

after) fire and how the animals and food web got affected from the fire (Abby), engaging students in the PhET simulation to help them understand the relationships between pressure and the other variables such as volume and number of molecules (Bryan), and engaging students in a demonstration about how increased carbon dioxide levels in the air affect the temperature and thus climate (Mark).

After teaching and debriefing their second rehearsals, they decomposed their own practice, but the activity of discussions of decomposition for the second rehearsals happened after their field experiences during the last four weeks of the course. It is also included in Figure 3-10.

In this chapter, I described the design and context of the study as well as data collection and analysis methods. In the following chapter, I describe findings of how TCs negotiate meaning of ambitious science teaching practices in their discussions of teaching events.

Chapter 4

NEGOTIATION of AMBITIOUS SCIENCE TEACHING PRACTICES

In this chapter I present findings for the first research question focused on how TCs negotiated and made meaning of ambitious science teaching when they engage in discussions in the first five weeks of the science teaching methods course. The specific research question I investigated in this chapter was: how do science teacher candidates negotiate meaning of ambitious science teaching when they engage in discussions in the first five weeks of methods course?

My findings indicate TCs negotiated meaning around three key questions: who has agency for creating the explanations; what is the definition of an explanation; and how do they identify the relationship between the phenomena and the content storyline? Through these negotiations TCs learned how to work with students' ideas and how to plan ambitious science teaching practices in their discussions of teaching. Those negotiations emerged and are observed as negotiations between TCs and the instructor, between TCs, and self-negotiations by TCs. Those negotiations are represented as three themes that emerged from my analysis of the data. Each theme includes tensions or aspects that are representative of the negotiations in those themes. Overall themes and tensions/aspects are represented in Table 4-1.

Table 4-1: Themes and Tensions/Aspects Around Ambitious Science Teaching Practices.

Themes:	Theme 1: Agency: Who is responsible for generating the scientific explanations?	Theme 2: What is an explanation?	Theme 3: What is a phenomenon?
Tensions/Aspects:	Tension 1: Pressing versus Evaluating	Aspect 1: Evidence-based explanations versus clarity of explanations	Aspect 1: Explicitness of the phenomena and the focus of the lesson
	Tension 2: Pressing versus Leading	Aspect 2: Gapless Explanation and its connection to students' explanations	Aspect 2: Content Storyline, structure and set up in the lesson
	Tension 3: Entering and Exiting groups and how much to stay in the groups	Aspect 3: Levels of Explanations (What versus How and Why)	

In all of the findings, discussion of tensions and themes, I will refer to the work that TCs are doing in terms of Goodwin's professional vision framework, specifically using the terms highlighting and coding. I use these terms descriptively in this chapter to refer to the activities that TCs engage in, but a more in-depth analysis of the development of TCs professional pedagogical vision will be in the following chapter.

Theme 1: Agency: Who is responsible for generating the scientific explanation?

TCs negotiated who is responsible for generating the scientific explanation through ways of responding to students' ideas including pressing, leading, and evaluating students' ideas. TCs also negotiated who is responsible for generating the scientific explanations through the amount of time TCs stayed in dialogue with small groups. Their negotiations centered on the tensions and dilemmas they faced around understanding the nuanced differences between ways of responding: pressing, leading, and evaluating. As evidence of this negotiation, I present three types of tensions TCs experienced surrounding the ways of responding to the students' ideas.

Theme 1-Tension 1: Pressing versus evaluating

TCs negotiated meaning through highlighting and coding practice as they discussed pressing students' ideas and evaluating students' ideas. In their discussions of teaching, TCs expressed the tension they felt between knowing that pressing students' ideas was a target practice (the ambitious practice they were supposed to be learning), while they repeatedly evaluated students' ideas during their peer rehearsals. They also reflected on and criticized their peers for evaluating students' ideas instead of pressing. The following four episodes show different TCs negotiating this tension while debriefing after the teaching rehearsals.

Debbie taught her first rehearsal, where she provided students two pictures of statues, one undamaged, and one with significant degradation from exposure to acid rain. She was trying to elicit students' ideas about how acid rain might have affected the statues. The following episode occurred after she taught the lesson, when she was reflecting on the lesson; the conversation was between her and the instructor.

1. Debbie: I had the same problem with you guys [referring to one of the groups she worked with], you would say, "if the chemicals produced by this and something this [referring to what students said]", **I would try to get them to expand on it and sometimes it was just like I hit a brick wall because they'd say something completely off where I was thinking about. It wasn't right necessarily, or wrong.**

2. Sean: Right.
3. Debbie: **I will be like, okay, what do I say here? Do I say, "well, what did you think about this?" so I was really trying to take out pieces of their models and of what they had said, but it was hard at times, especially with the atmospheric part of it, I was trying to be like "Okay, use this, this and this, but don't use this, this and this [referring to what they have written on their poster papers]"**.
4. Sean: Okay. **(09.10. Episode 20)**

In this episode Debbie reflected on the tension she felt after getting students' ideas. She tried to press them to expand on their ideas, but she did not know how to respond to those ideas. In the first turn, Debbie coded her concern about what to do and how to respond to the students' ideas, she talked about how she tried to press them to expand their ideas, but then the students' responses were not what she was expecting (*"something completely off"*). In her second turn, she expressed what she felt during instruction in terms of how she was thinking about how to respond to the students. She talked about her dilemma in terms of whether or not she should ask for students' reasoning based on what they had said. Then, she highlighted and coded how she responded to students by evaluating what they said and pointed out what they needed in their models. In this episode Debbie unpacked how she felt the tension about pressing to help students expand their ideas and what to do when the students expand in unanticipated ways, and then whether to evaluate the ideas to get students back "on track". She negotiated pressing ideas and at same time she was not sure how to press them, and she ended up telling them what was relevant in their responses as a way to focus them.

The following episode is about Bryan's first rehearsal lesson where he asked students to think about the relationship between fracking and earthquakes. In this episode, Kayla and Erika were talking about how Bryan taught the lesson based on the instructor's (S) prompt. Before this instance, TCs acting as students talked about Bryan's lesson. In this episode, the instructor asked Erika and Kayla to talk about how their explanation process went as students and how Bryan asked questions to their group.

1. Kayla: Ahm, I mean I think that both groups have similar ideas. **I just, I don't know how to phrase this, ahm, he did a good job of taking the ideas we had written down on paper and then trying to get us to expand on them. But then sometimes you were almost giving us what we were missing.**
2. **Bryan: Yeah.**
3. Kayla: I don't know, I can't think of a specific example.
4. Bryan: I think you guys were on the one track.
5. **Kayla: We were missing a vital part and I feel like you...**
6. **Bryan: Yeah, I told you to stay away from fracking, you came up with other good ideas and I looked at them and I was like "alright this one is good" and then I told the whole class about reinjection.**
7. **Kayla: Yeah.**
8. Sean: Yeah, but you felt like maybe Bryan was leading you too much or giving you too much information and not getting information from you, because I am trying to.
9. **Erika: He did do, he did a little bit of the both. Yeah, he definitely did a good job of making us explain what we had written down. When he'd come over, we'd tell him what we were thinking, he would say "okay, well, what is", like even with fracking we had written down, "fracking cause earthquakes", that's all we have written down. And he said "okay, what is fracking, explain the process of fracking". Later on he came and said to us "okay explain to me what happens before, during and after with fracking and stuff." But then, there definitely were obviously the pressure one is a great example; he was like freaking out when we got the pressure.**
10. Kayla: I was like I know I got this because you [referring to Bryan] were so ready to "go yes, go with this".
11. Sean: Yeah. **(09.12. Episode 9)**

In this episode, in line 1, Kayla acknowledged Bryan's attempts to press their ideas to expand on what they were saying, and she criticized him for telling them what they were missing. So, she coded that it was good he pressed their ideas, but later he ended up evaluating them or telling students what they needed to complete their explanations. Then in lines 2 and 6, Bryan agreed and highlighted how he evaluated their ideas by telling them which of the ideas they came up with were good. Then later in line 9, Erika also highlighted and coded a similar pattern of him pressing students' ideas but later evaluating their ideas in their groups. Kayla and Erika were in the same group when Bryan was pressing and evaluating their ideas. They both felt he was simultaneously pressing and evaluating their ideas. This instance shows how TCs are conflicted about pressing their students and don't have a clear sense of when is best to press and when is best to evaluate ideas.

Another example that shows tension between pressing students' ideas and evaluating students' ideas includes Debbie's comments on her lesson after she taught her second rehearsal. In this lesson, she let students experiment with dissolving chalk with fluids at different pH levels. The following episode includes her reflection during the debrief of her lesson.

1. Debbie: And then another thing was when Mark was like, "oh, look, it's reacting", **I am so anxious to say, "yeah, okay, let's keep going with that." But I need to be able to use that to take a step back and say, "how do you know it's reacting?" And to really press them on what they're saying to make sure they really understand what they're saying and not just throwing out terms. (09.26 Episode 2)**

In this episode, Debbie reflected on her lesson, coded (interpreted), and highlighted that she should have pressed what Mark said instead of accepting what he said, and she negotiated the meaning and purpose of pressing students' ideas to make sure they know the words or phrases they used. She recognized this missed opportunity and realized she should have pressed. She also thought about how she should have responded and specifically highlighted what question she should have asked. This episode shows how Debbie negotiated the tension between pressing and evaluating students' ideas through highlighting a specific student idea and a specific question she should have asked to press.

Another example of the tension between pressing and evaluating came from Debbie's analysis of her own lesson. On this day, TCs watched and analyzed themselves eliciting students' ideas in the first rehearsal. In the following episode, Debbie shared what she noticed in her analysis of her own teaching. The conversation was between Debbie and the instructor.

1. Debbie: (...) **And also, instead of pressing where I thought I could have, I continuously just say "okay."**
2. Sean: Interesting.
3. Debbie: **Yeah, I am like "Okay," "okay, okay" like I want them to say more, but I should really press them and ask them a further question as opposed to just saying okay....[Inaudible] that's definitely**
4. Sean: **Did you listen to what you said okay?**
5. Debbie: **Yeah, I was like trying to keep going.**

6. Sean: Right, yeah, it's sort of like Bryan's thing with, what does he say to this back group?
7. Abby: "Ohh I liked that!"
8. Debbie: "Ohh, I liked that!"
9. Sean: "Ooo, I liked that".
[Laughter]
10. Sean: **So, that's Bryan's version of okay**, "Ooh I liked that." Yeah. **(09.17. Episode 1)**

In this episode, in lines 1 and 3, Debbie coded and highlighted her noticing of how she should have pressed her students' ideas and asked questions to get more ideas from them; however, during instruction she repeatedly said, "okay" to them. In these lines, Debbie interprets (codes) the pressing practice and evaluating practice and suggests what she should have done (ask further questions), and highlights from her instruction of how she evaluated students' ideas through restating what she said ("okay") to the students. Then in line 4, the instructor asked her to what she was saying okay. Then, in line 5, she stated that she was trying to move them further in their thinking and keep going. Then in line 6, the instructor coded that her response was similar to Bryan's version of evaluating students' ideas. Thus, in her observation of her own teaching, Debbie negotiated pressing students' ideas as opposed to evaluating their ideas or responding them with unclear expressions such as "Okay". This episode shows how this TC was able to recognize the difference between pressing and evaluating students' ideas through self-negotiation of her own practice.

Pressing versus evaluating students' ideas was one of the tensions of responding to the students' ideas negotiated between classroom members. This negotiation was important because it shows that TCs see pressing students' ideas as an important practice, as opposed to evaluating ideas; however, as it is clear in their reflective expressions that they tended to evaluate ideas in the moment of teaching as opposed to pressing student ideas. Their negotiations between these two practices show that they took up the pressing practice but were not quite sure how to not evaluate ideas during instruction. This may indicate a tension around who is responsible for

explaining. As teachers evaluate students' ideas they indicate that they approve of what students say or don't say and that gives students' directions or guidance to create the explanations.

However, when teachers press students' ideas (without evaluating), it gives students more of a sense of agency as they feel they have to evaluate their own ideas, rather than having the teacher do it. Pressing for ideas without evaluating gives students agency in creating explanations.

In teaching, every decision is situational, and there might be times when teachers may choose to evaluate ideas instead of pressing students' ideas for explanations. However, the discussions around pressing versus evaluating happened in this context involve TCs' trying out ambitious science teaching practices, especially eliciting students ideas and engaging students in material activity. Engaging in the approximations of ambitious science teaching practices requires TCs to try out talk moves, such as pressing or probing, rather than only evaluating students' ideas.

Theme 1- Tension 2: Pressing versus leading

Another piece the TCs and the instructor negotiated was the contrast between pressing students' ideas versus leading students' ideas. TCs struggled with differentiating and understanding which questions lead and which questions press. Part of the negotiation of the meaning of practices is between the instructor, and his vision of ambitious science teaching, and the TCs notions of good science teaching, largely grounded in their apprenticeship of observation. So, not only are TCs negotiating the meaning of these practices as a peer group, they are doing so in a context where negotiations are being facilitated toward particular outcomes of meaning by the instructor. Especially during the discourse 1 (D1) practice: eliciting students' ideas, TCs are expected to press or probe students' ideas without leading them to certain ideas they were expecting students to come up with. In most of the episodes, the instructor identified TCs' leading students' ideas as opposed to pressing student ideas; in only one episode did one of the TCs

question whether or not the teacher led students to certain answer. The following three episodes are representative of this tension.

The following episode was early in the semester. Kayla was the first TC to teach the first rehearsal, eliciting students' ideas around how fracking chemicals affect animals' (cows') reproductive systems and, specifically, how the fetuses die. The following conversation was between Kayla and the instructor during the debrief of Kayla's first rehearsal:

1. **Sean:** This is the first time you are doing this. Things to think about that I thought about while doing this were: try to keep your questions and comments, again especially this stage, generic. So like, when you are talking to Bryan back here, I tried to catch some of it; **you were sort of leading them towards the placenta, right? So you were like, 'how does it get into the body, and then how does it get into the blood into the calf?' and so you were, you were asking sort of specific questions, which is okay.**
2. Kayla: **So, okay, wait.**
3. Sean: Go ahead.
4. Kayla: So, like I saw they had written 'mother passes to child in humans, same is in cows since they are mammals.'
5. Sean: Yes.
6. Kayla: And I asked, "How is this happening?" **So, I shouldn't do that?**
7. Sean: No, no, I think you should.
8. Erika: When I said placenta,
9. Kayla: You said placenta, and I was like, "okay".
10. Sean: So, I think, this is sort of **I wish we could see the video**, because I think, ahm, I am not saying you didn't do that, what I am saying is,
11. **Kayla: Haa**
12. **Sean: As you are doing that one of the ways to think about doing that is to use generic language, so.**
13. **Kayla: Okay.**
14. **Sean: And you did that some of the time. So, things like, "can you say more about that? Can you explain this part to me?"**
15. **Kayla: I see.**
16. **Sean: "You have got this part; can you tell me what this means?" Or somebody says something out loud to you, say "I don't see that here, like you just said something really interesting, I don't see it represented in your model, add that to your model."**
17. **Kayla: [nods]**
18. **Sean: So that along the placenta, I think you know again, it is really hard not to want to guide people, right? (09.10. Episode 8)**

In this episode, in line 1, the instructor coded that Kayla was leading students' ideas and should keep her questions generic. He coded that through interpreting that she led students' ideas

to placenta and through giving suggestion that she should keep the questions generic especially when eliciting students' ideas. Then he highlighted specific questions through restating the questions she used (*"how does it get into the body, and then how does it get into the blood into the calf?"*) in her instruction. In lines 2-10, Kayla was negotiating whether or not she should have asked those questions, and in line 10 and 12, the instructor was acknowledging that she should ask those question but with a generic language rather than specifically trying to lead students to certain vocabulary she expected them to come up with. In lines 11, 13 and 15, Kayla agreed and understood what the instructor meant, and in lines 14 and 16, the instructor highlighted specific example questions that used generic language to get ideas from the students rather than leading or guiding them to specific answers. Thus, in this episode, Kayla and the instructor negotiated leading students' ideas versus pressing students' ideas through paying attention to the specificity of the questions, especially during eliciting their ideas early in the unit.

Another example of the tension between pressing and leading students' ideas came from an analysis of Bryan's lesson. The following episode is on the day that TCs were looking at their analyses of their own rehearsal videos. They were looking at Bryan's lesson. The conversation was between Debbie, Kayla, Abby, and the instructor.

[They watched the video]

1. Debbie: I think that was a good question.
 2. Sean: What was that?
 3. Debbie: I think that was good, he **pressed** [inaudible] trying to explain herself.
 4. Sean: She asked about dumping, she says, "dumping on the land is gonna effect the biology" and you agree with that?
 5. Debbie: [inaudible] "how is that dumping affect?"
 6. **Sean: Right, but then you sort of redirect them to remind them to think about the water being pushed back down in right?**
 7. Abby: Yeah, she was like "re-injecting it probably".
 8. Sean: "Probably yeah", is that what you did?
- [They watch the video to understand what exactly Bryan said]
9. Sean: Okay, so they say something about injecting and
 10. **Kayla: I don't know if you lead that?**
 11. Sean: So, you are saying?

12. Kayla: I don't know how we eventually got on to pressure. You eventually directed us on pressure, I don't know, if we keep watching.
13. All: Yeah, keep going. (09.17. Episode 22)

In this episode, they looked at one of the instances that Bryan coded himself in Studiocode as pressing students' ideas for explanations. In lines 1-8, TCs coded Bryan's pressing students' ideas and highlighted specifically what questions he asked them. Then, they watched the video again to make sure they heard what words were used in the conversation. Then, in lines 10 and 12, Kayla who was one of the students in the group when Bryan was pressing their ideas in the video, questioned whether or not Bryan led them to say pressure. So, Kayla realized the teacher led them to a specific answer he was looking for and she was questioning whether or not this was pressing or leading students' ideas. In this episode, TCs recognized that they needed to press the students' ideas to develop agency on thinking and explaining rather than leading them to specific results. This episode shows how TCs started to take up and question the ways teachers phrased the questions and how those different ways of phrasing impacted the notion of who is responsible for explaining the phenomena.

The following episode was another example of the negotiation of pressing versus leading students' ideas. The episode came from the debrief of Kayla's second rehearsal. She engaged students in building a model of the lung and reasoning with questions to help students understand how chemicals go into the alveoli, affecting the animals and their reproductive system. The conversation was between Kayla, Abby and the instructor.

1. Sean: Because there was one piece that I heard from these guys that I think—So, one of the big questions was, the gas to get into the lungs, and then these guys were starting to talk about—I think you were pressing them on it. “Okay, gas is getting to the lungs, what happens if there's bad gas that's in there? Like Toxic gas, what happens?” And I think at that point, **you sort of led them down the path as opposed to pressing them.** Right?
....
[There were discussions to understand which part of the instruction the instructor was referring, then in the next turn, the instructor clarifies that he is talking about where Kayla started talking about hemoglobin.]

2. Sean: No, I think it was when you were actually started talking about the hemoglobin. Because the question I was wondering about is: could you have said, so when you get to that point, like - because you guys were talking about there's something else bond to the hemoglobin, basically. And so, the question I think you could have asked them at that point and left them to think about is, "if that happened, what would that do? Like, if there was another gas, that's in the air that you breathe in and it can bond to the hemoglobin when it gets into the lungs, what would happen then?" And then leave them to try and think about an explanation for what would happen if the gas bonds to the hemoglobin. Because for you, when you want to get into this one, that's the central piece, right? That there's other stuff that bonds to the hemoglobin when it does, it basically starves both organisms of oxygen until they die. So, getting them to think a little bit about that piece, at that point, you might have. And maybe that was your intent and maybe it just wasn't possible at that point. But, that's one of the things you want to look for is those sort of flexion points, like points where they really have to do some explaining to get over a major hump. And I think in this explanation, it's what happens when the toxic gas is in the lungs and when they bond in to the hemoglobin instead of the oxygen bonding to the hemoglobin. So that little peak, that little nugget is the whole, it's sort of the little piece of your larger explanation of the big phenomena of why the cows died, which is this lab is actually about. And then they need to think about "well, when it's in, there's got to be transports to the blood." Right? So the next time you do it, that's what I would focus more on is that the gas exchange. And you talked about it in your opening piece.
3. Kayla: Yeah.
4. Sean: But if it was more of the focus and when it gets to smaller groups it gets a little clearer to them that the focus is on, "okay well I've got the air in, what is the air made of, and once it's in there, what does it do?"
5. Kayla: Yeah.
6. Sean: Yeah. (09.26. Episode 15)

In the first turn line, the instructor coded and highlighted that Kayla led students' ideas as opposed to pressing them; then, they tried to understand which part of the lesson Kayla was leading as opposed to pressing ideas. TCs tried to understand which part of the lesson the instructor was referencing, so Kayla was talking about different instances she thought the instructor was referencing. Then, in turn line 9, the instructor highlighted which part of the lesson he was talking about. He highlighted how she led students' ideas and coded some questions that she could have asked to help her to not lead the students' ideas and help them construct explanations as a suggestion or alternative to the problem of leading their ideas. So, in this

episode, the instructor highlighted and coded the problem of leading students' ideas instead of pressing students' ideas in Kayla's rehearsal.

Pressing versus leading students' ideas was the second tension negotiated between classroom members around responding to the students' ideas. TCs focused this negotiation through paying attention to which questions enable or afford the two different purposes. This tension indicated the negotiation of agency for who is responsible for explaining the phenomena. As teachers lead students' ideas to certain concepts or vocabulary, they indicate that they have a specific idea in mind that they want their students to come up with. Through very specific questions they lead them to that idea instead of pressing their ideas with generic questions. However, when teachers press students' ideas, it gives students more of a sense of agency as they feel they have to come up with the ideas, rather than waiting for teachers' very specific questions to help them guide in a certain path to create the explanations.

Negotiation of pressing versus leading was mostly observed between TCs and the instructor, which indicated TCs found it a difficult practice to differentiate between these two ways of questioning. In the second example episode, Kayla was able to recognize the difference between leading and pressing and questioned Bryan's practice. During that episode, TCs observed the teaching again and looked specifically at which questions he asked and the order of the questions he asked, which might have helped Kayla to highlight, code, and problematize the difference between these two ways of questioning. Also, unlike the first negotiation of pressing vs. evaluating, this negotiation was not observed during instruction. In other words, the TCs expressed their tensions around differentiating pressing and evaluating in the moment of teaching, indicating take-up of pressing practice from TCs; however, the negotiation between pressing vs. leading was not observed in the moment of teaching and was typically initiated by the instructor or recognized later when TCs were observing video of the teaching. Even though all the

discussions of teaching happened after they taught their lessons, I described negotiations happening during instructions and after instruction. During instruction means that when TCs negotiated tensions between pressing and evaluating, they indicated that they had those tensions in the moment of teaching. Whereas, when they negotiated tensions between pressing and leading, they did not see the differences between leading and pressing questions until they observed it multiple times after instruction. This indicates the TCs had difficulty in understanding the nuanced differences between pressing and leading when responding to students' ideas. However, they were still seeking to understand the distinction between pressing and leading students' ideas.

Theme1-Tension 3: Entering and exiting groups, and how much to stay in groups

TCs needed to negotiate entering and exiting groups, what to do during these transitions, how long to stay in each group, and balance talk time in and between groups. Some of the negotiation in this area also related to the tension about who is going to explain and how the teacher is going to make sure students are talking about what he/she wants them to talk about. The following three examples represented negotiation of how to enter and exit groups and how those choices affect students' agency.

The following example was from Mark's first rehearsal debrief. Mark's lesson was about how the greenhouse gases caused by fracking fluids affect the polar ice caps. The following conversation was between Erika, Abby, Debbie, and the instructor. Since this episode is a long episode, I divide it in two parts and explain it separately.

1. Erika: I think **he kinda spent too much time. I feel like especially the other ones** [referring to other TCs who taught before], **they'll be like, Okay. Press, probe like two, three questions back to other group, back to other group. He really sat there and we would have these like five-minute conversations and then Bryan and I were left to go over all these different things. And then once we got to the end of what we thought we were supposed to get to, we'd be kind of like waiting for Mark to come back and ask us more questions, you know.**

2. Sean: Right. So why do you think that is? Because I noticed that too and it's in my notes and I have my own hypothesis, but I'm curious because you did do that. You maybe switched groups three times in the whole.
3. (.....)
4. **Abby: Like when you [to Mark] would sit down with us, we would get more information because we had more of a chance to analyze body language and kind of assess what he was saying. So that kind of made it, I don't want to say easy but less difficult to come up with an explanation. So, when he wasn't there, I guess things would probably stagnate just because, oh well now we got this bit and then we'd wait for him to come back and he gives us something else and we'd hash out that bit. Because again, we can read him and see what's going on.**
5. Sean: Okay. Okay.
6. **Erika: I just feel like with more back and forth, it almost like it keeps you guessing. I feel if Kayla would press my group for a couple of questions or say "this is a good thought process, keep going with that", we keep talking about it more and by the time she got back to us, which was a minute later. We would say, " Okay. We have this now." And then she could analyze that. And I just feel like it kept us on our toes more whereas now with Mark, he would give us information, I keep thinking almost like an assignment. "Okay. This is what you're working on when I come back in five minutes, I expect that."**
7. Sean: I think, no I think he actually said that, I think at least once.
8. Abby: Yeah, he told us, "I want you to draw a diagram when I come back, we'll talk about your diagram."
9. Sean: Yeah. That ended in an assignment and then he would go to the other group and teach like a little mini lesson and then they got an assignment. **(09.12. Episode 14-1. Part)**

In this episode in line 1, Erika highlighted that Mark spent more time in the groups compared to the other TCs who asked a couple of questions then went to another group. Erika also interpreted how staying longer in the groups affected students' dependency to the teacher. Then in line 2, the instructor agreed with Erika and prompted the TCs to interpret why he stayed longer in the groups. In line 4, Abby interpreted how they as students were able to get immediate implicit feedback from the teacher and that made their explanation building less difficult but also made students dependent on the teacher. Then in line 6, Erika compared Kayla's pressing and leaving them more while coming back and forth more regularly to Mark's staying more, giving them extended tasks and coming back less often. In this line, Erika also highlighted how Kayla and Mark responded differently to the students' ideas. Then in lines 7 and 9, the instructor agreed

with Erika's highlighting and interpretation, and in line 8, Abby highlighted an example of discourse from the teaching about extended tasks. Following those lines, Debbie continued the conversation with the following statements:

10. Debbie: I think it's also like instinct when you have the teacher sitting there for an extended period of time; you start to become dependent on them. So, I think that may have had something to do with when you [to Erika] said, you guys were fine while he was there, and then he walked away and you [to Erika] talked about what he said or regurgitated whatever he said. And then you were at a loss for words because you were dependent on him after he sat there for five minutes and you could read his expressions and read what he was saying.

11. Erika: Yeah

12. Debbie: And when he disappears, it's like, "uh oh."

13. Erika: I think that's like the downside of staying there too long.

14. Debbie: Right. So if you balance, like they're [students] not used to having you there so it forces them to talk amongst themselves vs. you sitting there where they're [students] like, " Okay. Teacher's here, we can get all the information now." (09.12. Episode 14-2. Part)

Then, in lines 10, 12, and 14, Debbie interpreted the situation in terms of how the students become dependent on the teacher and his feedback, and when he was not with the group, students did not know how to move forward. Between lines 11 and 14, Erika and Debbie proposed and agreed to move between the groups more often to give more agency to the students to come up with the explanations in the groups rather than seeking the teacher's feedback and evaluation when the teacher was with them for longer times. Overall, in this episode, TCs collectively negotiated Mark's waiting more in the groups, trying to make sure that the students explained every detail as opposed to pressing more often and leaving the group to let them talk among themselves and come up with explanation. Thus, TCs negotiated the teacher's not letting students have agency to explain and to make sure that they come up with the 'correct' explanation through spending more time in the groups.

The following episode was also related to Mark's lesson on the same day and represents an example of negotiation of how to enter and exit groups. The conversation was between the instructor, Abby, Erika, and Bryan.

1. Sean: Yeah so, I mean I had more to say about that, but I wanted to know if anybody else has anything else to say about the group stuff?
2. **Abby: I mean I did notice he waited to go till after I had hashed out my explanation. Like he didn't ask a question, let that question fester and then leave.**
3. **Sean: Oh I see. He waited until you were done.**
4. **Abby: Yeah.**
5. Sean: Hmm. That's interesting. Did you guys feel the same way or not?
6. Kayla: What did you say?
7. **Abby: When he was asking about the explanation, he waited until I hashed out the whole details that he wanted me to hash out before I moved to the next part.**
8. **Sean: You're contrasting that and you're saying like other folks did, where they would leave before it was all hashed out?**
9. **Abby: They [other TCs] would ask the question, you would kind of come up with a beginning, and then they'd be like, " Okay. Keep thinking about it." And then move on. Which allowed the question to fester; we could bounce back and forth between the groups.**
10. Erika: Yeah. I liked that better.
11. Sean: You liked that better. **(09.12. Episode 15)**

In this episode, based on the instructor's prompt in turn line 2 and 7, Abby coded how Mark waited for her to tell all the details of the explanation before leaving the group and then the instructor asked other TCs if they felt the same way. In line 9, Abby compared other TCs in terms of how they pressed and left the groups as soon as students started reasoning and talking about the problem. So in this episode, Abby noticed how Mark did not want to leave before he heard all the details of the explanation and made sure they had the "correct" explanation. Thus, she contrasted teachers' staying longer for the purpose of making sure the students come up with the correct explanation through teachers' immediate feedback with pressing and leaving students so that they can generate explanations on their own without teachers' constant feedback.

Another example of negotiation of how to enter and exit groups came from Bryan's first rehearsal debrief. The conversation was between Abby, Bryan and the instructor.

1. Abby: One thing I noticed that's different from Kayla and Debbie was **I knew when he was coming in**, with Debbie and Kayla [inaudible]
2. Sean: Just because he is big?
3. Abby: **No, I don't know what it was, but Debbie and Kayla were fading in and out, but I knew when he was coming and I knew when he left.**
4. Sean: Yeah, you were more declarative like you would say, "oh you guys are working on the spelling, while you are working on the spelling part, I am gonna go over to that group".
5. Bryan: Right.
6. Sean: **Whereas I think, you are right, the three of you [referring to Kayla, Debbie and Abby] tended to just sort of talk and, then when it looked like things were sort of going in the way you wanted, you sort of faded away, and disappeared. And something to think about, you know, again not right or wrong but some to think about in terms of how you enter and leave the groups, right? And what sort of impact does that entering and leaving, if you have a stronger entrance and exit, it tends to focus more attention on you, when you do. It's harder to look, right? if every time you come up, the first thing you do is start talking, where, when you leave you have your last words before you leave. Then one effect of that is that when you come up, the kids stop what they're doing and turn their attention to you, because you've made a statement that you are gonna talk to them.**
7. Bryan: Is that how you guys felt?
8. Abby: What?
9. Bryan: Is that how you felt?
10. Sean: That's how I am interpreting what Abby was saying.
11. Abby: I mean I felt like I knew when you were coming and I would always look up.
12. Debbie: I mean I can see you are coming so.
13. Sean: Yeah, that's different.
14. Abby: My back was turned to you, you come over and the first thing I would do is ignore Debbie [inaudible] (09.12. Episode 5)

In this episode, in turn lines 1 and 3, Abby highlighted how Bryan entered and left the groups noticeably. Then, in turn lines 4 and 6, the instructor highlighted specifically which phrases (such as, "*oh you guys are working on the spelling, while you are working on the spelling part, I am gonna go over to that group*") made the noticeable entering and exiting along with how those ways of entering and exiting groups impacted students' dependency and interaction in the groups. Then in turn line 5, while Bryan was agreeing with what the instructor said in turn line 7, he questioned and wondered if other TCs as students felt the same way as Abby did. In this episode, Abby was negotiating Bryan's entering and exiting groups and how he was noticeable. Thus in this episode, TCs negotiated ways of entering and exiting the groups and in what ways

those choices impacted students' interactions with each other and their dependency on the teacher. In other words, how a TC interacts with students as they enter or exit student groups has implications for students' agency around creating explanations and having ownership around coming up with explanatory models for the phenomena they investigate. In this theme, I found TCs negotiated the nature and purpose of entering and exiting the student groups and how it impact students' agency in creating explanations.

The final tension TCs negotiated around agency was around the amount of time they stayed in dialogue with small groups and their ways of entering and exiting student groups. This negotiation was expressed mostly by the TCs. They were able to highlight this tension in their peer teaching rehearsals, especially during their experience as a student rather than as a teacher. TCs were also able to code how different ways of entering or exiting groups or staying different amounts of time with the groups impacted students' dependency on the teacher around creating their explanations and moving forward on a given task. TCs also coded how they talked to the students and what questions they asked as they enter and exit the groups, thus they negotiated the substantive talk as well as the decision to how to enter and exit the group. TCs also interpreted this tension in terms of getting more ideas from students and around the implicit feedback it provides from the teacher. In addition, TCs were able to identify the complexity of entering and exiting groups in other TCs practice; however, none were able to recognize those complexities in her/his own teaching either during debriefs of the lesson or in the moment of teaching reflections.

Entering and exiting groups is not one of the practices specifically described in the ambitious science teaching practices or in the discourse tools. Considering how they enter and exit groups during teaching emerged during the first discussion of rehearsals, after Kayla taught her first rehearsal. Then, the classroom community continued to talk about how they enter and exit the groups, they even take that as an additional practice to code during their analysis of the

first rehearsal videos in the Studiocode. Thus, entering and exiting groups became a practice for the TCs to consider in their teaching. Even though it is not explicitly described in the ambitious science teaching practices or in the discourse tools, because putting students in groups to help them talk about science is inherently part of the ambitious science teaching practices, considering how the teachers enter and exit groups and what impact it has on students' explanations is also an important component of their professional vision.

Thus far, I have illuminated how TCs negotiated the agency of who is responsible for explaining the phenomena. TCs negotiated three primary tensions around student agency: 1) pressing vs evaluating, 2) pressing vs leading and 3) entering and exiting groups and how long to stay in the groups. All of these tensions contribute to the negotiation of student agency that emerged within their conversations of teaching. Another negotiation that TCs seemed to make includes explanations and what an explanation is as represented in Theme 2 in the next section.

Theme 2: What is an explanation?

TCs and the instructor negotiated what counted as an explanation along with focusing on certain aspects of scientific explanations. The negotiation occurred through discussions of the levels of explanations, the importance of evidence in the explanations, and the importance of the gapless explanations they created for themselves and its relationship to students' explanations. TCs took up that explanations are important, but it is not clear if they connected the gapless explanation they created to the explanation they got from the students. Also, in a few episodes, they talked about the importance of evidence in creating explanations. I present their negotiations in three types of aspects/tensions below. Not all of the negotiations sounded like a tension, so I did not frame all of them as tensions but, rather, as aspects of explanations they negotiated.

Theme 2-Tension/Aspect 1: Pressing for evidence-based explanations versus pressing for clarity in explanations

TCs and the instructor negotiated the meaning of pressing for explanations in their discussions of teaching during the first five weeks. TCs knew they needed to press students' ideas for explanations, but it was not clear from their discussions of teaching if they were paying attention to evidence when pressing students for explanations. TCs were mostly attending to pressing for clarity, expanding or pressing for reasoning in students' explanations. There was only one episode in the video data where the instructor prompted them to press for evidence use in constructing explanations when discussing one of the TCs' rehearsals. I provided two example episodes below; one is related to pressing for clarity, and the other one is related to pressing for evidence use in constructing explanations.

The following example shows how they talk about pressing for explanations, but it was not clear if they meant evidence-based explanations. This episode was from the discussion of Bryan's rehearsal, where he engaged students in a PhET simulation (<https://phet.colorado.edu/en/simulation/legacy/gas-properties>) where they explored the relationship between volume and pressure as a material activity to explain the earthquakes caused by the effects of the fracking. The conversation was between Erika and the instructor.

1. Erika: So I think it was good that this is what he focused in on. And also, I thought the simulation was good, and allowed us to see it. And I thought it was cool that you could change the volume. I think that was important for us to...
2. Sean: Mm-hmm.
3. Erika: Because it's just like in Bethany's thing, like that it's so easy for us to just look at the equation and be like, "Oh, this is what each letter stands for," and that's all we know. But it's good that we actually discussed it, because... **and I thought he did a good job of pressing in the beginning. Like what Mark was talking about, the difference between, like gas molecules and liquid molecules. And he did a good job of really making him explain everything.**
4. Sean: Mm-hmm. (09.24. Episode 3)

In this episode, in line 3, Erika highlighted pressing practice and coded that Bryan pressed students' ideas for explaining the difference between gas molecules and liquid molecules. So, the purpose of pressing was pressing students' ideas for explanations. However, it is not clear from this episode if she thought about explanations as evidence-based explanations. This episode is more about teachers pressing students' ideas to explain what students meant rather than providing evidence-based explanations of the phenomena. In this case, Bryan chose to press students' ideas for the difference between gas and liquid molecules. Erika coded Bryan's pressing practice and interpreted the purpose of pressing for what students meant and if the students understood the difference between gas and liquid molecules.

Another example of negotiation of pressing for clarity in the explanations versus pressing for evidence-based explanations came from Erika's lesson debrief. The following example occurred during Erika's second rehearsal, where she engaged students in a material activity by providing actual data of how different acid levels affect the environment (soil, plants and animals, specifically fish.) The conversation was between Erika and the instructor.

1. Sean: All right. Other things about Erika's lesson? I mean the big thing I would say; I think you talked about a lot of the stuff. The one thing I would push you on is to **get them to talk more about the data. You started doing that at the beginning, and again probably if you had more time. But to really say, 'OK, we looked at this data. We picked these species because they're, you know...'**
2. Erika: Right.
3. Sean: **I mean, why did they pick the crayfish and the trout? And then how did they use that data to build their explanation of what happens to them?**
4. Erika: Mm-hmm.
5. Sean: **And the same with the... But that's a relatively small piece. But it could have been one of the things you did as you moved back and forth, was push them to really say, like "really draw on the data when you're making your explanation. And how you use the". Because [inaudible] when this group came up. But you could have pushed a little more.** [Inaudibly talking over Erika]
6. Erika: **Yeah. I think they talked about one of the [inaudible]. They referenced the case study** [she is referring to data sheets].
7. Sean: Right.
8. Erika: **They referenced more of the...**
9. Sean: They did [inaudible].
10. Erika: Yeah.

11. Sean: But I think part of that is you asked them to, too.

12. Erika: Right.

13. Sean: A little more than this group. So. Okay. Very good. **(09. 24. Episode 15)**

In this episode, in lines 1, 3 and 5, the instructor prompted and oriented them to press students to talk about evidence and press them to construct explanations using the evidence. In line 1, the instructor highlighted that she started pressing students for evidence at the beginning, but in line 5, he also highlighted and coded that she should have pressed students for evidence in their explanations as she moved back and forth between groups. Then in line 6, Erika highlighted that one of the groups used evidence as they referred to the case study compared to the other group. And in lines 9 and 11, the instructor agreed and coded that one of the groups used the evidence more than the other groups, but it was because Erika pressed them to use evidence. In this episode based on the instructor's prompt, Erika and the instructor negotiated the meaning and importance of pressing students for evidence-based explanations.

Paying attention to evidence when creating explanations was the first way TCs and the instructor negotiated the nature of explanations. TCs and the instructor negotiated pressing for evidence-based explanations rather than pressing for clarity, expanding, or reasoning in explanations. TCs highlighted and coded pressing for explanations both during their first and second rehearsals. The discussion of evidence in creating explanations emerged during the second rehearsal, which was understandable given the foci of the two rehearsals. In the first rehearsal, TCs were able to talk about pressing for explanations, as it was one of the sub-practices of discourse practice one - eliciting students' ideas. The majority of discussions around explanations included pressing for clarity in the explanations, pressing for expanding the students' explanations, or pressing for students' reasoning in explanations. The main idea in that practice included pressing students' ideas to explain the phenomena; however, the explanation does not necessarily have to include evidence unless students bring evidence from their past experiences.

Whereas in the second rehearsals, since the TCs engaged students in material activity during the lesson, TCs had the opportunity to use and press for the use of evidence in creating scientific explanations for the phenomena. Thus, the discourse regarding pressing for evidence in creating explanations emerged during the second rehearsals; however, the number of instances of that discourse was limited because not all of the TCs included material activities, which can support students' use of evidence.

Theme 2- Tension/Aspect 2: The importance of teacher gapless explanation and its relationship to student gapless explanation

During their discussions of teaching, the instructor brought up the importance of the gapless explanation to be able to press students' ideas for the explanations, to be able to ask the right questions to press students' ideas, and to have students generate productive ideas towards creating explanations. Even though the instructor brought up the importance of the gapless explanation both in the discussion of the model teachers' teaching and TCs' rehearsals multiple times, it is not clear if the TCs understood the importance of the gapless explanation or what counts as a gapless explanation and for whom. In the discussions of teaching, there was only one instance of uptake from the TCs related to a gapless explanation where they connected the gapless explanation created by TCs to the explanation the TCs hope to get from students.

The following episode shows how the classroom members were decomposing model teacher Bethany's teaching for eliciting students' ideas. The conversation was between Abby and the instructor after they watch a clip of Bethany's teaching.

1. Abby: She is like, "okay, let's take a step further on that idea, what comes next?"
2. **Sean: Yeah, so, what is she trying to push them to think about? Cause she is, and again, presumably she has got an explanation in her head, right?**
3. **Kayla: [nods]**
4. **Sean: She has the right explanation, and she doesn't want to tell the kids, like, "okay this is what you need to explain" but she is pushing them towards a specific thing. So, listen, she does it again, right? She just, what was the first question she asked? "What happens to water?"**

5. Abby: “When the steam turns back to liquid, what happens?”
6. Sean: Yeah, so now listen how she is [Inaudible]
[They watched the video]
7. Sean: So, what did she do?
8. Abby: She basically repeats the question.
9. Sean: She basically asked the same question again, slightly different way, right? So now that's indicated again, obviously this is important, right? Because she just asked the same question again twice, so if teacher asks you the same question twice, you know this is probably something you need to think about, **so she is pushing them, but she is not moving around, she keeps pushing them on the same thing, “here is what you need to think about,” she is not even saying that, she is just asking a question, over and over again, right? (09.05. Episode 2)**

In this episode, in lines 2 and 4, the instructor reminded and oriented TCs that the teacher had the gapless explanation in mind and that helped the teacher to press students’ ideas for explanation because she knew what she wanted them to come up with. TCs nodded their heads and seemed to agree with the instructor, but there was no clear evidence for their uptake of understanding the importance of gapless explanations.

While the previous example did not show up TCs’ uptake clearly, the next episode shows how a TC agreed. The following example was from the debrief of Bryan’s first rehearsal. Bryan taught about the effects of fracking sites on the occurrence of earthquakes. The conversation was between Bryan and the instructor.

1. Sean: Is there anything else you wanna say about the lesson?
2. Bryan: No, I mean for me it was really tough finding a topic so this is kind of a last minute thing, so I thought it went pretty well, it was not perfect but it could have been worse.
3. Sean: **Yeah. I mean my guess is part of the struggle for you might have been that you don’t have a complete gapless explanation for this thing yet, because you only had it a day or so.**
4. Bryan: Right.
5. Sean: So, my guess is if you look to your explanation, there are pieces in there where you don’t have it completely and without that it is much harder to ask questions that push people in the right direction.
6. Bryan: Yeah.
7. Sean: So, you end up having to be more directive and
8. Bryan: Yeah.
9. Sean: So that, I could be wrong about that I didn’t see your explanation but yeah, I keep asking you to write these explanations, but that's part of the reason is that it

does really help you when you get into these small groups. If you really know the explanation you want the kids to come up with because it helps you ask good questions and pat them on the back in the direction you want them to go.

10. Bryan: Cool.

11. Sean: Well nice job, any other comments? **(09.12 Episode 10)**

In this episode, in line 2, Bryan reflected on his lesson based on the instructor's prompt in the first line, and in lines 3 and 5 the instructor interpreted why he had some problems with pressing students' ideas due to the lack of a complete gapless explanation. In lines 4, 6 and 8, Bryan agreed with the instructor's interpretation. Then in line 9, the instructor continued to interpret why it is important to have a complete explanation and how that helps TCs to ask questions to push students in the right direction. This episode showed agreement of the importance of TCs to understand the complexity and difficulty in creating a gapless explanation even when pressing students' ideas.

The following example was the only episode that showed the recognition of the connection and relationship between teachers' gapless explanation and the explanation the students created. The episode came from Abby's first rehearsal debrief. She taught the recovery of ecosystems after Ohio Lake caught fire. The conversation was between Abby, Kayla, Erika, and the instructor.

1. Sean: Were there ideas that came up that you hadn't anticipated?
2. Abby: Ahm, yeah actually, **where you guys went with your after portion is completely different than where I wrote my after portion.**
3. Kayla: Ours?
4. Abby: Both groups actually.
5. Kayla: Oh, okay.
6. Abby: I went further down the road and you guys stayed immediately after the fire, which I hadn't thought about, so I am gonna add that into my explanation.
7. Sean: Ah, so say more about that, explain?
8. Abby: I wanted to get into reclamation, biology people you know what that is. That's like when farmers let their field just, they've harvested everything.
9. Erika: I thought there is a term; I was trying to think of the term for that.
10. Abby: Weeds and bugs start coming in again.
11. Erika: Yeah, yeah, right.
12. Kayla: Yeah. [Inaudible]
13. Erika: Exactly.

14. Abby: You [referring to Kayla] started to get there.
15. Kayla: Eventually.
16. Abby: **Eventually, so hmm, that was different for me because I was thinking further down the road; I didn't think that we would launch onto immediately after the fire, so that was pretty, that was an interesting [inaudible] and how I adjusted to go with you from then.**
17. Erika: And maybe if you'd have given 15 more minutes then that's something you would get to, **because we both had the soil component as an immediate thing like with it being like basically burn to ash and being harder to renew because not only where it is just a tough thing to bring the ecosystem completely back, but also the water that is sort of using as a source is now polluted, so but yeah.**
18. Abby: **And I think that was a great learning experience for me being like, "ohh, I wanted to go to further down road but I am not going to stop you where you are because you were doing good things. So I had to be able to adjust to that, so that was a great learning experience for me. (09.10. Episode 14)**

In the first line, the instructor asked Abby if she had any student ideas that she did not expect. In line 2, she coded how students' ideas and explanations of what happens after the fire were different from her gapless explanation that she wrote for after the fire portion of her explanation. During the lesson, she scaffolded students' explanation building by structuring the task for students to explain what happens before, during, and after the fire. So, in line 2, she referred to the students' after portion of the explanation and coded that it was different from her gapless explanation. In lines 6, 8 and 10, she compared what her explanation included and what students' explanation included and clarified where she was trying to go with her explanation. Then in lines 16 and 20, she further interpreted how she adjusted to the different paths of explanation and how she did not force students to go to the part she included in her explanation. Thus, in this episode, Abby reflected on her noticing of how the explanation the students created was different from the explanation she created during planning, and, thus, how her explanation was not really a complete gapless explanation, how she took that up during instruction, and adapted her instruction in the moment of teaching.

The second aspect of explanations under negotiation by TCs centered around gapless explanations and their role in planning practice. Gapless explanations are one of the most

important aspects of ambitious science teaching. Identifying the big idea for the phenomena under investigation and writing the gapless explanation of the phenomena are crucial steps in the planning phase of ambitious science teaching. During the discussions of both Bethany's teaching and TCs' rehearsals, the instructor oriented TCs' attention to the importance of the gapless explanation. In most of the cases, he repeatedly emphasized the importance of the gapless explanation for teachers in terms of orchestrating the classroom talk and to be able to move students forward in their explanation through pressing and probing questions. While this notion was emphasized throughout the course by the instructor, there were only a couple of episodes that showed TCs' take-up of the importance of gapless explanations or the connection between the gapless explanations they created and the explanations their students created.

Theme 2-Tension/Aspect 3: Levels of explanations (what versus how/ why explanations)

TCs and the instructor also negotiated the levels of explanation. The instructor suggested TCs press students' ideas to make causal explanations through asking how and why questions rather than pressing only to explain what is happening. Thus, the instructor mostly suggested TCs ask students how and why questions so that they can better narrow and target the explanations for the students. The instructor and the TCs negotiated it through orienting TCs to pay attention to the phrasing of the questions and the purposes of the questions.

Two example episodes of the negotiation of levels of explanation presented below were from Kayla's first rehearsal debrief. Kayla taught the effects of fracking fluids on the animals' death and their reproductive systems. The following conversation was between Kayla and the instructor.

1. Sean: I noticed in both groups **you were really pressing towards what is happening, what is actually killing the cows basically.**

2. **Kayla: Yes, because therein lies why, if they are pregnant the actual baby cow and you guys have the correct thing in that with the placenta. If the mother cow's blood was affected thereby...**
3. **Sean: It crosses** the barrier into the calves.
4. **Kayla:** Yes, and therein lies the other thing, as why cows cannot get pregnant, "well their blood is affected their menstrual cycle is affected. Therefore the eggs doesn't..."
5. Sean: Doesn't drop...
6. Kayla: Yeah.
7. Sean: So, I think either you can focus on stillborn calves or you can focus on the cows dying but the thing came to my mind is more about the cows dying. **So if the question was more about what is, how do you say it? "how are the cows dying?", right? Because there's lots of ways animals die. So, they could die of starvation, they could die of suffocation, they could die of like stress, right, like you were talking about fish, that they just sort of waste away, which is sort of like starvation but it's not the same thing, so the question if you pushed on them even in the beginning, like "How are these cows dying?", like, you are saying cows are dying, well, how are they dying? What is causing them to die on the inside? Then I think you would have gotten faster into this bit. Because then I think.**
8. Kayla: I mean, once they reached those ideas, they just went.
9. Sean: Right. **(09.10. Episode 4)**

In this episode, in line 1, the instructor coded Kayla's pressing for what was happening to the cows, and then in lines 2 and 4, Kayla explained why she was pressing towards what was happening, the relationship of cows' dying and why they had stillborn calves. Then in line 7, the instructor suggested pressing towards how the cows were dying and what was making them die inside so that they could talk about the mechanisms that affect their death. He also highlighted specific questions she could ask. Thus, Kayla and the instructor negotiated the types of explanations and the related questions to press students to create those explanations. During her lesson, Kayla asked students to explain what happened to the cows and made them die, but it took a long time for her to orient students to explain how the cows die, so during the debrief of the lesson, the instructor suggested that Kayla ask for how the cows died instead of what happened to the cows.

Another example of negotiation of levels of explanations included the instructor's (S) suggestions again later in the Kayla's debrief of the lesson. The conversation was between Kayla and the instructor.

1. Sean: Remember that **there are sort of levels of explanation that you can think about right, so the simplest is the what, okay, what chemicals going into the stomach, what happens next, well it gets into the intestine, what happens next, right, so you can certainly do a chain of 'what's' but then the next piece of it is the 'how', so like once it is in the intestines, how does it get from the intestines into the bloodstream.**
2. Kayla: [Inaudible]
3. Sean: Right, so that's one of the ways, no no I am agreeing with you, so that's one the ways you can start to press, too, is **once people have a pretty clear 'what' chain you can start asking how and why questions, why does it do this, how does it do this, what is the process, because that's the 'what is' very descriptive and important, but it doesn't get at the mechanism, so one of the things you ultimately want to do is you get into the how this is happening or why is this happening.** So I am just agreeing with you that you can just.
4. Kayla: Okay.
5. Sean: These are places that you can, they know it goes into the stomach and you pushed them to think, well, are the nutrients going from the stomach into the blood stream and then... it's the intestines, so then they have to start thinking about the intestines as an organ and what that organ does to food that's in it, how does that work, right?.... but this just a way to think about the layers of explanation. **So ultimately what you want is a why explanation because that gives you a larger model, why is it that chemicals in the environment kill cows, well if you have a why explanation, that means you really understand all that notion of how mechanism.** Okay. All right. (09.10 Episode 10)

Similar to the previous episode, in lines 1, 3 and 5, the instructor oriented the TCs' attention to the levels of explanation and associated questions for those levels such as "what", "how", and "why". He suggested that Kayla press students' ideas towards why and how the cows die to help students explain the mechanism of how the cows die. He also reminded TCs that "how" and "why" questions and explanations to those questions encompass most of the explanatory model to explain how the cows die.

The final way TCs negotiated tensions (aspects) around explanations is through a discussion of levels of explanation and the types of questions asked for those levels. TCs and the instructor negotiated levels of explanation for students and how "why" and "how" questions

enabled students to move toward the causal explanatory model for the phenomenon under investigation. In the episodes, it was typically the instructor who oriented TCs to pay attention to these levels of explanation. The discourse about the negotiation of levels of explanation occurred only in one rehearsal debrief (Kayla's).

In this section so far, I illuminate how TCs negotiated what constituted an explanation along with its components and levels of explanations. TCs and the instructor negotiated three aspects or tensions of explanations: 1) pressing for evidence-based explanations vs pressing for clarity in the explanations, 2) gapless explanations and their relationship to explanations students created, and 3) levels of explanations. Another negotiation that emerged from the data included negotiating what the phenomenon was along with its explicitness in the lesson and its relations to the content storyline of the lesson, represented as Theme 3 in the next section.

Theme 3: What is a phenomenon?

TCs and the instructor negotiated what counted as a phenomenon in the lesson and its relation to the content storyline of the lesson. Part of the big idea planning practice is to focus on puzzling phenomenon and thus this became a key area of negotiation for TCs during their discussions of teaching. The negotiation manifested in two ways. One way was related to how TCs and the instructor negotiated what phenomena are in the lesson and how to make the phenomena explicit for students during instruction through asking better questions to make the phenomena more focused. The other negotiation was around the content storyline of the lesson and its presentation and structure in relation to the phenomena. I presented examples of these two ways of negotiation in this theme below.

Theme 3-Aspect 1: Explicitness of the phenomena and the focus of the lesson

TCs and the instructor negotiated what the phenomenon and the focus of the lesson were. In the debrief of rehearsals, TCs negotiated the focus of the lesson in relation to the phenomenon and making it apparent and explicit for the students. The purpose of this negotiation was to make it clear for students what to explain during the lesson. I gave examples of episodes to support this negotiation below.

The following example regarding the negotiation of the phenomena and its focus and explicitness in the lesson came from the debrief of Mark's first rehearsal lesson. Mark planned to teach how the greenhouse gasses affect the climate and eventually affect the species. In this episode, TCs negotiated what the phenomenon and the focus of the lesson were. The conversation was between Erika, Kayla and Debbie and the instructor.

1. Erika: I just think that it's interesting to see everyone's lesson so far, **we've seen some of them were too broad or some were too narrow**. [She is referring to other TCs' lessons] I feel like Bryan and I, once we got our ideas down and talked about it as much as we can. [Erika and Bryan were in the same group and trying to explain what causes the greenhouse gasses] **I feel like there was definitely a time we were just kind of like, "So yeah, this could maybe also cause air pollution, this could too" but we weren't...** I feel like when Debbie's and Kayla's and even Abby's and Bryan's, **I feel like I was constantly using as much time as possible thinking about all these new things, where I felt like with this one [referring to Mark's lesson] maybe it was too narrow so we kind of got to this point of like a lull period**. Where we like, like I could probably start talking to Bryan about what he was doing tonight, because I didn't really have anything else to say, and he didn't neither. And maybe that meant **we didn't know we were talking about it enough, but or we thought we got it, I don't know**. We, I never got to the end of Debbie's; we never got to the end of it. Bryan's, we were starting to get there but then time was up. Abby's we probably could have thought more, you know.
2. Kayla: **I think in this lesson, there is so much you could do with greenhouse gasses, I think both groups got the general gist of it, but "Okay, so how is this affecting the Ozone layer? What is it doing?" "How we can see it? So, what are other examples?" I mean you can keep going.**
3. Sean: Yeah.
4. Debbie: **We started to do that.**
5. Kayla: I also know, yeah.
6. Debbie: **Because we had like that whole orange flow chart down relatively quick.**
7. Kayla: **If you pressed them in the right way.**
8. Sean: **If you were pressed in the right way?**
9. Kayla: **Right way. Because there are ways we could go, but ...**
10. Sean: Yeah. (09.12 Episode 13)

In this episode, Erika, Kayla, Abby and Debbie, and the instructor (S) offered ideas about what was going on in the lesson. In the first turn, starting with line 5, Erika coded and brought up a problem or a dilemma she and Bryan had during Mark's teaching and compared his teaching and other TCs' teaching through her own active engagement in explaining the phenomena during other TCs' lessons. She coded the tension they felt as students in the lesson about the focus of the lesson and their non-engagement in explaining the phenomena (by stating "*So yeah, this could maybe also cause air pollution, this could too what we want.*"), so she interpreted it in terms of the phenomena being narrow when she stated "*where I felt like this one was maybe too narrow so we kind of got to this point of like a lull period.*" or they did not know what to explain or what the task was when she said, "*we didn't know we were talking about it enough, but or we thought we got it, I don't know*". The first turn of talk from Erika was coded as coding or interpreting of the focus of the lesson and her negotiation of whether or not the focus of the lesson was clear for them as students because Erika was trying to make sense of what the focus of the lesson was and how it was presented to them as the students and she was able to compare it to other TCs' lessons. Then in turn line 2, Kayla interpreted that there were multiple directions that the lesson could go on, and she highlighted some possible questions that could be answered with this lesson. Later in turn line 7, she coded that if he had pressed students in the right way or with right questions he could have determined and made the focus of the lesson apparent for the students. So, with these turns of talk, Kayla negotiated the focus of the lesson and the ways in which the lesson could go on through the questions the teacher could have asked to press their ideas. So, she saw that through asking the right questions or pressing students in the right way, the teacher could have narrowed down the phenomenon and made the focus of the lesson more apparent for the students.

Thus, within this episode, TCs identified the tension or problem that they struggled with during the lesson about the phenomenon and the focus of the lesson. They proposed how the

focus of the lesson could have been made apparent through pressing students' ideas in the right way, and they negotiated this tension mostly with each other without the instructor's input. So, overall they negotiated what the phenomenon was and the focus of the lesson about which the teacher wanted them to explain. TCs thought that through pressing in the right way the teacher could have made the focus of the lesson more apparent for the students.

The following episode shows another negotiation related to what the phenomenon was during the lesson. The episode came from Kayla's first rehearsal debrief. The conversation was between Kayla and the instructor.

1. Kayla: I think that **I should have picked one reproductive problem; so, for example, stillborn calves.**
2. Sean: Okay.
3. Kayla: And also I think that it would have been helpful to provide [she waits] hmm I mean I think that even in itself. Because I got into the issue with you guys [pointing to Erika and Bryan] when you were going on three different tracks of to why there are reproduction problems and they are all correct. **But now I am redirecting you to go after, "okay, so now why are not pregnant cows not being pregnant or why are stillborn calves being born, what is this have to do with", I think I was messing you up because I wasn't [inaudible].**
4. Sean: So, it was like you have two mini phenomena.
5. Kayla: Yes.
6. Sean: Stillborn calves is a phenomenon, the dying of the cows is a phenomenon, and there is too much, yeah, okay.
7. Kayla: Yeah [nods]. (09.10. Episode 2)

In this episode, in turn line 1, Kayla interpreted the problem of including multiple phenomena, and negotiated how she should have chosen one phenomena. Then in line 3, she elaborated on how presenting multiple phenomena made it difficult for her to orchestrate the classroom talk. So, she reflected that it was difficult ("*I was messing you up*") for her to orchestrate classroom talk ("*now I am redirecting you to go after*") and make the students focus on parts of the explanation she wanted them to focus on. This episode represented Kayla's negotiation of what phenomena to choose to represent and how that selection impacted her

teaching discourse to orchestra and orient students to certain aspects of the explanation of the phenomenon.

Another example of the negotiation of the phenomena and the focus of the lesson occurred in Mark's second rehearsal debrief. In his lesson, Mark showed a YouTube video to show the effects of greenhouse gases, specifically carbon dioxide, on the temperature change. The following conversation was between Kayla, Erika, and the instructor.

1. Kayla: I don't know. I mean I liked the video. **You [to Mark] got us thinking about greenhouse gases and how there are gasses in the air that are somehow affecting the environment. I think it's really difficult to connect the dots.**
2. Sean: **Connect the dots to which?**
3. Kayla: **I think it's hard. This! We're college age kids and we're having problems with this.**
4. Sean: **Yeah.**
5. Erika: It is a hard concept overall to explain.
6. Kayla: **I almost think that you need to break it down even more.**
7. Sean: **Okay. So that's an interesting question. Right. One possibility of that is you could break down.**
8. Kayla: I don't know how to...
9. Sean: I don't know either off the top of my head, but that's okay. You don't have to have the answer immediately. **So, one possibility is we break down. Another piece is you might be able to focus it more on what you really want. So, some of the questions you [to Mark] asked when you pressed and probed could have focused more on the pieces of the explanation. Again, like "what's coming off the lamp, what's it doing? Is it passing through the bottle and how is that like the Earth?" But I tend to agree with you. The thing I want to point out is that this is true of everything. Right? (09. 24. Episode 17)**

In this episode, in line 1, Kayla highlighted that there was a problem with connecting concepts within the lesson and then in turn line 6, she negotiated that the teacher needed to break down the lesson more. Then in turn line 9 the instructor suggested another solution to that as through pressing and probing questions, with which teachers can focus on the parts of the explanation. Thus, TCs and the instructor attended to teachers' breaking the lesson/phenomena to more pieces and focusing on the parts of the explanation that the teacher wanted students to focus on by pressing and probing students towards that path. This episode represented how TCs

negotiated the problem of unclear tasks in the lesson and how it became difficult for students to see the connections in the lesson. Kayla identified and negotiated this problem from the student perspective as she had problems with moving forward in the lesson during the instruction.

Another example of negotiation of the explicitness of the phenomena came from the debrief of Abby's first rehearsal. In this episode, based on the instructor's prompt, TCs compared Kayla and Abby's teaching. The conversation was between Erika, Abby, and the instructor.

1. Sean: So, did you see differences between Kayla and Abby in terms of the way they interacted with the groups?
2. **Erika: I think Kayla pressed a little more, pressed, and probed.**
3. Sean: hm-hm.
4. Abby: [Nods]
5. **Erika: But then also it could have been because Kayla's original topic was more broad, so she had to focus us in more whereas like Abby said she heard us talking about good things so she didn't necessarily wanna stop the flow.**
6. Sean: Hm-hm, yeah, you [to Abby] were mostly silent, especially for the first five minutes or so, you [referring to Abby] were walking back and forth but you didn't really say anything.
7. Abby: Yeah.
8. **Sean: Whereas in Kayla, you [referring to Kayla] were doing more talking, that's something to think about in terms of I think Erika, at least I think what you [to Erika] are attributing that to is largely right which is that when you've got a task that is not well defined in the beginning, what you [referring to Kayla] end up doing in the group is defining the task, which is what you did. And from that you've learned. "Well I should have defined the task better at the beginning". And your task [referring to Abby] was a little more focused, and so there was less of that having to go back and forth saying, "no I really wanted to get at was this part."**
(09.10. Episode 16)

In this episode, in turn lines 2 and 5, Erika coded Kayla's pressing and probing students more compared to Abby's lesson in which she was mostly silent and did not interact much with the groups as she saw them generate explanations. Erika also interpreted the reason why Kayla had to press them more was due to her phenomena being broad in Kayla's lesson. Thus, Erika related the phenomena of the lesson and how it was set up as broad and how that affected Kayla's pressing and probing students' ideas. Thus, in this episode Erika associated the presentation of the phenomena in the lesson, and how the teachers needed to press and probe students to make it

more focused. So, she saw that to make the phenomena more focused in the lesson, the teacher uses specific questions to press students to help them make the phenomenon narrower. Then later in turn line 6 and 8, the instructor also agreed with Erika and further highlighted and interpreted the differences in Kayla and Abby's teachings. Thus in this episode, Erika saw the connections between the phenomena presented in the lesson and specific practices (pressing and probing) to make the phenomena and the task explicit for the students.

TCs negotiated the nature of the phenomenon through discussing its broadness and narrowness, its explicitness in the lesson, and the focus of the lesson. Choosing an actual phenomenon as an anchoring event to pose students as an explanatory problem and helping them generate explanations for that phenomenon is the central piece of ambitious science teaching. Thus, TCs' discussions of what a phenomenon was and its broadness or narrowness were especially important for their making sense of ambitious science teaching and differentiating it from the topic-based science teaching or mile-wide inch-deep curriculum implementation.

In their discussions of teaching, TCs were able to recognize if the focus of the lesson was not apparent or if the phenomena within the lesson was very broad and how those different ways of planning and presenting the lesson was problematic for students in understanding the focus of the lesson to make explanations. They were also able to offer ideas about what to do to make the focus of the lesson more apparent and explicit. The negotiations in this aspect occurred around what the phenomenon of the unit is and what is the focus of the individual lesson is. TCs were also able to compare different rehearsals and how different TCs' planning and enactment of the focus of the lesson was different.

Thus far, through the above classroom discourse events, I tried to illuminate one of the ways of negotiating phenomena and its explicitness in the lesson. The following type of

negotiation in Theme 3 was more related to the content storyline of the lesson and the set up and the presentation of the lesson.

Theme 3-Aspect 2:Content storyline, structure and set up in the lesson in relation to phenomena

TCs and the instructor negotiated the content storyline of the lesson, presentation and structure in the lesson through their discussions of teaching. They negotiated it through their discussions of how to set up and present the scenario in the lesson, how much deep science content to include in the lesson and what to include and exclude from the content storyline of the lesson in relation to the phenomenon. TCs developed lesson plans using a puzzling phenomenon for student to explain why that phenomenon (e.g. Cows dying in the fracking sites) occurs. In their discussions of teaching, they negotiated how to present and set up the scenario in relation to the phenomenon and what to include and exclude from the coherent content storyline of the lesson. The discourse regarding negotiations of content storyline, and the lesson set-up and presentation emerged during both rehearsal debriefs for multiple TCs' lessons.

The following episode represents an example of negotiation of the depth of science content to include in the lesson and comes from the debrief of Debbie's first rehearsal. Debbie's lesson was about how acid rain affected statues and their deformation. The conversation below was between Debbie and the instructor.

1. **Sean: I think one of the things that's interesting to think about when you look at these [other TCs' lesson] and yours [Debbie's] which is different than the others so far in that, at some point, you have to make a decision about how deep to go into the actual chemistry, like to go beyond just descriptive, like okay there is stuff in the atmosphere, it turns into acid, the acid comes down and interacts with stone in some way and like the acid breaks it down.**
2. Debbie: Right and
3. Sean: As opposed to
4. Debbie: Both groups definitely got to that.
5. **Sean: Right, but I do think that's the question is how hard do you push on them knowing like SO_2 and NO_x , like starting the actual chemical reaction and naming of the individual molecules involved in process and what that means. Ahm because**

these guys got to erosion and **that's one of the places I interrupted you and stepped in.**

6. Debbie: Yeah
7. **Sean: They started talking about erosion, and part of the reason, and this goes back to why writing that explanation is so important, because that's the thing you and I talked about when we met about this is one of the interesting things I think that I didn't think about with acid rain and probably didn't really understand is what is going on in is that there is a chemical process first that breaks the material into something that is soluble so that water can wash it away, like that's just a piece of the whole process that I'd just not thought about it. I was thinking of acid like corroding stuff, you pour it and it corrodes; that's not exactly what is happening. There is a chemical process that's breaking it into water soluble things, which is why it's washing away, and it is literally being eroded, but it can't be eroded before, because this stuff is not water soluble, so it can't just, so there is this mix of chemical and mechanical processes, that I think is really interesting.**
8. Debbie: I think something else too I don't know if would have helped, that we also talked about but I totally neglected was asking the difference or if there is a difference between the natural rain water and acidic rain water and I think that now I think about it, I would have maybe asked you guys that, I don't know if you would have said yes or no but, I think that, that may have led you into like what is making that acidic rain acidic. I was trying to get you guys to get gas in acid and creating the rain, but I thought that was interesting because I personally didn't know that like rain water itself is like actually pretty acidic, it is like 5.5. **(09.10 Episode 24)**

In this episode, between turn lines 1 to and 6 the instructor and Debbie negotiated how much deep chemistry content the teacher (should) push/press students to include instead of descriptive surface level explanation. So, they negotiated the depth of science content required to explain the phenomena. Then in turn line 7, the instructor reflected on his understanding of the mechanisms of how the acid rain really affects and breaks up the statues, emphasizing the importance of the gapless explanation to understand each detail of the explanation for the phenomenon. Then in turn line 8, Debbie highlighted some of the aspects of her lesson plan that she forgot to include during the lesson and negotiated whether or not those non-included parts, such as asking the difference between natural rain water and acidic rain water, could have helped students to come up with the explanation and deepen the chemistry content in their explanations. Thus, in this episode, Debbie and the instructor negotiated depth of content included in the lesson

and how the content storyline is presented to the students and how the forgotten parts of the content storyline could have impacted students' understanding and explanations.

Another example of the negotiation of broadness of the phenomena and how it is presented included below comes from the debrief of Debbie's first rehearsal. Prior to this episode they were talking about the think-pair-share strategy that Debbie used at the beginning of her lesson and at the beginning of this episode the instructor asked what they thought about the strategy to other TCs. The conversation was between Erika, Kayla, and Debbie, and the instructor.

1. Sean: How about the rest of you in terms of thinking prior to talking?
2. Erika: I liked it too because with Kayla and I, I could tell what I remembered obviously from the lesson I'll do. She brought like the erosion and then we brainstormed what the statue is made of, she came up with the CaCO_3 stuff, but, **definitely I thought this topic especially also it is like with Debbie and Bryan it is just going to be so different because it is like we are bio and they are the different ones** [she is referring to the students' backgrounds in the groups, Debbie and Bryan have chemistry and physics backgrounds]. **It was cool at the same time because we get to learn from them, but this topic I feel like it is a big topic, there is a lot goes into it, so** having us try to brainstorm by ourselves and then discuss it, it is nice.
3. Sean: **Right. Yeah, but in many respects this is tiny compared to if you look at Kayla's, right?**
4. Kayla: Well, I thought about that the whole time she had us do that in the beginning. If I would have done this, I think you all would have jumped in a lot faster, because you are bringing your initial thoughts written down.
5. Sean: **Ohh I see.**
6. Kayla: **There whereas you are sitting down and talking**
7. Erika: **Yeah, that's true, if you look at, you had presented the scenario and Abby presented the before, during, after with the ecosystem, but Debbie's is just, here's a picture, and how and why is this happening?**
8. Debbie: **Yeah, I didn't wanna say acid rain, I tried to avoid that.**
9. Erika: **Yeah, that's smart because we can come up on our own, but so this not, I mean it is not broad in terms of how it is presented.**
10. Debbie: **Yeah**
11. Erika: **So, I guess if you want to do more of a broad thing, maybe, do think-pair-share first and then discussion is smart way to do it.**
12. Sean: **Yeah, I guess, so you are differentiating sort of between how it is presented and how much content there is, right? So, Kayla and Debbie's presentation was both pretty broad in terms of what you can think about, so pedagogically broad, but what I was thinking of is in terms of the amount of content you have to understand Debbie's is much narrower than Kayla's.**
13. Erika: **Yeah. Definitely.**

14. **Sean: And even narrower than Abby's, right? I mean it is really pretty focused, you have to understand a little bit about acid-base chemistry, you have to know a few things about burning the fossil fuels; there is only five four things you need to understand but, even so, there is still, as you say, a lot to talk about even though it seems relatively simple on the surface, there is so much to think about and talk through. And Again, this is the thing you'll notice is when you pick these phenomena, how rich they can be even though superficially simple, right? (09.10. Episode 27)**

In this episode, in line 2, Erika interpreted that the phenomenon (she referred to it as topic) was big and she justified Debbie's use of the think-pair-share strategy as good to help students brainstorm ideas. Then in line 3, the instructor negotiated what Erika said about the phenomena (topic) being big with phenomena being narrower by saying "*this is tiny compared to like if you look at Kayla's*". Then in lines 4 and 6 Kayla reflected on her lesson and stated how she thought about changing the presentation of the phenomena and how that could have made a difference in students' orientation and talking about concepts in her lesson. Then in lines 7, 9, and 11 Erika compared how three TCs presented their scenarios and what type of structures (such as Abby used before, during, after structure) they used in presentation of the phenomena and how those structures made the presentation of the phenomena broad versus narrower. Then in lines 12 and 14, the instructor interpreted what Erika brought up in terms of the presentation of the phenomena in different lessons and how he was thinking about the depth of the science content that the students needed to explain the phenomena and how focused the phenomena was. Thus, in this episode, Erika and the instructor negotiated the science content required to explain the phenomena and the presentation and orientation of the phenomena that TCs set up for students. Therefore, they negotiated the set up and presentation of the phenomena with how much content was required to explain the phenomena in different representations of practice.

Another example of the negotiation of the relationship between the presented information and the content storyline of the lesson comes from the debrief of Mark's second rehearsal. Mark

taught effects of greenhouse gasses on the temperature change. The conversation was between Abby (A), Mark (M), and the instructor (S).

1. Abby: I do have one question.
2. Sean: Okay.
3. Abby: The combustion of methane. Does that release CO₂? Is that why you brought it up?
4. Mark: Yeah.
5. Sean: Yeah. You could have... Yeah, put that back up, Mark.
6. Abby: That was only up for like 30 seconds, and I was like, "Where does CO₂ fit?"
7. Sean: In fairness, that's true. It was a bit of a fast jump. But if you did this, you could have had the big burning thing. You could have said, "Well, what happens when you burn something?" The whole point of fracking is to get this stuff out of the ground so you can burn it, and "what happens when you burn something?" Now, they don't have to come up with this equation, but to some extent this equation distracted them from the point that you were trying to make, and that's evidenced by your [to Abby] now asking the question. Which is all that you really cared about, which is when you burn something, one of the byproducts of that is CO₂. Of all this mess that's up here, like, ultimately all you really cared about was that they understand that when you burn fossil fuels, one of the byproducts is carbon dioxide. Right?
8. Mark: Right.
9. Sean: So, I think this is sort of important piece too. That's why you burn it in the first place.
10. Mark: Yeah.
11. Sean: You want to power your lawnmower or your gas grill or whatever it is. You can't fire your gas grill if it's [inaudible]. So, another thing to think about when you're teaching a lesson is, what representations, what information are you giving kids? And to what to degree is the information that you're giving them distracting them from the point you're trying to make, right? So, you gave them all this, and they didn't really need it. So, what could you have given them that would have gotten them to where you wanted them to be, which is understanding that carbon dioxide is a byproduct of fossil fuel burning. That didn't necessarily involve this. Now if you really cared about this, like if you're in a chemistry class, and one of the things that you're really concerned about is that they understand exothermic reactions, then you might want to put the whole equation up with the energy and all of that. But you then talk about it. "Here's the equation for the combustion of methane. What do you see here?" "Well, you've got methane. It requires oxygen, which combustion does. Right?" Then you get these sort of typical byproducts. So, you could talk about general burning of stuff. And then methane is a particular example of that, and how you get it. Right?
12. Mark: Hm-hm. (09. 24. Episode 18)

In this episode, in lines 1, 3, and 6 Abby interpreted and questioned the reason why Mark put the formula of combustion of methane and its relationship to the lesson. Then, in lines 7, 9,

and 11, the instructor interpreted that using the equation of combustion of methane distracted students from the purpose of the lesson. And he offered suggestions of why he had to do it differently or what impacts he had when he did this way. In lines 8, 10, and 12, Mark agreed with the instructor's interpretation. Then in turn line 9, the instructor continued to interpret how Mark presented information and questioned the relation of the presented information to the phenomena through connecting Abby's questioning of the relationship of the formula to the lesson. Because Mark included the methane combustion chemical formula in the presentation of the information, the other TCs, as the students, were confused about how it is related to the phenomena of fossil burning and the effects of greenhouse gasses. In this episode, Abby and the instructor collectively negotiated the relationship of presented information to the phenomenon and coherent content storyline of the lesson. They negotiated it through Abby's coding of how the formula of the methane combustion fit into the content storyline of the lesson through her questioning of "*The combustion of methane. Does that release CO₂? Is that why you brought it up?*" and "*I was like, 'Where does CO₂ fit?'*" and through the instructor's interpretations in lines 7 and 11.

Another example of the negotiation of what to include and exclude from the content storyline comes from the debrief of Kayla's second rehearsal. In the second rehearsal, Kayla engaged students in making a model of the lungs and explaining how the air goes into the blood. During her lesson, she reflected that she rushed her lesson to go to the end of the lesson so that they can have a whole class discussion and presentation, but 20 min was up and she could not finish her lesson. The following conversation was between Kayla, Debbie, Erika, and the instructor.

1. Sean: So, what would you have done differently about the part of the lesson, since you feel like you rushed it? How would you have done that differently?
2. **Kayla: Well, a lot of the ideas that I thought they wouldn't get, like the air where the air is going. I thought that they wouldn't get that at first. Because, then I added an extra session where the air goes [referring to her introduction] and I feel like I would take that out of the script because they have those ideas, they really knew**

- what they were talking about. So I feel like, that could have been taken out, and then just gone [inaudible] through the section. I honestly think I should have just taken my time and not gotten completely through and that would have been fine too.
3. Sean: Yeah.
 4. **Debbie: I know at least for me not being bio and not really having a good sense of where the air went and all that; the beginning part for me was definitely necessary. So, to know like where the air was going. Because without Abby [Abby and Debbie were in the same group] I wouldn't have no idea where, I would have been clamored. So I kind of agree with and kind of disagree because if someone is not from a bio background, I wouldn't have known that.**
 5.
 6. **Kayla: I think that in my mind I was taking the big picture, I thought the respiratory system; let's connect it to big idea.**
 7. **Debbie: Because I saw the structure of how you set it up. It flowed really well. I just think it was too much that you had planned in too short of time.**
 8. **Kayla: Yeah.**
 9. **Debbie: That's all it was. I don't think, necessarily anything should have really been taken out, but I understand the reality of it.**
 10. **Erika: And obviously if it was a 50-minute period, and it would have been perfectly fine.**
 11. **Sean: Yeah**
 12. **Debbie: Yeah.**
 13. **Erika: Everything would have worked.**
 14. **Debbie: Yeah. Because I think it flowed really well the way you did it. I don't necessarily think you should have taken anything out. (09.26. Episode 10)**

Based on the instructor's prompt about what to do differently next time based on what she learned from the lesson, in turn line 2, Kayla interpreted taking out some parts of the content of the lesson based on the students' ideas she learned. Then in turn line 4, Debbie reflected and stated the necessity of some of the information that Kayla wanted to take out from the lesson, and Debbie thought that it was a necessary part for the students who do not have that biology background. Then, in turn lines 7, 9, and 14, Debbie interpreted the completeness of the content storyline of the lesson and suggested to Kayla that this lesson could have been good for an extended period of class time. Thus, in this episode, TCs negotiated what to include and exclude from the content storyline of the lesson based on the ideas they learned from the students and the experience they had as students.

Another example of the negotiation of presentation and set up of the phenomena comes from the debrief of Erika's first rehearsal. Erika taught about effects of fracking fluids on the ecosystem, specifically soil, plants and animals. The following conversation was between Erika, Bryan, Abby, and the instructor.

1. Sean: Yeah, other stuff, you noticed going back and forth?
2. Erika: **I probably should have made that more apparent in the beginning, because I don't think you can ever assume that everyone's interpretation is the same. They obviously were getting my message like from the get go, but these guys**
3. Sean: **Got a different message.**
4. Erika: **Yeah.**
5. Sean: **One of the things that I noticed in the beginning that you were doing that was related to the way you set it up. So, you had I think it was related to the way you set it up, you had the initial thing which is about the endangered species and the direct dumping of the fracking fluids.**
6. Erika: **Right and now looking back I probably should have had that be more of a thing of those by the fracking sites, because that threw people off.**
7. Bryan: **Yeah.**
8. Erika: **Because my main thing was that it is a phenomenon that comes from fracking is acid rain and you guys got that part, and then not only when acid rain is happening what will it make the water waste more acidic, but there is a lot of stuff so that's where I should have narrowed it more, there is an interaction between sulfuric acid and the soils and that releases aluminum ions which is what burns the fish gills, or the fish causing lesions and tumors, and gets into their organs, and so that's the thing. And that's why I originally thought I put aluminum on the board, but then I was like is that giving away too much, but then now looking back I don't even know, if you know I don't know this group was not. (09.12. Episode 22)**

In this episode, in turn line 2, Erika interpreted making the scenario clearer for the groups because groups have gone to different paths of thought for the explanation of the phenomena and she reflected that she should have made the scenario more apparent. Then in turn line 5, the instructor interpreted that the fact that the groups have gone to different paths was maybe because of her set-up and the presentation of the scenario as she included the endangered species and direct dumping of the fracking. Then in turn lines 6 and 8, Erika agreed with the instructor's interpretation and reflected that she should have made the phenomena narrower and made the scenario more explicit for the students. Thus, in this episode, Erika and the instructor negotiated

the set-up and the presentation of the phenomena in relation to what was included in the content storyline of the lesson. Thus, this episode showed the importance of the explicitness of the presentation of the phenomena in relation to students' explanation building.

The negotiation of content storyline involves what is included and excluded from the content storyline of the lesson, the pace for the content storyline, how it is presented and set up in the lesson and how much deep science content should be included in the content storyline of the lesson. Those negotiation points were crucial in the discussions of teaching for TCs' understanding of productive tasks that engage and move students in normative explanation building in addition to their understanding of how the decisions they made during the planning phase affect how they orient students in the explanation of the phenomena, especially at the beginning of the lesson. Thus, negotiating content storyline, set-up and presentation of information in relation to the depth of science included considerations for both in-discourse practices as well as planning practices of the ambitious science teaching practices. All TCs chose a phenomenon related to fracking and during planning sections in the course, as a class, they had discussions about how each TCs' unit built on to and fit into each other's in terms of content storyline. However, they did not have explicit guidelines or instruction for the content storyline within each lesson for their individual lessons.

Thus far, through the above classroom discourse events, I tried to illuminate ways of negotiating phenomena, its explicitness in the lesson, and content storyline, set-up and presentation of the storyline. The negotiations discussed in this theme related to planning stage including selecting the phenomena and selecting tasks and scenarios to present the phenomena and making the focus of the lesson apparent through discourse practices.

In this chapter, I investigated how science TCs negotiated meanings of ambitious science teaching in their discussions of teaching events during the first five weeks of the science teaching

methods course. Findings showed that TCs negotiated agency for defining and generating explanations and identifying science phenomena and how such phenomena fit into the content storyline of the lesson. Those various negotiations were manifested through multiple tensions and aspects within the described themes and, emerged and were observed as negotiations between TCs and the instructor, between TCs, and self-negotiations by TCs. In their discussions of teachings, they negotiated both in-discourse practices related to structuring classroom talk as well as planning practices regarding selecting the phenomena and structuring the content storyline. Through these negotiations TCs made sense of the science teaching practices. These negotiations are especially necessary for them to have a shared understanding of the observed and experienced teaching practices. In teacher education, it is widely discussed that there is no common language to discuss teaching practices. So, in that context, ambitious science teaching practices offer a common language but even this language needs to be negotiated to be understood and to be able to use to label the observed and experienced teaching practices. Especially novices need certain guidance and structure to decompose science teaching practices, and thus, ambitious science teaching practices provide both the practices as well as tools to make sense of these practices. The course instructor is at the same time a science education faculty facilitated TCs' making sense of discourse practices. He purposefully helped TCs negotiated the practices, but the analysis of how he facilitated TCs' negotiation will not be addressed in the dissertation but in the future papers. This data set represented how TCs negotiated those practices to make sense of them.

Discussion

Ambitious science teaching is a model of science teaching. During the science teaching methods course, TCs experience this model of teaching by trying out ambitious science teaching practices in their rehearsals, as well as analyzing video exemplars. These teaching practices are new to these TCs and they struggled and negotiated key aspects of ambitious science teaching practices through their discussions of teaching in the first five weeks of the methods course. I analyzed their discussions of teaching experiences and observations to address the question: how do teacher candidates negotiate meaning of ambitious science teaching when they engage in discussions in the first five weeks of methods course? My findings indicate that in their discussions of teaching, TCs negotiated the agency of who is responsible for generating the scientific explanations, what an explanation is, and what the nature of the relationship between the phenomena and the content storyline of the lesson.

Negotiating agency of creating explanations

In the current study, TCs negotiated with each other about who should be responsible for creating the scientific explanation through three tensions. Those tensions include differentiating pressing vs. evaluating students' ideas, differentiating pressing vs. leading students' ideas, and consideration of how to enter and exit and manage small groups. Those tensions provide important areas of focus for teacher educators to help TCs work on the ambitious practices over the traditional practices.

Sewell (1992) describes the relationship between structure and agency. Structure refers to the underlying principles that shape the patterns within social groups. The concept of structure

has been used in sociology to both explain and predict the actions of those within social groups. Sewell (1992) argues, “Structures shape people’s practices, but it is also people’s practices that constitute (and reproduce) structures. In this view of things, human agency and structure, far from being opposed, in fact presuppose each other” (p. 4). TCs negotiation around the agency of who is responsible for creating the scientific explanations contained three tensions. In this case, structures of the classroom discourse affects students’ agency while they are creating explanations and thus the norms and culture of the science classroom.

In the literature, various reform documents suggest that students should engage in scientific practices (NRC, 2007; NRC, 2012; Achieve, 2013). In science education literature, researchers call for teachers to engage students in science through “productive disciplinary engagement” by taking up “disciplinary authority” (Engle & Conant, 2002; Ford, 2008). Thus, it is important that TCs negotiated who is responsible for creating the scientific explanations because those negotiations initiate the problematization of traditional ways of teaching and promotes pivotal shifts in the way teachers see the disciplinary authority.

Stroupe (2014) also argues for instruction that enables disciplinary authority for students. Stroupe (2014) investigated how beginning teachers enacted ambitious science teaching in their classrooms. He specifically focused on how cognitive authority is distributed between teachers and students and whether science is framed as a “private” enterprise engaged in by individuals or is a “public” practice negotiated by a larger community. He compared teachers who enacted ambitious instruction and those who frequently engaged in conservative forms of teaching and looked at the ways in which science ideas were treated and by whom in their classrooms. Stroupe (2014) found that some of the teachers he followed actively promoted the stance of ambitious instruction that “students could and should take up the role of epistemic agents in classroom science rather than act as passive participants as their teacher determined the science work” (p.

513). He argues for students' roles as epistemic agents. The first negotiated theme in this data set is similar to Stroupe's finding that teachers who have an ambitious science teaching orientation provided environments where students can be the epistemic agents who participate in the practices of science.

The Stroupe study followed TCs who were in his methods course to their first year teaching, and his data focuses on the first year teachers' ambitious science instruction. He based his results on his observations of teacher's teaching and the interviews he made with them. In contrast, I looked at how TCs negotiate teaching practices in their discussions of teaching after they enacted the practices in their rehearsals as students and as teachers.

Carlone (2004) also attends to agency and identity of science students and how they are shaped and developed by the norms and practices of classrooms. She argues:

Structure and power relations within a community may encourage and/or inhibit access to legitimate participation for individuals ... the promoted science identities may not be socially available, achievable, or interesting to all participants. Thus, these alternative, 'inappropriate' identities may become marginalized within the community. (p. 396–397)

Similarly, Tan and Calabrese Barton (2007) have explored how teachers' behaviors and reactions impact the ways in which students see themselves in science and the identities they are able to envision for themselves. Tan and Calabrese Barton (2007) examined the experience of one sixth-grade student as she transforms from a marginalized student to an active and engaged participant. Their focus is on understanding agency. In introducing the study, they argue that students may have several ways of being, depending on the particular figured world in which they are immersed (e.g. small group discussion versus whole-class demonstration). They may even have a repertoire of identities which the authors call the student's 'science classroom identity kit' (p. 4). The kit may be expanded as the student tries on and acquires new identities that "have proven useful to her in increasing her agency in the science class" (p. 4). They propose:

New opportunities to participate in different ways also present themselves when a new topic that may interest the student is introduced, when a girl is partnered with a new small group from whom she can learn, or when the teacher assigns a project that allows the student to leverage on and showcase her unique skills and talents. (p. 4)

Their findings suggest there were ‘critical instances’ that transformed student’s participation. They also note the importance of discourse in allowing her to create new positions within the interactional surroundings. Carlone (2004) and Tan and Calabrese Barton’s (2007) studies are primarily with the K-12 students and their identities and agencies in science lessons and around equity issues.

The current study contributes to our understandings about how TCs’ develop their understandings of their impact on their students’ agency, specifically around who is responsible for creating explanations. My findings indicate TCs’ negotiations of agency represent on aspect of their visions for the teaching of science. Certain visions may lead TCs to set up environments for students create or expand their science identities. So, for example, teachers who have a vision grounded in ambitious science instruction may create environments for students to develop science identities or let students have active science authority and agency rather than passive engagement with science. More attention will be paid to this issue in the next chapter.

Pressing and its alternatives

Pressing student ideas is one of the most important teaching practices in the reform-based ambitious science teaching practices (Windschitl, Thompson, Braaten, & Stroupe, 2012). TCs were able to recognize pressing students’ ideas with different purposes. Even though they were successful in identifying and attending to the practice in the discussions of teaching, while they were enacting the practice they struggled in differentiating between pressing, evaluating and leading students’ ideas. Those struggles and tensions were salient when they were trying to make sense and negotiate the practices in their discussions. Prior research demonstrated that TCs do not

attend to the students' ideas in instruction (Mikeska et al., 2009; Davis et al., 2006) or have limited ideas about what to do with students' ideas during instruction (Zemba-Saul et al., 2000; Mikeska et al., 2009; Davis et al., 2006). TCs have been students of science and education for most of their lives, and their teaching experience is typically limited to their previous science teaching methods course in which they taught middle school students in two microteaching events and had a few peer teaching experiences. The findings in this study demonstrated that TCs do not have problems with attending or responding to the students' ideas, but they do have difficulties in terms of evaluating vs. pressing.

Teachers tend to teach in the way they were taught. Lortie (1975) explained the apprenticeship of observation as the effects of these extensive prior experiences in the classrooms and how these experiences led TCs to make assumptions about teaching and learning. One possible explanation for TCs need to negotiate differences between pressing vs. evaluating and pressing vs. leading students' ideas could be that in most of their classroom experience as students, either at the K-12 level or at the university level, the dominant type of discourse TCs experiences were with the Initiate-Response-Evaluate (IRE) structure (Cazden, 2001; Lemke, 1990). In this context, their ideas were evaluated by teachers or they saw the teacher lead students' ideas to specific answer and this acculturated TCs to evaluate and lead students' ideas in their own rehearsals. Because of the predominance of authoritative discourse in science classes (Lemke, 1990), science teachers are most familiar with that model of instruction. Even practicing teachers seem to have difficulty shifting from traditional forms of discussions even when using curriculum materials designed to support more student-centered talk (Alozie, Moje, & Krajcik, 2010; McNeill & Pimentel, 2010).

Negotiating what an explanation is

Another theme emerged was around defining an explanation. In their discussions of teaching TCs negotiated what an explanation is by addressing key aspects of explanations including: evidence-based explanations versus clarity of explanations, importance of gapless explanations, and levels of explanations. Among these negotiations, TCs took up pressing for the clarity of explanations, but pressing for the use of evidence in students' explanations, levels of explanations and the importance of gapless explanations were not taken up well by TCs.

Evidence-based explanations versus clarity of explanations

TCs gave limited attention to the importance of evidence in creating explanations and how they as teachers were pressing for the evidence use in helping students create explanations. The reason TCs might not have paid particular attention to evidence might have been the result of their experiences in the methods class. TCs engaged in developing a rehearsal lesson for the discourse 1 and discourse 2 practices. TCs mostly highlighted and coded those practices instead of the pressing for evidence-based explanations because at that point in the lesson they did not provide students explicit data or evidence to draw on. They were eliciting students' initial ideas based on their prior knowledge and experiences. Also, during rehearsals, the students were their peers and this may have contributed to a possible discomfort around pressing. That's why pressing for clarity or pressing to expand students' ideas were dominant practices discussed especially during the discourse 1 practice, eliciting students' ideas.

Another explanation of lack of pressing for evidence could be TCs had only one "making sense of material activity" lesson (D2) in which they prepared activities for students to help them engage in some sort of lab or hands-on activity. Also, most of those experiences that they did ask their peers to engage in were conceptual (such as PHeT simulation) and only one of them was based on explicit evidence or data (data sheets with acids levels and affected fish). So, the lack of

use of material activity maybe an important factor to support the development of evidence based explanations. Also, only Erika included actual data in her material activity to help students create evidence based explanations, and the discussion about evidence based explanations were limited because they did not have examples of representations of practice to refer to the evidence. The only discussion of evidence based explanation came up was during Erika's rehearsal discussion. The material activities can become the basis for discussion of teaching where reference to evidence is possible.

Pressing for evidence-based explanations is a difficult discourse practice for TCs. There have not been any studies that investigated how teachers negotiate pressing for evidence-based explanations. There are a few studies that found that elementary teachers did not focus on evidence-based explanations in their lesson plans and reflections. Plummer and Tanis Ozcelik (2015) investigated preservice elementary teachers' lessons plans and reflections for the coherent science inquiry investigations. They found preservice teachers missed opportunities to include sense-making practices involved in developing evidence-based explanations in their lessons or to discuss this aspect of inquiry in their reflections. They also found that some preservice teachers' lessons lacked explicit connection between their plans for their students to collect data and opportunities to construct explanations. They suggested curricula should provide explicit support for teachers in how to support students in moving from collecting data to using evidence purposefully in constructing an explanation.

There has also been research investigating how K-12 students used evidence or work with evidence (Manz, 2014; McNeill, Lizotte, Krajcik, & Marx, 2006; Sampson & Clark, 2009; Berland & Reiser, 2009; Sandoval & Millwood, 2005). Several studies have demonstrated that norms for discourse and argumentation in the classroom impact how evidence is considered and contested, and those norms are deeply embedded in classrooms' cultures and histories (Berland &

Reiser, 2011; Tang, 2010). Thus, teachers' pressing for evidence use in creating explanations influences how students use evidence and how the use of evidence becomes part of the culture of classroom practice in how students engage in science. Therefore, it is important that teachers consistently press their students for the use of evidence in creating explanations and make that practice a classroom norm. However, in order to engage in those practices and make those practices a classroom norm, TCs need to understand the importance of evidence use in creating explanations. The findings from this study show that negotiating evidence use in creating explanations is not enough to support evidence based explanation building. Only one of the TCs included data in her teaching, so negotiation of limited example of evidence use may not be enough for TCs to understand the importance of evidence use in science teaching. Thus, teacher educators should emphasize and problematize the use of data in science teaching and TCs' pressing for evidence use in creating explanations in the discussions of teaching before TCs go to the classrooms.

Importance of gapless explanations

Creating gapless explanations is an important part of ambitious science teaching practices and was expected for TCs to develop as a planning practice. It is a foundational part of the process necessary to be able to help students develop evidence-based explanations and structure the classroom discourse. TCs wrote gapless explanations for the phenomena they taught, but in their discussions of teaching they did not pay attention to the importance of the gapless explanation and they did not seem to connect their own gapless explanation to the explanation they want their students to create. The importance of gapless explanations and being able to press students' ideas because of having the complete gapless explanation was negotiated between TCs and the instructor. Being able to develop a complete gapless explanation was important in terms of how the teachers structure or orchestrate the classroom discourse including deciding on the

questions they ask during their planning as well as phrasing the questions in the moment of teaching.

Being able to create complete gapless explanation could be related to TCs' content knowledge for the phenomena they are trying to explain. Prior research demonstrated that secondary teachers' subject matter knowledge impacts their questions and questioning skills (Carlsen, 1991; 1992) and elementary teacher's content knowledge is correlated with how successful they are able to engage in inquiry teaching (Luera, Moyer, & Everett, 2005; Plummer & Tanis Ozcelik, 2015). Carlsen (1991; 1992) showed that teachers with inadequate subject matter knowledge control classroom conversations by privileging facts rather than treating concepts in a dialogic and interactive approach. When the topics are less familiar, teachers generally stayed closer to the textbook representations by orally reproducing what was written as science. They were also more likely to ask factual, rather than provocative questions.

In his later study, Carlsen (1993) investigated four secondary biology preservice teachers and found that when the teachers' knowledge was low for the topics they taught, the teachers frequently asked students low cognitive level questions. When their knowledge was greater for the topics they taught, however, they asked more demanding questions and gave students more opportunities to speak. My results indicate the way TCs and the instructor negotiated gapless explanation and how well they were able to press and probe students' ideas was impacted if they did not have a complete gapless explanation. TCs came to a consensus that if they did not have the complete gapless explanation, it was difficult for them to press, probe and leverage students' ideas. Thus, current study showed that TCs negotiated once they have more of the gapless explanation, thus more content knowledge about what they are teaching, they were able to structure the classroom talk and respond better to students' ideas.

Negotiating what phenomenon is

The last theme that emerged from the data was around the negotiation of what counted as a phenomenon in the lesson. TCs negotiated what phenomena are in two ways; one was through making the focus of the lesson apparent and explicit to students and the other one was through the content storyline of the lesson and its presentation and structure in relation to the phenomena.

Phenomena-based instruction requires teachers to organize and plan instruction around observable phenomena instead of science topics, and thus calls for planning of instruction focused on explaining a phenomenon using science ideas and answering scientific questions.

Apparent and explicit focus in the lesson

In their discussions of teaching, TCs and the instructor negotiated the focus of the lesson in relation to the phenomena. Since planning and enacting instruction using phenomena is a new and different practice for TCs, TCs ended up using broad phenomena or not focused phenomena, thus causing students to be confused with what the task or the question is in the lesson. Thus, TCs ended up pressing or probing students' ideas more to help them focus on the part of the phenomena they wanted students to explain. Choosing the phenomena, mapping out the lesson and deciding on the focus of each lesson are crucial to help students develop explanations during the enactment of the rehearsals.

Content storyline of the lesson and its presentation and structure in relation to the phenomena

In their discussions of teaching, TCs tend to be reflective and critical about the set up and presentation of the lesson as well the content storyline of the lesson in relation to phenomena. TCs developed lesson plans using a puzzling phenomenon for student to explain why that phenomenon happens. They also discussed how the relation should be or could have been improved based on their experiences as students and as teachers in the rehearsals. They discussed

how the concepts introduced to them as students should be structured within the content storyline. They questioned the necessity of some of the concepts fitting in the presented content storyline of the lesson. In their discussions of teaching, they negotiated how to present and set up the scenario in relation to the phenomenon and what to include and exclude in the lesson in relation the coherent content storyline of the lesson. Those negotiations happened mostly between TCs. They were able to question those ideas without much instructor input. That indicates those concepts are well taken up by TCs.

Research in science education shows that U.S. science classroom instruction has the characteristics of disconnected, hands-on, science activities compared to the other countries (Roth & Garnier, 2006). Researchers suggest organizing instruction using a coherent science content storyline (Roth & Garnier, 2006; Roth et al., 2011) to move away from discrete science activities and toward instruction other that promotes coherent science learning through selecting and sequencing science ideas building on each. In this data set, TCs' conversations also included how some of the concepts fit together and which concepts should be included or excluded from the developed storyline of the lesson. Similarly, Plummer and Tanis Ozcelik (2015) investigated how preservice elementary teachers develop coherent science investigations to engage students in the connections between questions, evidence, and explanations. They looked at preservice teachers' five consecutive lesson plans and investigated the coherence between questions, evidence, and explanations in those five lesson plans. They found while some of the lesson plans included coherence among questions, evidence, and explanations spanning over five days of instruction, others included coherence among questions, evidence, and explanations in less than five days of instruction around one science phenomena. They argue that preservice teachers are beginning to consider developing coherent investigations that engage students deeply with a single phenomenon over time rather than a more fragmented approach of hands-on activities.

In this study, the way TCs negotiated the content storyline of the lesson and its relation to phenomena included their considerations of what science ideas should be included or excluded in one lesson as opposed to multiple lessons or a unit of instruction. During their planning sections, TCs and the instructor had conversations about how each TC's unit plans fits into each other's unit plans in terms of the connectivity, but they did not have conversations about planning coherent sequence of learning opportunities in individual units over time.

Negotiation of the contextual nature, and goals or purposes of the questions could be an overarching discussion point across the all negotiations described in the three themes. We can see that discussion of how to phrase pressing questions or how to ask right questions to press, and discussion of the difference between leading versus pressing questions in theme 1 could be related to negotiating the goals and purposes of the questions. Discussion of phrasing questions for the levels of explanations in theme 2 is related to goals of the questions. Discussion of how to phrase the questions to make the phenomena more focused and explicit in theme 3 is also related to the goals of the questions. Negotiation of contextual nature of questions included phrasing questions better to adjust to other student levels and phrasing questions differently based on where (when) in the lesson (such as review questions or guess my head questions) the questions are being asked. TCs and the instructor negotiated the contextual nature of questions depending on when in the lesson and to what level students they were asked.

In this chapter, I discussed how TCs negotiated ambitious science teaching practices. My findings showed that TCs negotiated the agency of who is responsible for generating the scientific explanations, what an explanation is, and what the nature of the relationship between the phenomena and the content storyline of the lesson. The next chapter will analyze how TCs develop professional pedagogical vision in their discussion of teaching during the first five weeks of the methods course.

Chapter 5

DEVELOPMENT of PROFESSIONAL PEDAGOGICAL VISION

In this chapter I present findings for my second research question: How does the professional pedagogical vision (PPV) of science teacher candidates develop around ambitious science teaching practices in a semester-long secondary science teaching methods course? And how do science teacher candidates highlight and code in their discussions of teaching and what material representations do they produce?

Goodwin identifies professional vision as a “socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (p. 606). He proposed three practices for professional vision: *Coding schemes* are labeling or interpreting. *Highlighting* is marking and or emphasizing certain parts of instruction, and *the production and articulation of material representations*. This chapter presents four claims in answer to the research question. The chapter is organized around these claims and associated episodes as evidence followed by a discussion section at the end of the chapter.

Claim 1

TCs initially identified a small set of important practices and over time identified additional practices, as well as becoming more sophisticated about all of the practices, thus develop a professional pedagogical vision increasingly aligned with ambitious science teaching.

As the semester progressed TCs move from less sophisticated ideas to more sophisticated ideas about teaching practices. They progressed to more sophisticated practices but they also got

more sophisticated about the practices they identified at the beginning. Tables 5.1, 5.2, and 5.3 show practices and talk moves identified by the TCs along with total number of episodes for each practice and what percentage of those practices emerged at the beginning of the data. I considered the initial ideas as the practices they identified when they observed Bethany's practice in the first four classes of the methods class. Thus, the percentage of practices is organized around how many of the total number of practices emerged in the first four classes. So, for example, total # of episodes about *pressing* practices are 76 and of those 76, 15 of them (thus, 20%) were identified in the first four classes when they were looking at Bethany's practice and rest were identified later in the semester.

TCs initially identified the following practices from analysis of Bethany's examples: *putting students in groups, establishing a safe environment for students to put ideas out and talk, putting ideas on hold, probing, not evaluating but questioning, guiding and leading*. TCs identified these practices early in the semester, and the practice they identified evolved over the course of the semester (see Table 5-1). In the table, I represent some practices with single code and others with sub-codes. The purpose of that differentiation is based on how TCs talked about those practices during their discussions of teaching. For example, TCs talked about different ways of *establishing a safe environment for students to put ideas out and talk*. One of those ways is to *ask students make predictions*; another one that TCs thought is *asking students to externalize their ideas through drawing*. So, TCs attributed those different ways or practices to establish a safe environment for student to put ideas out and talk. Another example that included sub-codes includes *probing* code. TCs attributed different purposes or ways that a teacher can probe students' ideas. One of the purposes of probing students' ideas that TCs brought up is to *help students make connections to prior knowledge*. While those two codes included sub-codes, other codes did not include sub-codes.

Table 5-1: Early Professional Pedagogical Vision Ideas.

Codes⁴	Sub-codes⁴
Putting Students in Groups (3/3) %100	
Establishing a safe environment for students to put ideas out and talk (4/4)%100	Ask them to make prediction (1)
	Ask them to externalize their ideas (drawing)(1)
	Put them in the groups (2)
	Not evaluate their ideas (2)
	Question their ideas instead of evaluating (1)
	Put students in the groups and let them ask questions to and disagree each other. (1)
Putting students' ideas on hold (2/2) %100	
Probing (10/12) %83	General probing (2/3)
	Pro1: Probing to help make the connections to prior knowledge. (5/5)
	Pro2: Probing students to get more ideas from them, probing to get deeper ideas (1/1)
	Pro3: How to do probing, and choosing phrases, words to use when probing (1/1)
	Pro4: Probing students on to say scientific terms instead of everyday language (1)
	Pro5: Concern with Probing students who say "I don't know". (1/1)
Phenomena Create Student interest (student attention) (5/6)%83	
Not evaluating but questioning, guiding and leading (7/9)%78	
Authentic/Real phenomena (6/8) %75	Be real thing, Connecting to real life example and students' daily experiences, relatedness (4/5)
	Challenging to talk or not challenging to talk (authenticity)/provide context for science talk (2/3)
Negotiation of labeling students' ideas as misconception, wrong ideas, alternative ideas, partial understandings, and productive ideas (8/11) %73	
Norms in Small Groups: Evaluating/giving feedback, Disagreeing and questioning, Contributing to each other's ideas in the Small Groups (2/3) %67	
Use of Think/Pair/Share Strategy (4/8) %50	
Parking lot (1/2) %50	

⁴ The numbers in the parenthesis show the total number of episodes for each practice and what percentage of those practices emerged at the beginning of the data when they were looking at Bethany's practice.

They also started to identify more sophisticated practices such as *pressing*, *revoicing*, *eliciting hypothesis*, *working with student's ideas*, but the majority of those practices were identified later in the semester (see Table 5-2). For example, TCs identified 40% of *eliciting students' hypothesis* instances during the first classes and rest are spread over the remainder of the semester. Again, among the codes in the table some include sub-codes. For example, TCs' identified *revoicing students' ideas* with different purposes or ways of revoicing. TCs identified only one episode of *general revoicing* without attributing to any purpose to revoicing ideas and other episodes about *revoicing ideas instead of evaluating ideas* early in the semester. So, there are only two episodes related to revoicing identified early in the semester, the rest of the revoicing students' ideas were identified later in the semester.

Table 5-2: Developing Professional Pedagogical Vision Ideas (that started early in the semester but most of them developed as the semester progressed).

Codes⁴	Sub-codes⁴
Eliciting hypothesis (2/5) %40	
Prior Knowledge (6/15)%40	Levels and types of prior knowledge and how to work with different levels of prior knowledge (1/6)
	Using prior knowledge to make explanation and required prior knowledge (3/4)
	Student's statues of prior knowledge (2/3)
	Scaffolding Students' Prior knowledge (2)
Revoicing (2/6)%33	General Revoicing (1/2)
	Rev1: Revoicing ideas instead of evaluating ideas (1/1)
	Rev2: Revoicing to put students' ideas on better track (1)
	Rev3: Rephrasing with Questions (1)
	Rev4: Revoicing to recognize ideas (1)
Working with Student Ideas (3/11) %27	Taking ideas in students' explanation and (or not being able to) building on them in the lesson (1/6)
	Teachers' use of language and working with students' language and their choice of words (3)

	Responding to the wrong ideas (2/2)
Pressing (15/76) %20	General pressing (2/8)
	P1: Pressing for clarity on the word meaning (2/7)
	P2: Pressing for expanding the idea students have. (Elaboration)(2/7)
	P3: Adjusting pressing questions for different student levels (2)
	P4: Pressing for explanation or reasoning (3/16)
	P5: Pressing to create external representations of the idea (3/7)
	P6: Importance of asking right/better question to press: (2/5)
	P7: Pressing for the gapless explanation and Importance of gapless explanation. (1/12)
	P8: Pressing to make the phenomena more focused. (12)
Summarizing (1/6) %17	
Balancing Talk time in and between groups, and How much to stay in the groups (2/12) %17	
Scaffolding for the explanation (2/14) %14	Cueing, giving hints and when to give hints (2/4)
	Using aids/structures [such as, before, during and after] to connect pieces of the whole phenomena (5)
	Asking students to use representations to show the connections in explaining the phenomena. (1)
	Providing data helps students make the connections in creating explanations for the phenomena (3)
	The ways the teachers ask questions help students connect the concepts. (1)
Evaluating (3/24) %13	E1: Saying "okays": saying okay instead of pressing and saying okay to wrong things (3)
	E2: Tacit/implicit feedback (Facial/ body expressions): head motion, stepping back (2/5)
	E3: Evaluating using declarative statements and Positive encouragement (9)
	E4: Redirecting students' ideas using declarative statements [such as "try not to think about that"] (6)
	E5: Evaluating and then Guiding: This is not just evaluating and leaving, but proposing kids to work on something else. (1/1)
Entering and Exiting Groups (1/15) %7	Fading in and out-non-noticeable (2)
	Not interrupting- Lurked (observing), and Just listening, Not evaluating (4)
	Questioning vs. not questioning (3)
	Entering and Leaving groups-noticeably (1)

	Student/group autonomous and dependency to the teacher (1/2)
	How teacher leaves the group and how the group make changes in their understanding (1)

Some of the potential candidate practices only came up later in the semester during the rehearsal discussions, but not during the negotiations of Bethany's practice at the beginning. In Table 5-3 you can see that those practices did not come up early in the semester. These practices included: *eliciting observations in relation to the phenomena, differences in groups understanding of the phenomena and teachers' efforts to work with one group more over the other one, formative assessment and use of the results of formative assessment in instruction, negotiation of the storyline and its presentation.*

Table 5-3: Sophisticated Professional Pedagogical Vision ideas that are only discussed during the rehearsals later in the semester.

Codes ⁴
Eliciting observations in relation to the phenomena (2) %0
Negotiation of the contextual nature and goals of the questions: (7) %0
Differences in groups understanding of the phenomena and teachers' efforts to work with one group more over the other one. (4) %0
Formative Assessment and Use of the Results of Formative Assessment in Instruction (Walking around for formative assessment, not to caught up off guard) (8) %0
Bringing groups together and putting ideas together, connecting different ideas (5) %0
Negotiation of the Storyline and Its presentation (13) %0
Expected/Unexpected Student Ideas (Prior knowledge) (5) %0
Narrow vs Broad-Making the phenomena narrower or clearer, breaking it apart (12) %0
Making the focus of the lesson apparent (15) %0
Connection between the material activity and the larger phenomena (3) %0

TCs' professional pedagogical vision increased in sophistication not only by an increase in the number and type of the practices as the semester progressed but also through the meaning

and purposes that TCs developed for those practices. So, for example, TCs identified pressing practice or revoicing practices early on, but as the semester progressed they identified pressing for explanations or pressing to make the phenomena more focused or revoicing to recognize students' ideas. So, they developed a better sense of purpose and meaning for those practices over the five weeks of the course. This finding is also related to the second claim about the multi-temporality of professional vision. I give example episodes during the second claim to make purposes of practices more clear.

Claim 2

TCs develop professional pedagogical vision through in-the-moment and over-time negotiations of the teaching practices in their discussions of teaching events. This is manifested in the negotiation of highlighting and negotiation of coding practices.

When TCs negotiate the practices at the beginning, those negotiations may include negotiation of highlighting of the practice. Over time, the negotiations of teaching practices may turn into the negotiation of the coding schemes including the purposes and meanings of those highlighted practices. This claim is related to part of claim 1 as well in terms of how practices are negotiated over time and the way purposes and meanings of those practices are developed as the semester progressed.

The following episode is from the first day of class and represents their early professional pedagogical vision and their negotiation of highlighting practices. This episode is an example of one of the types of probing (Pro 1) practice represented in Table 5-1. TCs individually engaged in analyzing model teacher Bethany's teaching in Studiocode. Their task was to analyze her teaching for "good science teaching". Then,

after their analysis, the instructor asked them what they were looking for as good science teaching in their analysis. Each TC provided their coding schemes. The conversation below was between Kayla (K), Abby (A) and the instructor (S).

1. S: When you look at good teaching, what are you looking for in science teaching?
....
2. K: [inaudible] **she tried to give them, incorporated what they already knew in the explanation.**
3. S: Okay, **when you say what they already knew, what do you mean?**
4. K: They already learned that gasses expand or the gasses have molecules.
5. S: Ahh!
6. K: So, **she prompted them.**
7. S: So, **she prompts them to remember things that she taught them previously or they learned somehow**, we don't know for sure. (08.27. Episode 3)
8. A: At one point, at one point, **she connected what they were trying draw in poster to lab previously.**
9. S: Okay, so she made an explicit reference to some of the labs they have done in the past, **so you thought that was good to make connections across.**
10. A: Yeah, because she was like, what about the balloon thing we did last week? (08.27. Episode 4)

In the above episodes, Kayla coded teacher's asking students to incorporate previous experiences as good science teaching [line 2]. Then, the instructor asked what she meant by what they knew [line 3] and Kayla highlighted specific previous knowledge the teacher drew from the students [line 4]. Then, she coded that teacher prompted students [line 6] and then the instructor revoiced what Kayla said. Then Abby coded a specific instance of when the teacher asked students to incorporate a lab they made previously and she highlighted the balloon experiment [line 8]. Abby's highlighting that specific instance supports Kayla's coding schemes and provides another point in the instruction that Bethany asked students to incorporate previous experience and both of those moments were highlighted and coded by the TCs.

In this episode, TCs highlighted and coded what Bethany asked and what she tried to incorporate in students' ideas. So early in the semester, TCs highlighted and coded the practice of probing to connect students' prior knowledge and experiences and they negotiated that highlighting and coding through giving similar example instances from Bethany's teaching to develop an agreement on the coding. So, there were agreements in the way they saw the practice, thus about initial aspects of professional pedagogical vision.

The following example episodes include multiple developing professional pedagogical vision ideas that TCs negotiated through highlighting and coding. Some of the ideas negotiated in this episode is represented in Table 5-2 include scaffolding for the explanation, working with students' ideas and types of evaluating. The conversation was on the fourth day of the class after TCs observed an instance of Bethany's teaching. On this day, the classroom members observed Bethany's first day of instruction to look at the details of how she elicited ideas from her students. The conversation was among Abby (A), Debbie (D), Kayla (K), Erika (E), Bryan (B) and the instructor (S). The conversation was long so, I divide it into two episodes.

1. S: She did a bunch there. What did you see there?
2. A: **She gave the students a piece of information that seemed to be missing.**
3. S: Which was?
4. A: The assumption **that the tanker is sealed.**
5. S: Yeah.
6. A: The students thought there was a little bit of flow in and out.
7. S: So, you could get this tornado that comes in through the valve, or, yeah
8. E: Right, and she talked about; she said **"remember it was overnight that it happened"**
9. S: Right, **so she cues them to this little thing they are not paying attention to that she knows is really important.** (09.05. Episode 6)

In this episode, they observed a video instance and then the instructor asked what they saw [line 1]. Abby highlighted that the teacher gave students a piece of information

they were missing [line 2], then the instructor asked what is that missing information and then Abby highlighted the assumption that the tanker is sealed through restating what the teacher said [line 4] and then she interpreted students' ideas that they think there is flow in and out [line 6]. Then, Erika highlighted another piece of information the teacher told students [line 8], so the fact Erika highlighted another piece of information that was very similar to Abby's piece showed that Erika agreed with Abby's identification and brought similar evidence from the teacher. Then the instructor agreed with Erika and interpreted that the teacher cued students to the things they were missing [line 9].

- 10. D: She also lets them fully say their tornado idea, and then picks out the word 'steam' to lead them down the right path. She says, "okay okay, okay" then she listens for that key word.**
11. S: Right.
- 12. D: That could lead them, without saying "no, that has nothing to do with tornadoes, you are dead wrong."**
13. S: Yeah.
14. D: She allows them to kind a, you know, steer them.
15. S: Yeah, no I think you are right, I mean I think that's.
16. D: She had to **have said steam at least three times and**
- 17. E: And molecules.**
18. D: Yeah, they [referring to the students in the video] had said tornado
19. E: Steam and molecules.
- 20. D: Yeah, they had said tornado like four times, and she just like never said tornado.**
- 21. S: So, she never says tornado.**
22. D: No.
23. S: **She says steam, she says molecules, she says movement.**
24. D: Right.
25. E: Hm-hmm.
26. S: Right. She does.
- 27. D: [Inaudible] key word to say in their explanation.**
28. S: There is stuff moving, you are right, there is stuff moving in there,
29. D: Yeah.
30. S: So, explain what is moving and how it is moving, ohh and it is steam and like there might be some air in there, right.
31. E: Yeah.
- 32. S: So, she is very careful, that's right, she is very careful to**
33. D: Key words
34. S: Yeah,
35. D: [inaudible]

36. S: But like you [referring to Debbie] said, let them explain it, not tell them that's the craziest thing I have ever heard like a mini tornado inside the tank.
37. D: And she is like calm and
38. E: Yeah, calm and doesn't laugh
39. S: Right, Doesn't laugh, doesn't smile.
40. E: Yeah.
41. S: Doesn't shake her head, like what on earth like, none of that stuff. (09.05. Episode 7)

Then, Debbie coded teachers' listening students' ideas and carefully choosing key words in their explanations to further their thinking without evaluating their ideas [line 10 and 12]. Then, she highlighted which words Bethany chose to use and which words she ignored in their ideas [lines 16, 18, 20]. Then, there are back and forth complementary conversations about what the teacher chose to use and ignored, so they negotiated highlighting practice [lines 16-36]. Then Debbie, Erika and the instructor highlighted teacher's body language for being calm and not giving feedback and then the instructor codes that the teacher did not give implicit feedback for students' tornado idea [lines 37-41]. Thus, in these episodes, TCs and the instructor had multiple interwoven in-the-moment negotiated coding and highlighting practices.

The following episode represents sophisticated and developing ideas about professional vision and the constant negotiation of the coding practices for the highlighted material activity. In this episode, the practice represented from Table 5.2 includes scaffolding students' explanation through providing data and other practices represented from Table 5.3 include connection between the material activity and phenomena, making the focus of the lesson apparent and making the phenomena narrower. The conversation was between Debbie, Bryan, Abby and Kayla and they are talking about Erika's second rehearsal. Erika's phenomenon was the effects of acid rains on the ecosystems specifically soil, plants and animals (fish). This episode shows how those patterns of talk are a negotiated process later in the semester. I divided the conversation into two sections.

1. D: **I think that the fact that you picked the three main components that really factors into the whole phenomenon was good. You really narrowed us in right off the bat with our top question.** And then also the fact that you broke it down into that group is fish, and we are plant and soil, **it allowed us to be more focused on like a specific topic.** Rather than saying, “Ok, tell me or role-play all three of these.” So we really could hone in on the one. We were a group of three, so it was easy for us do soil, and plant, and [inaudible] fish. But I think that was good. It **allowed us to be more focused**, and get more into what we act like our role-play.
2. B: I thought it was a pretty creative. It was a [inaudible] demonstrations of everything. **It got groups to talk.** It was creative. I thought it was good. **And I really think you see the big picture better when you see how fish are affected, how plants are affected.**

In the above episodes, Debbie highlighted the material activity Erika used and coded that it helped them narrow the phenomena and made it more focused [line 1]. Then Bryan agreed and coded that the activity helped them connect it to larger phenomena and helped them see the connections between how the specific organisms are affected [line 2].

3. D: I think **the papers [referring to data sheets Erika provided] helped, too.**
4. B: Yeah.
5. D: Because it [referring to data sheets] allowed us to, it didn't give us, like you said, the answers. But **we were able to get more detailed information out of them.** You guys would not have probably been able to say, “ph of 4-point” whatever affects the fish. So, I think it would have been a lot harder without those aids in the groups.
6. A: Primary resources.
7. D: What?
8. A: Primary resources.
9. D: Primary resources. Yeah, okay.
[Laughter]
10. K: **I liked her case study because I had trouble when Erika first started connecting how acid would truly affect the environment.** Ours kind of broke down each lowering of the acid on the [inaudible] and how it affected [inaudible] fish. **So, I could see it better, and I could see what it was doing.** Kind of like if there's more acid rain, what would it do. How it could be causing these massive fish kills.
11. S: Mm-hmm.
12. K: I definitely could see it better. (09. 24. Episode 11, 12 and 13)

Then Debbie highlighted the data Erika used and coded that those papers helped them get more detailed information [lines 3 and 5]. Then Kayla agreed and she coded that case studies helped her see the connections between how acid levels can affect the organisms and environment [line 10 and 12]. In their descriptions, they use “papers”, “primary resources” or “case study” to describe the data Erika gave them. During the lesson, Erika introduce those data as case studies, so they kept the same language, but what those case studies showed was some data for soil, plants and fish and how they are affected by the acid levels.

So, in these episodes, TCs highlighted and coded the material activity and the case studies Erika used in the material activity and how the activity helped students narrow and made the phenomena more focused at the same time, give evidence for their explanation and helped them connect it to the phenomena. TCs negotiated coding schemes and provided more sophisticated ideas about the professional pedagogical vision and came to an agreement on how those data helped them in their explanation process as students.

The following episodes represent how TCs negotiate developing and sophisticated practices; in this case Kayla negotiates how to phrase pressing questions and pressing to make the phenomena more focused. This episode also represents how those practices are negotiated over time during the semester. The practices negotiated in these episodes are included in Table 5.2 as p6: importance of asking right/better question to press, p8: pressing to make the phenomena more focused and summarizing codes and in Table 5.3 as making the phenomena narrower and making the focus of the lesson apparent codes. The conversation was about Kayla’s first rehearsal and between Kayla (K) and the instructor (S). This is on the day they analyzed their own rehearsals for the discourse 1 sub-practices. The conversation is divided into three sections.

1. K: **I don’t think I asked the correct manner of questions.**
2. S: What does that mean?
3. K: Like, there is one point where you guys [referring to groups] had gotten to the alveoli exchange of oxygen within the blood system. **I should have**

asked more almost broader questions like, "okay, so what might be going on here?" Instead I almost backtracked you, and then eventually I got you to where you needed to be, but I don't think I was asking good, correct [questions], I don't know how to explain that.

4. S: Do you mind if we look at your video?
[There is talk about where in the video analysis she identified those instances.]
[The instructor shows the video on the smart board]
5. S: Okay, do you wanna see all this whole cluster, or are there, so you've got two pressing for explanations with summarizing before it, and then another almost the same pattern, summarizing and then pressing.
6. **K: I think what I did with it is summarize and then I try to press them but I asked the wrong questions to press them.**
7. S: Okay, so you wanna look at them?
8. K: Yeah. (09.17. Episode 7)

Before this instance the classroom community was talking about what they noticed in their analysis of their own rehearsals. Erika talked about how she summarized and highlighted that she remembered Kayla was summarizing too. Then in line 1, Kayla coded that she did not ask correct questions and then instructor pressed her to explain what she meant. Then, in line 3, she highlighted a specific instance where she was working with Debbie and Abby and she coded that she should have asked broad questions. Then, in line 4, the instructor asked if they could look at the video. Then, they found the instances in the Studiocode that Kayla coded as summarizing and then pressing. The instructor read her coding on the Studiocode [line 5] and Kayla coded what she did [line 6].

- [They watched video of Kayla's teaching]
9. K: Is that, I feel like they had the diagram and they, **I just feel like I could have phrased it better for you guys.**
 10. A: You gave us four questions in [inaudible] succession
 11. K: I didn't know,
 12. **S: You were trying to narrow down, but you were sort of doing it out loud is what you are saying?**
 13. **K: Yeah,**
 14. S: So, you were sort of saying I know I want to ask a question here but I don't know exactly what the question is.
 15. K: What to ask to get [inaudible]

16. S: **So, you ended up with broad questions. So, well, two things about that, one is that's a nice way to think about why back pocket questions can be so useful.**
17. K: hmhm
18. S: But also then **let's just think about what you could have asked, did everybody hear that well enough to understand what is going on at this point? I mean you've experienced the lesson, so you have some sense of, so basically at this point they are talking about that the toxins are in the blood stream, right?**
19. K: They are talking about the air has come into the respiratory system and that I think we had already talked at this point that it's what, I think, I already asked like "what are you trying to get when you breathe in air", and they were like oxygen and so we kinda lead to "okay where does oxygen go?", and then I feel like I backtracked them, and eventually we got, "okay, it goes into the blood" and that's what was going on.
20. S: Okay, so at this point, you've got them thinking about, well, the purpose of breathing is to get the oxygen into the bloodstream, but then all this other stuff is coming into the lungs at the same time and what is happening? is what you are trying to get at.
21. K: Hm-hm
22. S: And then, so you've asked them what is going on, basically, right? [They watched the same video again]

Then they observed the instances. Between lines 9 and 16, TCs and the instructor negotiated what Kayla was identifying as problem through describing what Kayla did and how she is identifying the problem of practice with pressing questions. Then, in line 16, the instructor coded the importance of back-pocket questions as a suggestion to the problem of asking wrong pressing questions. Then in line 18, the instructor problematized the situation and asked TCs what Kayla can do and if the TCs understand what the problem is. Then lines between 19 and 22, they collectively highlighted and coded what the students were talking about and what Kayla asked them.

23. S: **Okay so yeah, let's think about the way she is asking that, so how she could ask that better? Because I agree there is a problem here.**
24. K: Yeah
25. S: And I am agreeing with you. You could tell because you are reading the situation very well, right? You are looking at them and you realize that your question is not getting them to think about what you want them to think, about because they are staring at you sort of blankly still.
26. K: Right.

27. S: Which is an indication of they don't understand what you want them to think about, we can't see Debbie, we'll presume that she's staring blankly, but certainly Abby is in the midst of staring blankly at you in this moment. So, what can we do to tweak that question because these are exactly the sort of problems you're gonna have, right?
28. A: So, the question you [referring to Kayla] were trying to get at is once the toxin is in the blood, what does it do?
29. S: Right. [Conversation continues] (09.17. Episode 7 and 8)

Then in line 23, the instructor agreed with Kayla's coding of the problem and brought to classroom attention to find alternatives Kayla can do. Then, lines between 25 and 27, the instructor also highlighted and coded students' behaviors and confusion with not knowing what to do with the questions Kayla asked. Then, conversations continued between classroom members and they negotiated alternative questions Kayla could have asked to press their ideas better. They negotiated the alternatives and agreed on the solutions.

So, in these episodes, Kayla highlighted her practice of asking wrong pressing questions, and she negotiated what pressing questions should do based on what she was trying get students to do. So, they negotiated definitions and meanings of pressing and how to phase pressing questions to make the phenomena more focused instead of broad within the observed instances. So, this negotiation is more about the purposes of pressing questions and how to phase the pressing questions to bring students' ideas where the teacher wants them to get.

I have presented various example episodes from discussions of Bethany's teaching as well as TC's rehearsals to capture how their negotiations changed over time. Professional pedagogical vision practices are analyzed in terms of how coding schemes and highlighting practices occurred within those discussions and how the content of their discussions changed over time. TCs developed professional pedagogical vision through in-the-moment and over time negotiations of the teaching practices in their discussions of teaching events. As the semester

progressed TCs move from less sophisticated ideas to more sophisticated ideas about teaching practices. They progressed to more sophisticated practices but they also get more sophisticated at talking about the practices they identified early in the semester. It is important to conceptualize professional pedagogical vision as a negotiated, social and cultural process occurring within the classroom of becoming (or well-started) professional teachers.

Claim 3

Material representations of decompositions of teaching practice were important in supporting the negotiation of professional pedagogical vision.

TCs engaged in building material representations through their analysis of Bethany's teaching as well as analysis of their own Discourse 1 (eliciting students' ideas) rehearsals in the Studiocode files and through creating lesson and unit plans. So, the material representations in this data set include decomposition of teaching as Studiocode files and TC created curricular materials. I included only the results of the shared material representations in this claim. I found that negotiation of a shared material representation of decomposition of practice supports creation of shared definitions associated with ambitious science teaching practices. In the following section I provide evidence from the discourse of their negotiations of shared material representations, their Studiocode documents where TCs coded Bethany's teaching, and their own discourse 1 (D1): eliciting students' ideas rehearsal Studiocode files.

The following episode represents how TCs negotiated the shared material representation through highlighting and coding. TCs observed the videos of instruction from Bethany's lesson and the instructor stopped the video, and asked why they think it was good science teaching. The conversation occurred on the second day of the class and

was between Debbie (D), Erika (E), Mark (M), Bryan (B) and the instructor (S). Figure 5-1 is what TCs are looking at on the smart board and includes the material representation TCs created in the Studiocode.

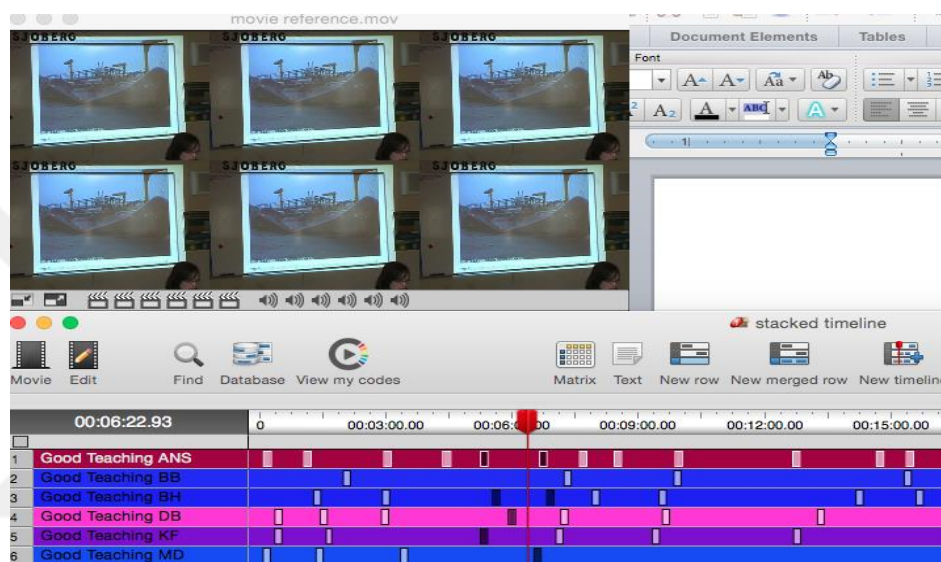


Figure 5-1: Material Representation 1-Studiocode Timeline 1 and Video of Bethany's teaching.

[They started watching Bethany's video, and they looked at the instances where it looks like everyone agreed that something happened in the instances based on TCs' analysis in the Studiocode timelines.]

1. S: So, you all agree that that was good science teaching, so what is good about that? What is the principle you can draw from them?
2. D: **She initially summarized right you started it, she was receiving their initial thoughts.**
3. S: Okay.
4. D: And then **she showed real life example** there.
5. E: Yeah, I liked it because **it was a real life example**, she had the video, was actually happened, this is you know, it is like not ... not from each students' life, but **something that is actually happened.**
6. S: So, real thing!
7. E: Clearly, **the kids all thought it was cool.**
8. S: So, she picked something real, Mark and Bryan, why did you like this, because you marked this too?
9. M: I liked it because **something that happened in real life, and gets students' attention.**
10. S: Okay.
11. B: I agree.
12. S: Do you? So, why would you use something from real life?

13. B: Well, **you connect it to them; it is easier for student to think about it.**
You know instead of just saying here is the mass, this is pressure,
14. E: I also think, like, we need to use life examples like this, if the students in the class were tested on like the gas laws, I mean not only they do this activity but like just that exciting example they can, that's something ohh gas law I remember seeing it where the tanker imploded, **so it is easy for them to recall, [inaudible]**
15. S: So, picking this thing that sort of exciting **helps them connect.**
16. E: Hm-hm, and **remember more.** (08.29. Episode 8 and 9)

In these episodes, the instructor asked them why they think the observed instance was good science teaching. He is referring to their Studiocode timelines and their coding that they highlighted as good science teaching on those timelines. Then, in line 2 and 4, Debbie interpreted what the teacher did (summarized students' ideas, she was receiving students' initial ideas and showed real life examples) in her discourse. Then in line 5, Erika also agreed and interpreted that she liked it because she showed something real even though it was not related to students' lives, it was something real and in line 7, commented on real phenomena getting students' interest (the kids all thought it was cool). Then in line 8, the instructor asked Mark's and Bryan's ideas too. Mark agreed with Erika and Debbie and offered the coding schemes of real phenomena and real phenomena getting students' attention. Then Bryan agreed with other TCs. Then in line 12, the instructor pressed Bryan's idea and asked him why he liked it. In line 13, Bryan interpreted that using real phenomena connects and helps students think about the phenomena. Then in line 14, Erika agreed and offered using real life phenomena helped students remember concepts more easily later.

So, in this episode starting with Debbie's comments, all the TCs offered interpretation regarding why using real phenomena is a good science teaching. The group did not take up Debbie's comment about teacher's summarizing and eliciting their initial ideas. All the TCs agreed with her second half of the comment regarding using real phenomena and all included specific interpretation to negotiate that idea. Some of the TCs included real phenomena getting

students' interest and attention and helping them to connect to concepts and remembering things easily as their interpretation.

The following instances are how TCs highlighted and coded the same instance in their timelines individually prior to the conversation above. So, the following coding schemes (interpretations) included are from TCs' initial building of material representations for the same observed instance in the above episode. The specific instances I gave below come from what TC wrote in those highlighted instances in black in Figure 5-1 in the stacked timeline.

“Gave **a real world issue** to get students to think in concrete and tangible terms.”

(Abby, 5th instance)

“**Uses video to get student input**...unprompted questions and enthusiasm”

(Abby, 6th instance)

Interesting scenario! (Erika, 3rd instance)

“Great video, **got the students very involved**.” (Erika, 4th instance)

“Important to demonstrate **the relevance of gases in the real world**, so students can answer “Why do I need to learn this?” for themselves.” (Debbie, 4th instance)

“She is giving the students **a scenario where they can incorporate the ideas they have been learning about molecules and gasses** to explore why the tanker imploded.” (Kayla, 3rd instance)

“Engages students with video of tanker getting crushed. **Good attention-getter**.” (Mark, 4th instance)

Figure 5-1 shows the highlighted instances, and the above instances from each TCs representing what they have coded for those marked instances. TCs included similar coding schemes in their individually created material representation. While some of the TCs (Abby, Erika, Mark and Kayla) coded the video and scenario Bethany used in her lesson (she showed the tanker crush video) as a real thing, others (Mark, Erika, Debbie) coded the video and scenario getting students' interest and attention. Those initial coding schemes support their negotiation of the shared material representations in the above episode. Thus, they create shared definitions or meanings of good science teaching practices within the negotiated episodes. Their individual material representations are the first step and provide a context for the coding and highlighting and thus negotiations of definitions and meanings of teaching practices. In the above episode and

the instances, TCs negotiated the importance of providing real phenomena for students' science talk and getting their interest.

The following episode is another example episode representing TCs' negotiation of shared material representations. The conversation was on the second day of the class where they looked at their analysis where most of the TCs seemed to highlight the same instance. The talk is between the instructor (S) and Kayla (K), Erika (E) and Debbie (D). Figure 5-2 represents the shared material representation and includes video of Bethany's teaching and TCs' stacked timeline. This figure is what TCs are looking at on the smart board during the conversation in the below episode.

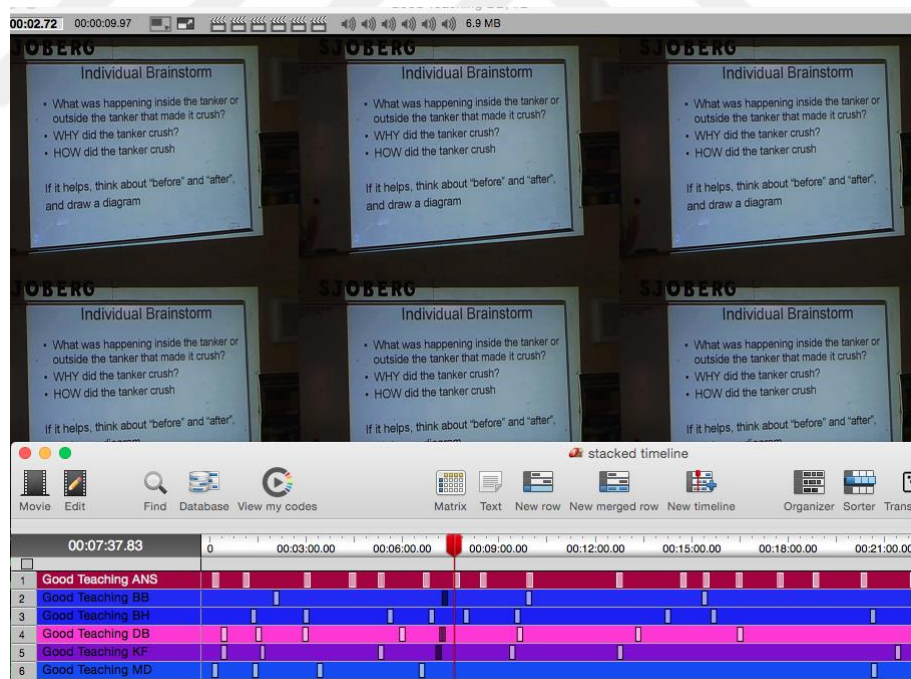


Figure 5-2: Material Representation 2- Studiocode Timeline 2 and Video of Bethany's Teaching.

1. S: Let's see how she sets up this bit.
[They watched another instance]
2. S: Okay, bunch of you marked this [referring to the black marked instances in the above timeline in Figure 5-2], what is going on here that you all liked?
3. K: [inaudible] **brainstorming**.

4. S: Why is brainstorming good?
5. E: Well, we know the activity they ended up doing, but it is appearing that **before it is the thinking on their own first and then they talk it to their peers.**
6. S: Okay, and she, one thing you'll notice, well it is a pattern often with this stuff, right? **She has got what, how and why; she got all three of these pieces. Don't just explain what is happening, but explain why it happened, or how it happened, right?**
7. All: hm-hmm
8. S: **Again, this is the levels of explanation all explicit in which we should ask to explain. Not just tell me what happened to this tanker, but why happened and how did it happen.** And then, this is a specific piece to this before, after during but, let's. We are not really seeing, why are not we seeing at least at this point a lot of the discourse practices that we talked about before?
9. D: [inaudible] **On their own.**
10. S: Right. They have not really started talking about it. They are about to. Because they are gonna do a little brainstorming. Now, we can probably take a look and see what is she doing. So, let's see. She starts walking around and talking [The instructor is showing the video without sound to fast-forward to come to the instances that TCs marked]
[They watched another video instance] (08.29. Episode 13)

They observed a video instance then the instructor asked why they liked it. Kayla coded that students were brainstorming [line 3] and then the instructor pressed her and asked why brainstorming is good [line 4]. Erika said even though they know what activity the students did, it was good that they think first and then talked to their peers, so she is referring to the think-pair-share strategy and why it is good [line 5]. Then, the instructor agreed and then highlighted and coded the questions the teacher put on the slide in terms of the levels of explanation [line 6]. He highlighted it through specifically pointing on the smart board screen and underlying each question, shown in the Figures 5-3, and 5-4. He repeats “what”, “how” and “why” questions multiple times verbally to emphasize the importance of levels of explanations [line 8]. As soon as the instructor highlighted and coded those on the smart board, Erika (with the green shirt) took notes on her notebook (see Figure 5-4), which I assume is building a material representation to think about those levels of explanation. I do not have their notebook copies to show evidence, but

TCs' taking notes may also be considered as material representations for the highlighted and coded practices in this case for levels of explanation.

The following instances from TCs' stacked timelines in Figure 5-2 support their interpretation about brainstorming.

“The teacher is having the students **predict and brainstorm ideas**, which is an important part of science.” (Kayla, 4th instance)

“It is critical in science **to write down all thoughts** (as the teacher asks the students to do in a journal) to be able to not only verbalize but also be able to **jot down initial thoughts** before the "truth" is revealed. The teacher is getting the students to **brainstorm or hypothesize**.” (Debbie, 5th instance)

“Uses a variety of methods of student response; first she was allowing **students to voice their thoughts**, but **writing them down is also beneficial**. Talking to students one on one helps their understanding.” (Bryan, 2nd instance)

In these instances, TCs highlighted the selected instances (in black) shown in Figure 5-2 and used the coding schemes in the above instances. TCs included brainstorming, predicting, thinking individually and writing their initial thoughts as their coding schemes for the highlighted instances in their initial material representations. Their initial coding schemes shown in the produced material representations support their negotiation of shared material representations later in the classroom during episode 13 above. In the above episode different from the TCs' coding of brainstorming, the instructor highlighted and coded levels of explanation and at least Erika created a material representation of the levels of explanation in her notebook. Even though TCs did not highlight or code levels of explanation in that observed instance, the fact that they highlighted and coded Bethany's using think-pair-share strategy and created the material representation to show that practice helped the instructor highlight and code what Bethany put in her slide (the questions for the levels of explanations). So, through negotiation of this shared material representation, TCs considered think-pair-share strategy as well as the importance of levels of explanations in the ambitious science teaching practices.

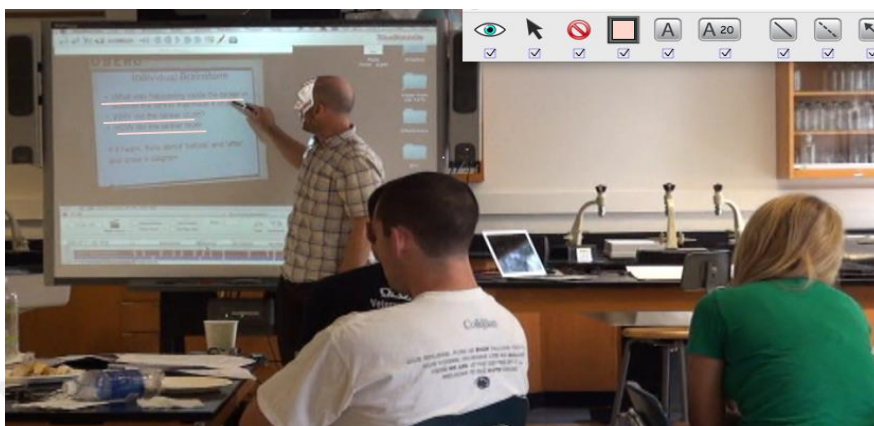


Figure 5-3: The Instructor Highlights 1 (The pale pink colors are added by the researcher to indicate how the instructor highlighted the questions).



Figure 5-4: Instructor Highlights and Erika Builds Material Representation (Those pale pink colors are added by the researcher to indicate how the instructor highlighted the questions).

The following episode is another example of negotiation of shared material representation through coding and highlighting practices. TCs observed an instance in Bethany's teaching and it was on the second day of class. The conversation was between Debbie (D), Kayla (K), Bryan (B) and the instructor (S). I divided the episodes into two sections.

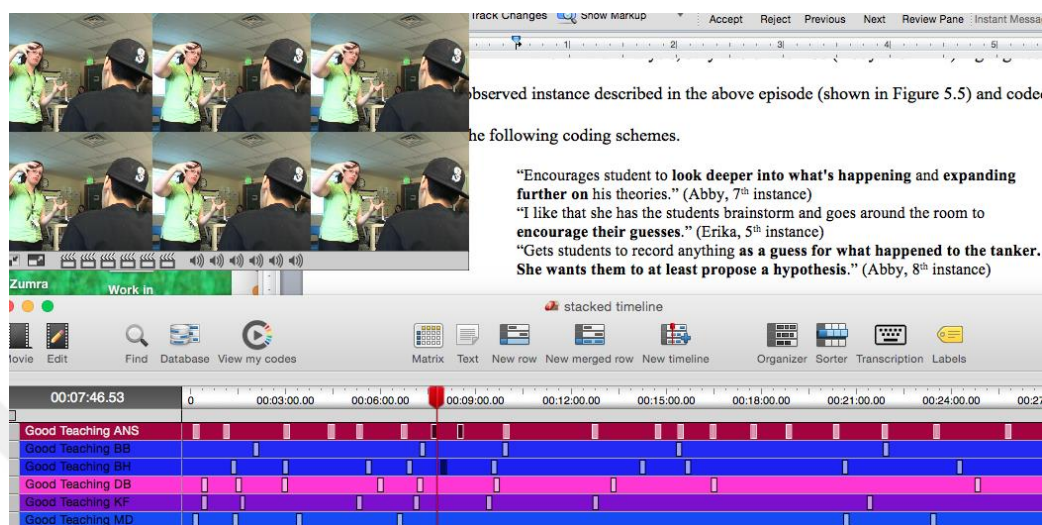


Figure 5-5: Material Representation 3-Studiocode Timeline 3 and Video of Bethany's Teaching.

[They watched a video instance. Figure 5.5 shows the screenshot of the video and TCs' initial analysis in Studiocode timeline.]

1. D: **Pressing.**
 2. S: Hmm? Pressing?
 3. D: **Especially kid in the jacket...**
 4. S: Yeah.
 5. D: [Inaudible]
 6. S: **Yeah, "I don't know, I don't know". Definitely, yeah. Anything else she was doing?**
 7. K: **Probing.**
 8. B: Hm-hmm [Agreeing to K]
 9. S: Probing? Where were the examples of probing?
 10. K: **..girl. oh no, (she is up the steam?)....**
 11. B: [Inaudible]
 12. D: **What did the first kid say?**
 13. S: Yeah it is really hard to hear.
 14. D: It is really hard to hear. I think he mentioned something about....
- [They watched the same video again] (08.29. Episode 14)

In this episode, they observed an instance of Bethany's teaching where she was working with groups of students and getting their ideas about why the tanker crushed. After observing, Debbie coded that she pressed students ideas [line 1] and then the instructor revoiced her statement [line 2] and then Debbie highlighted that Bethany pressed the student with the jacket [line 3] and then the instructor agreed and highlighted

what the student said (I don't know, I don't know) in the video. So, Debbie and instructor collectively highlighted Bethany's pressing the student's idea. Then, the instructor asked if the teacher was doing anything else. Then Kayla used probing coding scheme [line 7]. Then the instructor asked her where the examples of probing are so, he wanted her to give specific evidence thus highlight an instance that she was labeling as probing [line 9]. Then Kayla highlighted a specific student the teacher was probing [line 10]. Then Debbie wondered what the first student said and they watched the same instance again.

15. S: He says something about just exploding ... it is really hard to hear.
16. B: [Inaudible]
17. S: Like what?
18. B: Like "exploded because there is no more space, so it exploded".
19. S: Ha, there is no more space, [The instructor run the video again] Okay, so, is that probing that we were talking about? So, he says if Bryan were right, "there is no more space so, it exploded." so, she starts asking questions about what? What is she asking?
20. K: "Why is it go in?"
21. S: "Why is it go in?", right? So, she, what's she doing there?
22. D: She's revoicing (word?) that something wrong on kind of reiterated, but ...
23. S: Well, she is not really revoicing exactly, she is not saying back to him what he said. But, she is asking him about a piece of what he said.
24. D: Instead of saying you are wrong.
25. S: Right, because he says, "it explodes" and then she clearly knows that's not what happened. So, she is trying to get him to think about. So, she is saying, "ohh, it didn't explode it got crushed", right? So, she is saying it did not do this [makes hand gesture of explosion], it did this [makes hand gesture of implosion].
26. D: yeah, she revoiced [Inaudible]
27. S: yeah, so I don't know maybe. It is hard to tell. It does not matter, We don't have to classify everything, but I do want you to think about how she is doing this because again not in a very short period of time, not next week but a week after, you are gonna be doing this with us. You are gonna have to pick a phenomenon and you are gonna have to sit and talk to us, do what I did with you with those models, right? (08.29. Episode 15)

Then, there are back and forth conversations to understand what the student said. In line 18, Bryan highlighted what the student said and then in line 19, the instructor asked if it is probing and what the teacher asked. Then in line 20, Kayla highlighted what the teacher said and

then the instructor asked what the teacher was doing, so he wanted them to interpret what the teacher was doing. In line 22, Debbie coded the teacher was revoicing, and then in line 23, the instructor did not quite agree and he coded that the teacher asked about a piece of what the student said. In line 24, Debbie coded that the teacher did not evaluate and the instructor agreed and highlighted what the teacher knew and asked students. Then Debbie repeated revoicing with some inaudible comments and the instructor did not go to details but pointed out how the teacher elicited ideas from the students. So, in these episodes, there were multiple negotiated highlighting and coding practices of ambitious science teaching practices especially for the talk moves for eliciting students' ideas between the instructor and the TCs.

In their initial analysis, only two of the TCs (Abby and Erika) highlighted the observed instance described in the above episode (shown in Figure 5-5 in black highlighted instances) and coded it with the following coding schemes.

“Encourages student to **look deeper into what's happening** and **expanding further on** his theories.” (Abby, 7th instance)
 “I like that she has the students brainstorm and goes around the room to **encourage their guesses.**” (Erika, 5th instance)
 “Gets students to record anything **as a guess for what happened to the tanker.**
She wants them to at least propose a hypothesis.” (Abby, 8th instance)

In these instances, TCs do not use the same language like “pressing” or “probing” or “revoicing” they used in the above episode, but they used “looking deeper”, “expanding on their theories”, or “encourage their guess” or “at least to propose a hypothesis” to describe what the teacher was doing. The reason they are not using the same language is because in the first class, they have not been introduced to the ambitious science teaching practices and tools at this point. Even though they did not use the same language, their first step of creating material representations is an important practice for the professional pedagogical vision to help them negotiate these practices. Thus, their initial material representations support their negotiation of

ambitious science teaching practices, in this case specific talk moves that Bethany used to elicit students' ideas. Those negotiations provided more clear descriptions and meanings for the talk moves TCs observed in the teaching.

The following episode is an example of negotiation of shared material representation, however it is interesting in that the TCs did not actually highlight anything (mark instances in the video) in their material representations (the Studiocode documents), but the instructor highlighted in the discourse the fact that TCs did not identify any teaching practices in this segment (shown in Figure 5-6). So, this episode is an example of negotiation of material representation when the initial material representation does not include something of interest to the TCs. I divided the conversation into two sections.

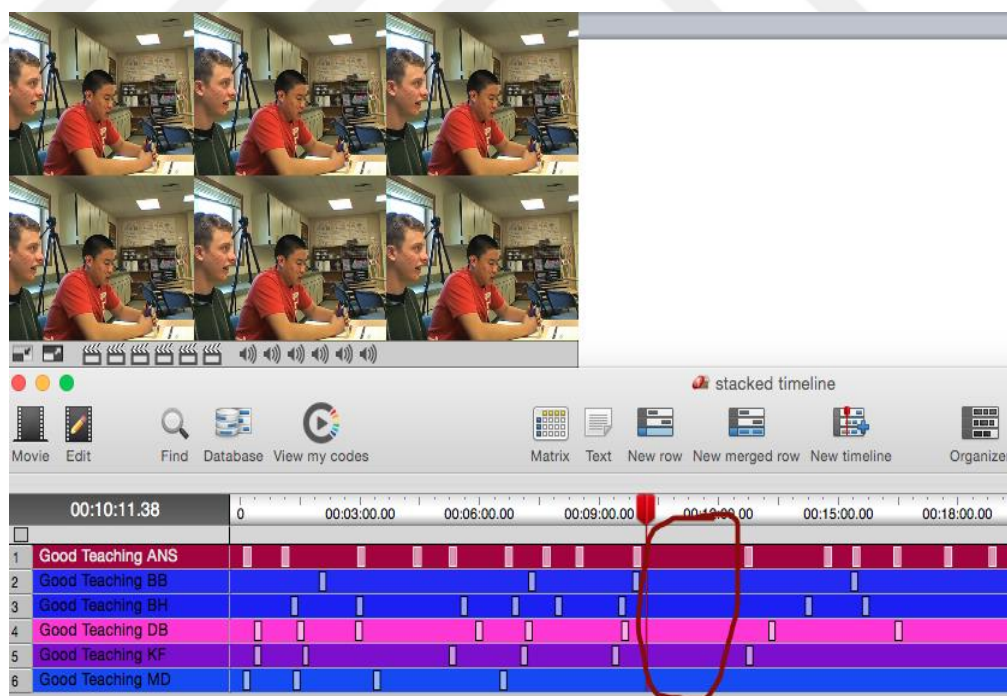


Figure 5-6: Material Representation 4-Studiocode Timeline 4-Lack of Highlighting-circled by the researcher.

1. S: Let's look at one more example of her talking to the group.
[They watched video]

2. S: Okay, right, I am just realizing something, so in that section we just watched those three girls talking and this whole segment with these three kids talking, **nobody marked this as good science teaching**. [He is referring to the section circled in the Figure 5.6.] **So, is there a reason for that? You think this is bad or is there something?**
3. E: Maybe we just thought she was not because
4. K: Yeah...
5. S: So, because she is not here, and let's see [The instructor scrolls the video]
6. B: Here she comes in
7. S: She comes in and suddenly it is a good science teaching.
8. E: Yeah
[Teachers laugh]
9. S: So, is there only good science teaching when she is present?
10. B: I think that's probably what we were looking for, that's why I didn't mark this instance, the fact that she puts them in groups ...
11. D: [Inaudible]
12. E: Yeah
13. B: Yeah
14. E: And they are talking about it obviously, if they weren't interested in it, they wouldn't do it, or ...
15. S: So, is this good science teaching?

In this episode, the instructor highlighted that no one highlighted this section where kids were talking in their groups [line 2]. He highlighted that through pointing to their stacked timelines where no one marked an instance shown in Figures 5-6 and 5-7. Between lines 3 and 14, TCs interpreted that they thought about good science teaching when the teacher was present. After the instructor's pointing out the group work and kids' talking, he asked TCs if the observed instances were good science teaching.

16. E: Yeah [nods]
17. B: [nods]
18. D: After reading, yes.
19. S: Oh, after reading, now you have to agree with me because I give you readings.
20. D: Well, I didn't really think, I mean I thought about putting them in groups but didn't really, when you said "good science teaching"[she stressed],
21. S: Yeah,
22. D: I associate her being in there, not....
23. S: Yeah I think that's totally fair. But, I think it is worth thinking about because I presume at some point in your teaching career, you are gonna put kids in groups, so, do you make assumptions about whether that's good teaching and you think it is good teaching to put kids in groups?

- 24. K and E: [nods]
- 25. D: Hmm [nods] ...make sure they stay on task...
- 26. S: Okay, so you want them to be nice if they stay on task to some extend.
- 27. E: But I think they are.
- 28. S: It seems they are.
- 29. D: Hmm, these kids are.
- 30. S: Yeah, well I mean, so that's a question too, how do you get kids to stay on task in groups? Go head. [The conversation continues on how to keep kids on task in the groups and what the teacher should do to keep students on task]
(08.29 Episode 18)

TCs agreed that it was good science teaching. In lines 18, 20, and 22, Debbie coded (interpreted) that it is good science teaching after the readings. In line 25, Debbie thought it is good science teaching if the kids stay on task. Then in line 30, the instructor continued to press them on how they can keep kids on task in small groups and conversation continued. So, TCs negotiated why they did not highlight and code in their material representation. So, in this episode, the lack of highlighted instances in the shared material representations also supported the TCs negotiation of practices. The lack of highlighted instances was helpful for the instructor to understand and identify to TCs how they were thinking about teaching. Even though it was not explicitly stated in the ambitious science teaching practices or in the discourse tools that teachers should put students in groups, putting students in groups is an anticipated practice to let them talk among themselves and generate ideas and explanations before the teacher elicits their ideas. Thus, in this episode, the classroom community negotiated the importance of putting students in groups and actually considered that as a teaching practice.



Figure 5-7: The instructor points out where no one highlighted.

So far, I presented evidence from their material representations of Bethany's teaching. The last example provides evidence from their material representations of Studiocode files when they coded their own D1 practice. This episode occurred on the day they analyzed their own rehearsals for the sub-practices of Discourse 1 (D1): eliciting students' ideas. They analyzed their own videos and the instructor was getting their ideas about what they noticed they were doing.

The following conversation was between Kayla (K), Debbie (D) and the instructor (S).

1. S: So, anything else you noted, what about some of the actual practices, like the behaviors that you were supposed to be looking for?
2. K: I noticed that I spent like a significant amount of time in each groups, there was big chunks where it was blank in my coding, because I was with this group when I couldn't see or hear anything.
3. S: Ohh, I see.
4. K: So I had to fast forward because I can't code that until I watch the other one.
5. S: right.
6. A: I was able to hear because I chose the further [inaudible]
7. D: **It made me also realize that I felt like I spent too much time at one group, and I should have gone back and forth more, I was watching Erika and Kayla, and I noticed that at times they were kind of lost and I could have been there to**
8. S: Yeah.
9. D: **Definitely ask something when they were talking.** (09.17. Episode 2)

In this episode, Kayla and Debbie coded and highlighted that they spend too much time with the groups. In their coding in their material representations one of things the classroom

members decided to look at was how they enter and exit the groups. Through their coding of entering and exiting the groups in the material representations, both of them negotiated how much they spend in each group and how the students needed their attention when they were not in the groups. Those patterns also indicated in their initial material representations through lack of coding in certain areas when they were with the other groups in the Figures 5-8 (belongs to Kayla's self analysis-material representation) and Figure 5-9 (belongs to Debbie's self analysis-material representation).

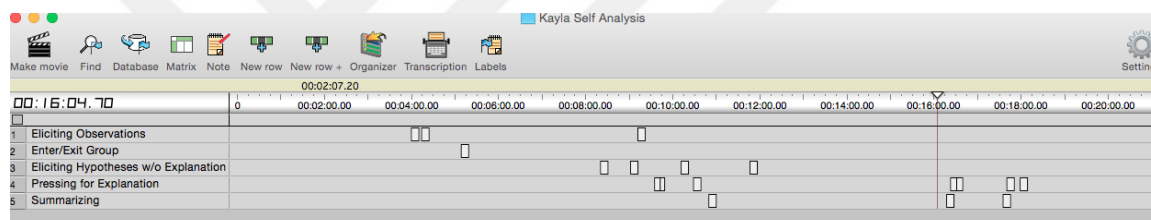


Figure 5-8: Material Representation 5-Studiocode Timeline 5.

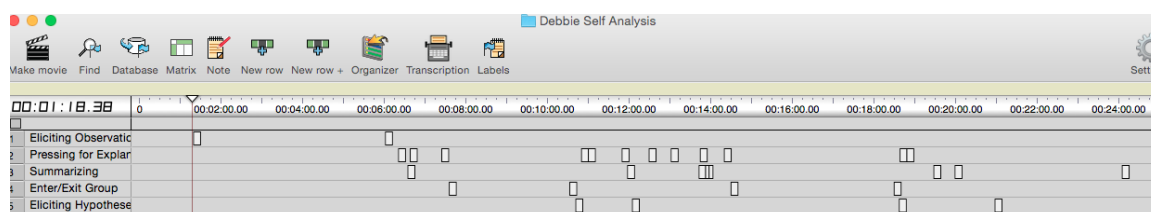


Figure 5-9: Material Representation 6-Studiocode Timeline 6.

I presented various episodes from their negotiations of shared material representations during decomposition of teaching and instances from the Studiocode timelines in their initial material representations. I found that material representations of decompositions of teaching practice were important in supporting the negotiation of professional pedagogical vision. Negotiation of a shared material representation of practice supports creation of shared definitions associated with ambitious science teaching practices through coding and highlighting. The role of material representations is to provide context for the highlighting and coding practices, so it

supports the creation of shared definitions by being an externalized articulation of their own highlighting and coding. In this case, Studiocode files inherently provide two material representations, video of the teaching as well as the timelines that show what TCs highlighted and coded of the observed teaching. Thus, videos of teaching and stacked timelines were publicly assessable artifacts that helped to build intersubjective agreement in the discussions of teaching events among classroom members. Especially, stacked timelines show what TCs individually highlight and code in the observed teaching, representing their initial professional pedagogical vision. Then, those timelines support TCs' creation of shared definitions and meanings of observed teaching practices in their later conversations in the group discussions. As they participate in discussions of teaching events, TCs develop common knowledge about teaching.

Material representations in general are an important and neglected part of professional pedagogical vision. Considering material representations is important to see TCs' professional pedagogical vision holistically. I considered material representations as their Studiocode timelines when they analyzed Bethany's teaching and their own rehearsals as well as the lesson plans they created. For this finding, I did not provide evidence from their lesson plans as it was difficult to track evidence of their referral to the lesson plans in their decomposition of practice unless it was clearly stated that their lesson plans helped them negotiate the ambitious science teaching practices. Another reason why I did not include evidence of created lesson plans for this particular claim was that the created lesson plans were not a shared material presentation among the classroom community for negotiation of ambitious science teaching practices.

However, I still think that created lesson plans are material representation that should be considered as one of the professional pedagogical vision practices for teachers because lesson plans also show TCs' visions regarding teaching. TCs included what they want to enact or emphasize during teaching based on the instructor's guidelines. For example, in their discourse 1

lesson plans: eliciting students' ideas, TCs included the description of the scenario they used to initiate the lesson, the gapless explanation they wrote for the phenomena, and back pocket questions that they used to elicit students' ideas in relation to specific sub-practices including eliciting hypothesis, eliciting observations, pressing for explanations and summarizing. Even though those sections (description of scenario, gapless explanation and back pocket questions) are asked to be included by the instructor, how well those sections were completed, how the activities were framed in the lesson plans, and how back pocket questions were phrased and framed may show TCs' professional pedagogical vision. Thus, it is still important to consider lesson plans as a source of material representation that represents TCs' professional pedagogical vision.

Claim 4

TCs negotiate professional pedagogical vision more intensely in the context of local examples of practice than in distal exemplars of practice.

TCs had a more critical and problem-solving approach to decomposition of the practices of their peers' or their own approximations of practice, while they were more descriptive and affirmative when decomposing exemplars from the ambitious science teaching website. When decomposing their own practices, TCs tend to identify problems in the practice; they problematize the situation, describe and articulate the situation, and tried to find solutions or alternatives to the identified practice in their teaching. Thus, they negotiate professional pedagogical vision through problem solving approach in their own or peers' practice.

Whereas when decomposing exemplars of practice from the ambitious science teaching, TCs tend to describe what the teacher is doing or what the students are doing

without being critical to the exemplars' practice. Thus, they were in more agreement when discussing practices from the exemplars. In the following three examples I provide evidence from TCs' negotiation of professional vision in their own and peers' practice, and that follows another two examples showing how TCs decompose Bethany's practice in the observed instances.

The following example shows how Kayla identifies a problem of practice and how she negotiates it with the course instructor in her first rehearsal debrief. Kayla is the first TC who taught during the first rehearsal. The conversation was between Kayla (K) and the instructor (S). This episode represents how TCs negotiate professional vision on her own practice. The conversation is divided into two sections.

1. S: How did it go for you Kayla?
2. K: Well, **I think that I really, really should have focused in more**, because I feel like they kind of touched the things I touched when I first started thinking of my explanation, **but it was getting into the details. And maybe that's time or and then the other thing is rephrasing what they say to get them, because they are not wrong, but to get them on a better track. It is a lot harder than I expected.**
3. S: How to redirect them without telling them they are wrong.
4. K: Or telling them that they're right.
5. S: Right. Or telling them they are right. Yeah, okay, so let's talk about it, talk about the first piece first, so **is there something now having done it that you think you could have done differently either at the beginning, during or later that would help with that focus issue?**
6. K: **I think that I should have picked one reproductive problem, so, for example stillborn calves.**
7. S: Okay

In this episode, Kayla coded a problem and solution in her teaching. She coded the problem of focusing on and not getting into the details of her gapless explanation with the student's explanation and offered the solution that she should have focused more [line 1]. Then, she coded another problem with rephrasing what students said to get them better without evaluating their ideas [line 1]. Then, in line 5, the instructor helped her problematize and think about a solution she could have done to the problem of focus.

Then in line 6, she coded that she should have chosen one reproductive problem such as stillborn calves as a solution to the focus issue.

8. K: And I also think that it would have been helpful to provide [she waits] hmm I mean I think that even in itself because I got into the issue with you guys [pointing to Erika and Bryan] when you were going on three different tracks of to why there are reproduction problems and they are all correct. But now I am redirecting you to go after, “okay so now why are not pregnant cows not being pregnant or why are stubborn calves are being born, what is this have to do with” **I think I was messing you up because I wasn't [inaudible].**
9. S: **So, it was like you have two mini phenomena.**
10. K: **Yes.**
11. S: **Stillborn calves is a phenomenon.**
12. K: **Right.**
13. S: **The dying of the cows is a phenomenon, and there is too much, yeah, okay.**
14. K: **Yeah [nods].**
15. S: So, hmm, the other thing I thought of that might help with that focus is. I agree with you that that was one of the problems that you it is too broad that you were thinking about too much, **but I noticed in both groups you were really pressing towards, ahm, what is happening?** [The instructor continued to identify a problem as well as solution related to focus issue] **(09.10. Episode 1 and 2)**

Then, in line 8, Kayla highlighted and coded a specific interaction with Erika and Bryan’s group and described how she worked with their ideas when they were explaining why there were reproduction problems and then how she included other phenomena such as why not pregnant cows not getting pregnant as well as why there were stillborn calves for students to explain. Then, the instructor revoiced what she identified as the problem as well as a solution for the focus issue [lines 9 and 11]. Then in line 15, the instructor agreed with her identification of the problem of focus and he coded the reason of problem might be because she was pressing towards what was happening instead of how it was happening and the conversation continued with elaborating the problem and suggesting another solution in the next episodes that I did not include here. So, in this episode, Kayla approached to her decomposition of her own rehearsal through problem solving approach

with identifying, articulating the problem in the practice, then suggesting a solution to that problem through negotiation with the instructor.

The following episode also represents a problem solving approach to decomposition of TCs' own practice. This episode is about Erika's first rehearsal and she negotiates identification of problems and solutions to the problems in her practice. The conversation was between Erika (E), Kayla (K) and the instructor (S). This example also represents a problem approach to own practice.

1. S: Okay, what do you think?
2. E: It is hard. One, **I probably should have focused mine in more** because okay that group [referring to Abby and Debbie's groups] was really on, they were easier to kind of with them though **my mistake is like "correct". They were easier to get into the right direction.** Looking at it now, **I probably should have put Kayla more in their group and maybe Mark over here or Abby over here, because Kayla is much more focused on what is happening inside the body directly to the fish, whereas I was more thinking about like what are maybe outside factors coming in and affecting the fish.** So, I think they were like 5 min going into all of this like internal things with the fish.
3. K: [Inaudible]
4. E: and then finally like Kayla is like, "wait are you talking about outside things in the environment that are now affecting the fish?", and I was like "yeah", whereas they [referring to other group] got that sort of right off the bat, it maybe took me saying one or two questions and they were focused in.
5. S: Yeah.
6. E: **So, that's what was hard. I was literally on two completely different things with both groups, so.**
7. K: I was tanker and tornado student
All: [Laugh]
8. E: You were the tornado and tanker student.
9. S: No, because tornado and tanker is just crazy,
10. E: Yeah, you were bringing
11. S: It was crazy
12. E: Of topic,
13. S: Yeah,
14. E: Yeah,
15. A: It was the implosion explosion.
16. E: Yes, you are explosion that was implosion.
17. K: Sorry.
18. E: Yeah, but that was challenging. (09.12. Episode 21)

After Erika taught her first rehearsal, in line 2, she coded that she should have made the focus of the lesson more apparent as a solution to the problem. Then, in line 2, she highlighted one of the groups and how it was easier to work with them and highlighted the problem of evaluating their ideas. Then, in line 2, she coded that she should have changed the group members because some of students were thinking about what is happening internally to the fish and killing it but she was more focused on how the environmental changes affecting the fish and killing them. Then, in lines 4 and 6, she coded the problem of how she was on different tracks working with two groups and making them focus on the things she wants them to explain. Then in line 7, Kayla associated herself with the student who has the tornado idea by making an intertextual connection to a student in the video of Bethany's class where the student was thinking a tornado when explaining why the tanker crushed. Then between lines 8 and 18, through negotiation with the instructor and Erika, Kayla again coded herself as the implosion and explosion student through making another intertextual connection to another student in Bethany's class. So, here, Kayla was trying to label her idea with shared intertextual connections through relating to the students' ideas they have seen and talked about. So, in this episode Erika highlighted and coded the problem of focus as well as different tracks in groups' explanation process and how she was dealing with that and what solutions she suggested.

The following episode includes another problem solving approach in Bryan's lesson. In this case, Abby is the one who initiates identifying the problem of practice in Bryan's lesson, so she identifies the problem in her peer's practice different from the previous examples. The conversation was after Bryan's first rehearsal discussion. The conversation was between Abby, Bryan, and the instructor. Bryan taught how fracking fluids affect the earthquake occurrences in the Ohio area.

1. S: So, sir Bryan has earthquake for us through 20 min of science, so let's talk about it. We've got two more to do today, so what can we learn from Bryan?

2. A: **Can I be a little bit critical for a second?**
3. B: Do it.
4. A: **You kept telling us “that’s right”.**
5. B: You are right.
All: [Laugh]
6. S: I agree, he did that, **he also had a classic one over here**, and I love that he did it right in front of the camera, ‘cause you’re gonna get to see it, but Kayla said pressure, and you said, **“ooh, I kind of liked that. Expand on that”**, so that was a classic example of like try not to say you are right but clearly say you are right, so like, “I am not allowed to say she is right, so I say “ooh, I kind of liked that”
7. A: And I think there is also point where you were like, **“ok, let's stop this train of thought and go that train of thought.” you clearly said almost exactly like that.**
8. S: I think you did some of the classics Bryan, you really did, I think it is in the sense that, there was a lot of good stuff mixed in there, and there were some points where **you clearly wanted to direct people so you just directed them.**
9. B: Yeah.
10. S: And so it is worth thinking about, how to do that, because it is hard, it is one of the hardest things, I don’t know, why don’t you talk about how you feel?
11. B: One of my biggest things coming in was obviously you guys are very familiar with fracking, and all its side effects, so, I don’t wanna say this is all caused by the fracking in the area, specifically putting the waste back in, so I kinda left that for you guys to figure out, and then when you brought up fracking, I wanted to let you know that it was not like on the be all and end all, of why I was having and I think you guys were talking about taking the gas out **and how that might cause [inaudible]which was not bad idea, but yeah I think you are right, I think I just kind of said alright, that’s nice, but stop thinking about that.** (09.12. Episodes 1, 2, 3)

In this episode, Abby highlighted one of Bryan’s evaluating instances and she coded it in a critical way. Then the instructor highlighted another instance where Bryan evaluated students’ ideas through telling them he liked their ideas. Then Abby highlighted another instance where Bryan evaluated, led and directed students to other ideas. It seems there is no clear coding for those instances but the fact that Abby started her sentence with “can I be critical?” and “you kept telling us that’s right” indicates that she coded it with “not evaluating students’ ideas” as one of the professional pedagogical vision ideas. Especially at this point in discourse practice 1 where they elicit students’ ideas TCs knew that they were not supposed to evaluate ideas but instead

elicit ideas from them. So, that looks like an established coding scheme in their classroom community and that is why when Bryan used those evaluative phrases, TCs and the instructor highlighted those instances and coded all those instances in terms of evaluating. So, there is a tacit agreement in terms of how those evaluating instances are something that is expected from them not to do. So, in these episodes, TCs negotiated the problem of practice, they identified and agreed on the problem, they did not offer specific solution instead of the obvious solution of not evaluating the ideas.

So far, I gave examples of problem solving approach to either own or peer practice, the following examples show how they use more descriptive and not critical approach to decomposition of practice. The following episode is an example of descriptive patterns of talk when they were decomposing Bethany's instruction. They observed an instance from Bethany's instruction on the second day of class and the conversation was between Kayla (K), Erika (E), Debbie (D) and the instructor (S).

[They watched video]

1. S: So, it is not great in term of what you can hear but what's going on in there? Is it good teaching or not good teaching? And what's she doing?
2. K: **She is having them recall something that they already did.**
3. S: Yes, she is making references to this other thing, **so is that fit into one of the categories, probing, pressing?**
4. E: **Probing.**
5. S: **Probing? What was she asking them about specifically in this case?**
6. E: Balloon.
7. D: [Nods] **phase change.**
8. S: Yeah, she is talking about phase change. She didn't say that though, right?
9. S: **How does she ask them?**
10. D: **"What happens when the steam turned into?"**
11. S: Yeah, so "what happens..."
12. D: Did the kid say something prior to her saying that or she ...
13. S: Let's find..[The instructor scrolls the video]
[They watched video]
14. S: It is pretty impossible to tell, but what would you guess?
[They watch again]
15. K: **She is rewording what she said.**

16. S: **Yeah, it sounds like she is repeating, revoicing what this girl said, but saying, "so when the" because presumably she said, "that's what happened."** (08.29 Episode 21)

In this episode, the instructor asked TCs what good science teaching was in that observed instance. In line 2, Kayla described the teacher had students recall a previous experience and then in line 3, the instructor pressed her to categorize and interpret the purpose of asking that question as a pressing or probing talk move. Then in line 4, Erika interpreted it as probing. Then, in line 5, the instructor pressed her to tell specifically what she was asking. The instructor's pressing TCs helps them to highlight the questions. Then, in line 9, the instructor pressed them again to highlight how the teacher asked them the question. Then, in line 10, Debbie highlighted what question the teacher asked. Then, in line 12, Debbie wondered whether or not the kid said something before that and they observed the video to find out if the kid said something. Then in line 15, Kayla highlighted that teacher revoiced what the kid said. In this episode, TCs used descriptive language to highlight and code Bethany's instruction and this pattern of talk was common when they decomposed Bethany's practice.

The following example is the only time TCs critically looked at Bethany's instruction and criticized and found problems in her practice. The conversation happened on the fourth day of class when they were looking at Bethany's practice to learn more about how she elicited students' ideas in the D1 practice. The conversation was between Debbie (D), Abby (A), Erika (E) and the instructor (S).

1. D: Something **I noticed with this group and not any other group is she seems to just speak to that one kid, and the other two kids**, I mean he says, "it does not explode", but that's all. The kid in the white, that's the only thing that he says, and the kid in the red is like a mute, he does not speak the entire time and I think she.
2. A: The other thing....he is only..say [inaudible]
3. D: [inaudible]
4. S: Yeah
5. D: **But I think that maybe trying to elicit responses from either of them may add to the group, 'cause you don't necessarily know.**

6. E: Yeah
7. D: **I didn't realize it until this time watching it.**
8. E: Yeah, this group is like riding on that one kid.
9. S: Yeah.
10. D: **Because they all wrote something at the beginning of the class, they all wrote something down I would assume.**
11. E: Yeah.
12. S: Right.
13. D: **So, they all have, like**
14. **E: Initial thoughts.**
15. **S: they thought about it.**
16. D: I would assume that they all have the initial thoughts, **I didn't realize until just now but.**
17. **E: Even the beginning of the video when you hear, not, she is not there but, when hearing the group's initial thoughts, it is that one kid talking [inaudible] that didn't talk the whole time.**
18. S: Yeah, he says, the other two kids said one or two little things.
19. D and B: But he is the one.
20. S: I agree, I agree. I think that's really good point, it is an important thing to think about when you're doing this kind of thing **because you can get sort of so focused on.**
21. **D: The one kid.**
22. **S: Getting the one kid to explain completely, that you don't move and say okay, can you, and she sort of tries to do that with the water, but it doesn't really take** because I think she turns to this kid in the red t-shirt to ask him about the steam and the water but,
23. D: Yeah but [inaudible]
24. S: Yeah, but he doesn't really answer. But I think that both of you bring up a really good point, **it is important when you're working in group work; and this only scales up when you are doing the whole group right, when you are talking to your whole class, if you make assumptions about what everybody understands based on one kid, you are gonna have problems, right?** So, you wanna make sure that you are engaging as best you can everybody, right? [Later in the conversation, they also negotiated alternatives Bethany could have done.] **(09.05. Episode 10)**

In this episode, in line 1, Debbie highlighted Bethany's interaction with one of the groups and her talking to only one student in the group instead of eliciting ideas from other group members. Then in line 5, she coded that eliciting ideas from other group members can contribute to the group understanding. Between lines 10-16, Debbie and Erika coded that all students had ideas because they wrote some ideas at the beginning of the class. TCs found it valuable to elicit other students' ideas and contribute to group

discussion and explanation process. Erika, Debbie and the instructor negotiated Bethany's interaction with only one kid within the group. TCs criticized her practice and found it problematic and later in the conversation negotiated alternatives or solutions she could have done to include other students' ideas. It was interesting to see how Debbie repeatedly said that "she noticed it now" in lines 1, 7 and 16, indicating that it was also interesting for her to see and identify a problematic practice in the model teacher's practice.

In the fourth claim, I presented example episodes from their discussions of Bethany's instruction and their own rehearsals. I found that TCs negotiate professional pedagogical vision more in the context of local examples of practice than in distal exemplars of practice. TCs had a more critical and problem-solving approach to decomposition of peer or their own approximations of practice, while they were more descriptive and affirmative when decomposing exemplars from ambitious science teaching. Different sources of examples of practice shaped the patterns of talk in their decomposition of practice.

While they were decomposing their own rehearsals or peer rehearsals, they tend to highlight and code a problem of practice, they describe the problem and agree on the problem then they find alternatives and solutions to the shared problem. Then, they negotiated those alternatives and solutions as well. Whereas in their discussions of ambitious science teaching practices they tend to use more descriptive and affirmative language to describe Bethany's teaching or what the students do in her class. Thus, they were in more agreement when discussing practices from the exemplars.

One possible explanation for the differences in TCs' analysis of different examples of teaching could be related to the time points of those analyses. TCs analyzed Bethany's lesson individually in the first class, and they continued to decompose her lesson as they learn ambitious

science teaching practices through readings in the first four classes of the science teaching methods class. Then, they performed their discourse 1 (eliciting students' ideas) rehearsals on the fifth, and sixth classes and they decomposed their own rehearsals individually and collectively on the fifth, sixth and seventh classes. Then, they decomposed Bethany's discourse 2 (D2) lesson: making sense of material activity on the eighth class. Then, they performed their discourse 2 (making sense of material activity) rehearsals on the ninth and tenth classes. So, the discussions regarding Bethany's lesson come from the first four classes and the eighth class, whereas the discussions regarding their own rehearsals come from fifth, sixth, seventh, ninth and tenth classes. It might be the case that TCs learned to be more critical and reflective as the semester progressed, thus had a more critical stance as they decomposed their own or peers' practices compared to Bethany's practice.

Even though the lesson, which they looked at Bethany's D2 practice, is on the eighth class and thus later in the semester, TCs did not criticize or find problems in her teaching. One of the explanations of that result could be that TCs may have the expectation that her teaching is a good example because it is shown in their class, and this is the first time they see how "making sense of material activity practice" is enacted in the classroom with the students. Another explanation could be that TCs start with the expectation that they are going to learn how to perform D2 practice from her due to the framing from the instructor of the course. Thus, the framing of the decomposition of Bethany's D2 practice by the instructor may have affected TCs' stance in how to analyze Bethany's lesson. What I meant by framing includes how the instructor framed the activity before TCs collectively looked into Bethany's D2 lesson. The reason they looked at Bethany's D2 practice on the eighth class is to learn how she did "making sense of material activity" practice with her students and the activity was not framed as how well she engaged her students in making sense of material activity, thus did not impose or suggest a

critical stance for the analysis of Bethany's teaching.

Another explanation for the pattern of seeing TCs being more critical and reflective of their own or peers' practices compared to Bethany's practice could be because of the classroom environment created in the class. In their discussions of teaching, it seemed that TCs feel safe to criticize each other, be reflective of their practice and voice their concerns or problems they see either in their own practices or their peer's practices.

In this chapter, I investigated how TCs develop professional pedagogical vision and specifically what they highlight and code in their discussions of teaching along with what material representations they produce during the first five weeks of the science teaching methods course. Findings show that TCs initially identified small set of practices representing their initial professional pedagogical vision ideas and over time they identified additional practices and became more sophisticated on all of the practices. TCs develop professional pedagogical vision through in-the-moment and over time negotiations of the teaching practices in their discussions of teaching events. Findings also showed that material representations of decompositions of teaching practice were important in scaffolding the negotiation of professional pedagogical vision. This finding emphasizes the importance of material representations in the professional pedagogical vision practices. Especially shared material representations provide additional context to negotiate and come up with clear and shared definitions of teaching among the classroom community. The last but not least, I found that TCs negotiate professional pedagogical vision more in the context of local examples of practice than in distal exemplars of practice.

Discussion of TCs' development of professional pedagogical vision

Goodwin (1994) identifies professional vision as a “socially organized ways of seeing and understanding events” (p. 606). During the science teaching methods course, TCs engaged in different activities that allowed them to observe, experience, and discuss teaching events. By examining their discussions of teaching practices and analysis of teaching videos, I aimed to understand how TCs develop professional pedagogical vision.

Findings showed that in their discussions of teaching, TCs identified a small set of practices representing their initial professional pedagogical vision and over time they identified additional practices and also become more sophisticated about all of the practices, thus developing a more sophisticated and complex professional pedagogical vision. The course instructor also facilitated TCs' development of professional pedagogical vision around teaching practices. Some of those initial practices include creating a safe environment for students to put ideas out and putting students in groups, not evaluating but guiding students, and probing.

When they observed Bethany's teaching, those were the initial practices they identified. It may be the case that TCs see Bethany's classroom structure differently from the way instruction is organized in a traditional class. Those practices such as not evaluating but guiding students' ideas, creating a safe environment to students to share ideas, are the initial practices teachers need to do to differentiate their practice from the traditional ways of thinking about instruction. Thus, TCs attended to those practices from the beginning, compared to the other practices they identified later. Once those practices are established and shared in the classroom community, they became tacit and TCs did not attend to those practices much as the semester progressed.

TCs also started to identify other practices such as using think-pair-share strategy, pressing, revoicing, types of evaluating, scaffolding students' explanation, eliciting hypothesis. However, those practices are less frequently identified by TCs and the purposes ascribed to the

practices are absent or less sophisticated. Nevertheless, it is still important that TCs were able to start identifying more sophisticated practices and as the semester progressed they developed more purposes for those practices. So, for example, TCs were able to identify pressing for explanations and reasoning on the fourth day of instruction and they continued to elaborate on their identification for pressing for explanations as the semester progressed. In addition to pressing for explanations in the pressing category they also identified another purpose, pressing to make the phenomena more focused, as the semester progressed. Thus, TCs were able to develop more sophisticated practices as the semester progressed.

There is another set of practices TCs identified only during the rehearsal discussions, which were not identified when decomposing Bethany's practice. Those practices include negotiation of the contextual nature and goals of the questions, differences in groups' understanding of the phenomena, the distribution of teachers' efforts across groups, formative assessment and use of the results of formative assessment in instruction, bringing groups together and putting ideas together, and negotiation of the content storyline and its presentation. These practices required TCs to try out instruction by themselves so they were able to talk about how to phrase questions differently, how to structure the content storyline and the presentation of the lesson, or how to bring students ideas together after they elicit all the ideas. Thus, some of those practices require TCs to try out and experience them in their own teaching rather than just observing them. However, I also think all the conversations throughout the semester may also have created a scaffold for TCs' identification of those practices. So, for example, in the data I saw many times, TCs made intertextual connections to the previous representations of practice, including Bethany's practice and peers' practices, in order to make sense and connect practices to each other. Thus, all those practices are negotiated as the semester progressed over time.

Understanding how TCs develop professional pedagogical vision around ambitious science teaching practices is important and has implications for organizing instruction for TCs in the teacher education context. Articulating which practices are initial and which practices are negotiated later in the semester will help teacher educators to push TCs to make connections between practices and help TCs develop practices.

Another claim emerged from the data is that TCs develop professional pedagogical vision through two interwoven timescales - in-the-moment and over-time negotiations of the teaching practices in their discussions of teaching events. This manifested in practices of negotiation of highlighting and negotiation of coding. Thinking about the development of professional pedagogical vision through negotiations of teaching practices contributes to the professional vision and noticing literature. The common method of investigating teacher's professional vision or noticing is through showing teachers video clips and asking them to describe what they notice individually (e.g. Colestock & Sherin, 2009). Researchers looked at the group discussions only in a few studies (e.g. Sherin & van Es, 2009; McDonald, 2016).

For example, Sherin and van Es (2009) asked teachers to watch and discuss excerpts of their teaching with peers, so they looked at how group conversations changed over time. Their analysis include content analysis of what teachers attended to during their discussions and what stances they took as they attend to the video. For example, Sherin and van Es (2009) investigated if teachers attend to students, teacher or other actors, management, climate, pedagogy or math thinking as the topics and if the teacher takes the stances of describing, evaluating or interpreting student ideas. Their focus was a categorization of the kinds of things that teachers attended to during their discussion. In this study, TCs' professional pedagogical vision is treated as a culturally shared and social negotiated collective interpretation of observed and experienced

teaching events. The analysis undertaken was intended to understand the negotiation of this shared vision both in-the-moment and over time.

The third claim emerged from the data was about material representations. I found material representations of decompositions of teaching practice were important in supporting the negotiation of professional pedagogical vision. TCs engaged in building material representations through their analysis of Bethany's teaching, as well as analysis of their own discourse 1 (eliciting students' ideas) rehearsals in both the Studiocode files and through creating lesson and unit plans. I found that negotiation of a shared material representation of decomposition of practice supports the creation of shared definitions associated with ambitious science teaching practices.

Including material representations in the professional pedagogical vision analysis is an important contribution to the literature because there is no research in the literature that considered the creation or role of material representations as part of professional vision practice. Most of the time, professional vision or noticing is investigated through what teachers attend to and what they interpret in their observations of videos (e.g. Sherin et al., 2011; Star et al., 2011; Seidel, et al., 2011), but TCs' material representations created as part of this work were not analyzed or considered in the literature.

In the professional development experiences using classroom work, such as student artifacts, to investigate teachers thinking about students' ideas is common in the literature. In noticing literature in math education, a common way that artifacts are used in professional development settings is to develop teachers' inquiry stance toward identifying and interpreting student thinking instead of evaluating student thinking (Goldsmith & Seago, 2011). Goldsmith and Seago (2011) discuss teachers' shifts in noticing over the course of artifact-rich professional development environments and effects of different types of artifacts in shaping teachers'

attention. However, the way Goodwin (1994) describes building material representations is as part of professional vision practices and requires professionals to create, build, or use the material representation in addition to highlighting and coding practices.

In the literature, the way artifacts have been used is similar to how researchers used videos to understand teachers' thinking about students or teaching through identifying what they attend to and what they interpret in the video. Artifacts or videos of instruction could both be considered the objects of inquiry, as teachers identify and interpret them, as opposed to material representations created by teachers that are expressions of their professional pedagogical vision. Thus, the way material representations are considered in my research through Studiocode timelines and their comments in notes is different from how artifacts have been used in the noticing literature.

In this data set, one of the example episodes showed how the instructor was able to recognize TCs' lack of highlighting and coding in their material representation and was able to problematize that situation in order for TCs to develop a conceptualization about whether or not putting students in the groups is a good teaching practice. Thus, material representations also provide an important formative assessment tool for teacher educators to see TCs' thinking about certain sections of the teaching events they observed.

The last claim emerged from data was TCs negotiate professional pedagogical vision more intensely in the context of local examples of practice than in distal exemplars of practice. TCs had a more critical and problem-solving approach to decomposition of the practices of their peers' or their own approximations of practice, while they were more descriptive and affirmative when decomposing exemplars from the ambitious science teaching website. When decomposing their own practices, TCs tend to identify problems in the practice; they problematize the situation,

describe and articulate the situation, and tried to find solutions or alternatives to the identified practice in their teaching.

An explanation for the differences in TCs' analysis of different examples of teaching could be related to the time points of those analyses. The conversations regarding Bethany's lesson happened earlier than the conversations around their own rehearsals. It might be the case that TCs learned to be more critical and reflective as the semester progressed, thus had a more critical stance as they decomposed their own or peers' practices compared to Bethany's practice.

Another explanation for the pattern of seeing TCs being more critical and reflective of their own or peers' practices compared to Bethany's practice could be because of the classroom environment created in the class. In their discussions of teaching, it seemed that TCs feel safe to criticize each other, be reflective of their practices.

In the literature, Seidel, Stürmer, Blomberg, Kobarg and Schwindt (2011) explored the effects of analyzing videos of one's own versus others' teaching on professional vision. Interestingly, they found no significant differences between teachers watching their own videos of teaching versus those of others with regard to professional vision. This seems to contradict the findings from my study. The way they operationalize professional vision, however, is significantly different and is based on a set of Likert scale scoring of goal clarity, teacher support, and learning climate. Then, they looked at the trends in written comments and found that teachers who watched their own videos noticed more relevant components of teaching and learning but were less self-reflective with regard to articulating critical incidents.

My research has found the opposite results in terms of being less reflective with regard to articulating critical incident. TCs were more reflective and critical when discussing their own or peers' practices compared to looking at other representations of practice. Prior research also demonstrated that discussing videos of one's own teaching in group settings leads to a shift in

teachers' attention with teachers learning to focus on student learning and the learning of subject matter (Sherin & van Es, 2009; Star & Strickland, 2008). In my findings, TCs preferred to look at the representations of practice from local teachers instead of distal examples. Later in the semester when they were asked about their preferences to watch another representation of practice from the ambitious teaching website versus a local teacher's practice, they preferred to look at the local teacher's practice because they thought they could make more connections in terms of the context and students they will be working in their student teaching classrooms. Thus, it is important to show TCs familiar representations of practices in terms of the context of teaching.

The findings of this research contribute to the literature in terms of how TCs develop professional pedagogical vision. Professional vision or noticing literature has investigated practicing teachers' or TCs' professional vision, but research around the development of comprehensive professional pedagogical vision is a few. Considering production of material representations as an evidence of professional pedagogical vision is an important contribution to the literature. The findings of this research have implications for how science teacher educators should organize and structure the instruction for TCs. The next chapter will discuss the conclusions and implications of this research study, as well as providing suggestions for future directions.

Chapter 6

CONCLUSION, IMPLICATIONS and FUTURE RESEARCH

In this study, I aimed to investigate the following research questions: 1) How do science teacher candidates negotiate meaning of ambitious science teaching practices when they engage in discussions in the first five weeks of methods course? 2) How does the professional pedagogical vision (PPV) of science teacher candidates develop around science teaching practices and what do they highlight and code in their discussions of teaching, and what material representations do they produce during the first five weeks of the science teaching methods course? I followed science teacher candidates who were enrolled in SCIED 412 course and concurrently CI 495C course during Fall 2013.

In this study teacher learning is considered as a socio-cultural and situated activity in which TCs develop understandings and practices as they interact in discourse communities over time (Lave & Wegner, 1991; Vygotsky, 2012). Socio-cultural and situated lenses on teacher learning draw our attention to the nature of teachers' participation in activities (Putnam & Borko, 2000) and the discourse in their interactions. As preservice teachers interact with other community members in their discourse communities, I consider how they develop professional pedagogical vision about teaching and learning. In this study, sociocultural theories of learning were applied to teacher candidates' negotiation of ambitious science teaching practices and their development of professional pedagogical vision. Through analysis of TCs discussions of teaching events over time, the project brings discourse analysis to pedagogical discussions of learning to teach.

Windschitl, et al., (2012) identified four core-teaching practices for science education including constructing the big idea, eliciting student ideas, making sense of material activities,

and pressing for evidence based explanations. TCs were provided with these ambitious science teaching practices as a foundation in their science teaching methods course. Using Goodwin's (1994) professional vision construct, I investigated the second research question. Goodwin (1994) introduced the term *professional vision* to refer to how professionals learn to recognize and interpret phenomena in their area of expertise and how their practices of seeing become socially recognized. He defines professional vision as "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (p. 606). Using Goodwin (1994)'s professional vision practices of highlighting, coding schemes and production of material representations, I tried to understand how secondary science TCs develop professional pedagogical vision around ambitious science teaching practices.

Using case study design, I collected data from six TCs and their instructor during a science teaching methods course. I collected various sources of data including video records, fieldnotes, documents created by the TCs as well as and given to them, and interviews with the TCs and the instructors. During the analysis of data, I used video records and fieldnotes as my primary data sources to answer the research questions. I also analyzed TCs' Studiocode files of video analysis model teacher's teaching as well as their own teaching to answer how TCs develop professional pedagogical vision. I started analysis through analyzing videos in the Studiocode to identify the events happening in the videos. Then, I used the video analysis and fieldnotes to generate event maps (Kelly & Chen, 1999). I took grounded theory approach (Corbin & Strauss, 2007) to analyze the transcribed data in this study through constant comparative method and through using interactional discourse analysis. This methodology allowed me to closely examine how TCs co-construct their own model for science teaching based on the events in the course.

Ambitious science teaching is a model of science teaching. TCs were provided ambitious science teaching tools and readings to help them develop the ambitious practices. When these tools and readings are introduced to the TCs in the class as well as when each of the episodes

occurred in the data in comparison to the readings and tools can be seen in the event maps. In the first research question, I investigated how TCs negotiate ambitious science teaching practices in their discussions of teaching events. There are few studies that investigate ambitious science teaching practices and how those practices are enacted in the classrooms (e.g. Stroupe, 2014). So, this research adds to the limited scholarship around ambitious science teaching practices.

Analysis of how TCs negotiate meaning of ambitious science teaching practices yielded three themes that contribute to the literature in important ways. The first theme was related to agency. TCs negotiated agency, who is responsible for generating the scientific explanation, through a discussion of ways of responding to students' ideas including pressing, leading, and evaluating students' ideas. TCs also negotiated who is responsible for generating the scientific explanations through a discussion of the amount of time TCs stayed in dialogue with small student groups. Their negotiations centered on the tensions and dilemmas they faced around understanding the nuanced differences between ways of responding; pressing, leading, and evaluating.

The first finding contributes to the literature in terms of how TCs negotiated ambitious teaching practices and traditional ways of instruction in two ways: one is related to how to respond to students' ideas during instruction, and the other one is related to giving agency to students in creating explanations. Prior research (Davis et al., 2006; Mikeska et al., 2009; Zembal-Saul et al., 2000) demonstrated that TCs and novice teachers tend to have very limited ideas about what to do instructionally with student ideas while teaching. The current research demonstrated that TCs do not have limited ideas about what to do with students' ideas but have difficulties in terms of deciding how to respond to students' ideas. In their post instruction discussions, TCs negotiated different ways of responding to the students' ideas including pressing, leading and evaluating. Thus, while teaching TCs were able to attend to students' ideas

and were able to take into consideration their ideas, but have difficulties on deciding how to respond to students' ideas. Levin, Hammer, & Coffey (2009) investigated teacher candidates' attention to students' ideas in their teaching and provided evidence of novice science teachers attending to student thinking from their earliest experiences in the classroom. Thompson et al. (2013) investigated preservice secondary science teachers' practices as they moved between two communities with different contextual discourses. One of the practices they investigated was working on student ideas. They found that preservice teachers' pedagogical discourses focused on eliciting students' ideas, and they also tried to understand how and under what conditions students' ideas changed over time. Similar to Levin et al. (2009), Thompson et al. (2013) also argue that novice teachers are competent on attending to student thinking. Similar to Levin et al.'s (2009) and Thompson et al.'s (2013) studies, my research findings also showed that TCs attend to students' ideas in their early experiences in the rehearsal discussions.

Another way my research contributes to the literature is around TCs' understanding of their roles in developing agency of who is responsible in creating explanations for students. Stroupe (2014) argues that students to become epistemic agents, "individuals or groups who take, or are granted, responsibility for shaping the knowledge and practice of a community" (p. 488), and ambitious instruction scaffolding students' learning of science-as-practice as students act as epistemic agents. In his case study, he found that novice teachers he investigated positioned some ideas as important by making discursive moves, signaling students to either work on the ideas as epistemic agents or, alternatively, to judge the information as "right" or "wrong".

In my study, TCs' negotiations of ways of responding to the students' ideas demonstrated that they negotiated agency of who is responsible for creating scientific explanations. The tensions TCs felt between, for example, pressing vs. evaluating students' ideas demonstrated how they negotiated who (student vs. teacher) explains the phenomenon under discussion and how the

teacher signals that to the students through ways of responding to the students' ideas. Thus, my findings support what Stroupe (2014) saw in his novice teachers' practices. In my study, those negotiations happened in their discussions of teaching after the rehearsal enactments and in his study, he investigated novice teachers' enactment of teaching in the classrooms. Thus, my study demonstrates what TCs' visions for the teaching of science are in relation to cognitive authority in explaining the phenomenon. So, for example, teachers who have a vision grounded in ambitious science instruction may create environments for students to develop science identities or let students have active science authority and agency rather than passive engagement with science.

The second theme was around explanations. TCs and the instructor negotiated what counted as an explanation along with focusing on certain aspects of scientific explanations. The negotiation occurred through discussions of the levels of explanations, the importance of evidence in the explanations and the importance of the gapless explanations they created for themselves and its relation to students' explanations. TCs took up that explanations are important, but it is not clear if they connected the gapless explanation they created to the explanation they get from the students. Also, in a few episodes, they talked about the importance of evidence in creating explanations.

Reform documents and standards identified constructing evidence based explanations as one of the science practices for students to engage in (NRC, 2012; Achieve Lead States, 2013). Constructing evidence-based explanations is critical to understanding the more conceptual ideas in science and is a valued scientific practice (NRC, 2012; Windschitl 2008). Science standards and framework require teachers to create environments for students to make sense of science and engage in the practices of science. However, creating lessons that press students for evidence-based explanations can be difficult work (Thompson et al, 2009).

Zemba-Saul (2009) proposes a framework for teaching science as argument in order to address the problems of practice preservice teachers face. She also argues that early attention to evidence and argument can leverage other important aspects of effective science teaching, such as attention to classroom discourse and the role of the teacher in monitoring and assessing students' thinking. She found that shifting preservice teachers' belief of centrality of evidence-based explanations in science is still difficult. She argued that preservice teachers have the capacity to adopt ways of thinking about science teaching that are more substantial and aligned with contemporary views of proficiency in science (NRC, 2007), as opposed to the more superficial, activity-based perspectives that dominate the literature on elementary science teaching (Davis et al., 2006; Zemba-Saul et al., 2000). My findings also showed that TCs took up that explanations are important, but they rarely talked about the importance of evidence in creating explanations. Pressing for evidence in creating explanations was a negotiation point between TCs and the instructor. My findings also show that TCs have difficulty in pressing for evidence use in explanation building. Teacher educators should emphasize the use of data in TCs' rehearsal lessons and guide them in pressing for evidence use in their rehearsals to help them attend to students' use of evidence.

In addition, several studies have demonstrated that norms for discourse and argumentation in the classroom influence how evidence is considered and contested, and those norms are deeply embedded in classrooms' cultures and histories (Berland & Reiser, 2011; Tang, 2010). Thus, teachers' pressing for evidence use in creating explanations influences how students use evidence and how the use of evidence becomes part of the culture of classroom practice in how students engage in science. Therefore, it is important that teachers consistently press their students for the use of evidence in creating explanations and make that practice a classroom norm. However, in order to engage in those practices TCs need to understand the importance of evidence use in creating explanations.

One of the aspects of explanations TCs negotiated was around the importance of the gapless explanations they created for themselves and its relation to students' explanations. TCs' gapless explanations could be related to their content knowledge. Prior research demonstrated how TCs' content knowledge impacts their classroom discourse (Carlsen, 1992; Luera, et al., 2005; Zembal-Saul, et al., 2000). In his study, Carlsen (1992) found that teachers' content knowledge influenced the extent to which they opened up classroom conversations to student participation, the range and type of questions posed to students, and their willingness to diverge from specific, defined curriculum goals.

Also, Zembal-Saul and colleagues (2000) discuss challenges new teachers face with representing content appropriately for their students due to limited content knowledge, and thus, implying challenges for planning investigations. In my study, TCs wrote gapless explanations during the planning phase. Being able to develop a complete gapless explanation was important in terms of how the teachers structure or orchestrate the classroom discourse including deciding on the questions they ask during their planning as well as phrasing the questions in the moment of teaching. My results indicate the way TCs and the instructor negotiated gapless explanation and how well they were able to press and probe students' ideas was impacted if they did not have a complete gapless explanation. Thus, current study showed that TCs negotiated once they have more of the gapless explanation, thus more content knowledge about what they are teaching, they were able to structure the classroom talk and respond better to students' ideas.

The last aspect of what counted as an explanation that TCs and the instructor negotiated was about discussions of the levels of explanations. In their performance progressions, Windschitl and colleagues (2012) used levels of explanations to describe progress in the pressing for explanations practice. They identified that the lowest level of progression is no press for scientific explanation, the lower level is what happened explanation, the middle level is how and partially why something happened explanation, and the upper level is causal why explanation. They

identified TCs' development of pressing for explanations (Discourse 3 practice) practice through these levels of explanations. In my findings, TCs and the instructor negotiated levels of explanation for students and how "why" and "how" questions enabled students to move toward the causal explanatory model for the phenomenon under investigation. In the episodes, it was typically the instructor who oriented TCs to pay attention to these levels of explanation. This indicates that in order to help TCs enact pressing for explanations (Discourse 3) practice in the upper levels of progression, teacher educators should remind them to include why explanations in their lesson plans in order to help TCs press for causal explanations.

The second theme was important in the sense that TCs negotiated the explanations during their discussions of teaching and those negotiations are helpful for science teacher educators and professional development providers to pay attention to evidence use, importance of gapless explanations and levels of explanations during discussions of teaching with teachers.

The third theme was around phenomena. TCs and the instructor negotiated what counted as a phenomenon in the lesson and its relation to the content storyline (Roth & Garnier, 2006; Roth et al., 2011) of the lesson. NGSS focus on the big ideas and moves away from organizing instruction based on fragmented and inconsistent activities to organizing instruction based on integrated systems of science ideas (NRC, 2012). In my data, TCs negotiated the nature of the phenomenon through discussing its broadness and narrowness, its explicitness in the lesson, and the focus of the lesson. Choosing an actual phenomenon as an anchoring event to pose students as an explanatory problem and helping them generate explanations for that phenomenon is the central piece of ambitious science teaching. Thus, TCs' discussions of what a phenomenon was and its broadness or narrowness were especially important for their making sense of ambitious science teaching and differentiating it from the topic-based science teaching or mile-wide inch-deep curriculum implementation.

Roth and colleagues (2006, 2011) argue that effective teachers identify clear and reasonable goals for student learning and develop coherent sequences of lessons related to these goals. They call these sequences as “coherent science content storylines.” In my data, TCs negotiated the content storyline of the lesson and its presentation and structure in relation to the phenomena. The negotiation of content storyline involves what is included and excluded from the content storyline of the lesson, the pace for the content storyline, how it is presented and set up in the lesson and how much deep science content should be included in the content storyline of the lesson.

Those negotiation points were crucial in the discussions of teaching for TCs’ understanding of productive tasks that engage and move students in normative explanation building in addition to their understanding of how the decisions they made during the planning phase affect how they orient students in the explanation of the phenomena, especially at the beginning of the lesson. Thus, negotiating content storyline, set-up and presentation of information in relation to the depth of science included considerations for both in-discourse practices as well as planning practices of the ambitious science teaching practices. The third theme also contributes to the literature as it provides specific ways TCs negotiated phenomena. Especially if we think that phenomena-based teaching is one of the new ways to think and plan instruction compared to organizing instruction around topics, it is important to understand how TCs negotiate what phenomena is in their discussions of teaching.

The findings of the first research question have contributions to the literature in terms of how TCs negotiate meaning of ambitious science teaching. Ambitious science teaching practices are demanding and difficult practices and TCs negotiated key aspects of those practices through the ways they experienced and tried out those practices. Those negotiations showed that TCs grapple between traditional ways of thinking about planning and enacting of instruction and ways promoted by the ambitious science instruction.

Professional pedagogical vision is described as socially organized ways of seeing events distinctive to a social group (Goodwin, 1994). In the second research question, I investigated how TCs develop professional pedagogical vision in the science teaching methods course. Analysis of how TCs develop professional pedagogical vision provided four claims that can contribute to the teacher education literature.

TCs initially identified a small set of important practices and over time identified additional practices, as well as becoming more sophisticated about all of the practices, thus developing their professional pedagogical vision aligned with ambitious instruction. As the semester progressed TCs move from less sophisticated ideas to more sophisticated ideas about teaching practices. They progressed to more sophisticated practices but they also got more sophisticated about the practices they identified at the beginning. TCs develop professional pedagogical vision through in-the-moment and over-time negotiations of the teaching practices in their discussions of teaching events. This is manifested in the negotiation of highlighting and negotiation of coding practices. When TCs negotiate the practices at the beginning, those negotiations may include negotiation of highlighting of the practice. Over time, the negotiations of teaching practices may turn into the negotiation of the coding schemes including the purposes and meanings of those highlighted practices. Understanding how TCs develop professional pedagogical vision is important. Those findings will provide information and guidance for teacher educators to organize instructional activities for TCs.

Studies of science-in-action document the processes by which scientific knowledge is discursively created by working members of scientific laboratories (Knorr-Cetina, 1995; Latour & Woolgar, 1986). Framework and NGSS argue that students' learning in science should involve the integration of knowing and doing science (Knorr-Cetina, 1999; Latour, 1990). Drawing from studies of sociology of scientific knowledge, Kelly and Crawford (1997) also investigated science-in-the-making in a physics classroom through bringing together ethnography and

discourse analysis to study school science. In the analyses of these studies, researchers gave priority to discursive practices to understand how knowledge is created in the moment by groups of scientists and students. Thus, these studies investigated what counts as science through tracing groups' interactive discursive patterns in and through language. We can think of TCs' development of professional pedagogical vision through in-the-moment and over-time negotiations of the teaching practices as science-teaching-in-the-making. There could be parallels in how students or scientists make science to how TCs' develop ideas about science teaching.

Most of the time, professional vision or noticing is investigated through what teachers attend to (Sherin et al., 2011; Star et al., 2011), and what they interpret in their observations of videos (Jacobs et al., 2011; van Es, 2011) or in their students' artifacts (Goldsmith & Seago, 2011), but asking teachers create material representations is a neglected part of professional vision literature. In my study, findings show that producing material representations of decompositions of teaching practice were important in supporting the negotiation of professional pedagogical vision. TCs engaged in building material representations through their analysis of Bethany's teaching as well as analysis of their own Discourse 1 rehearsals in the Studiocode files and through creating lesson and unit plans. Findings showed that negotiation of a shared material representation of decomposition of practice supports creation of shared definitions associated with ambitious science teaching practices. This finding shows that it is important to ask TCs develop material representations that can yield their professional pedagogical vision. Material representations can make TCs' thinking about instruction visible for the teacher educators and can help the classroom community have shared understandings about the practices under discussion.

Research on video-based approaches in teacher education shows that classroom videos can improve teachers' abilities to notice and analyze teaching and learning situations (Brophy, 2004; Star & Strickland, 2008; Sherin & van Es, 2009). Prior research studies focused on

teachers' learning with their own or others' videos (Kleinknecht & Schneider, 2013; Seidel et al., 2011; Zhang et al., 2011). For example, Seidel and colleagues (2011) explored the effects of analyzing videos of one's own versus others' teaching on professional vision. Interestingly, they found no significant differences between teachers watching their own videos of teaching versus those of others with regard to professional vision. Then, they looked at the trends in written comments and found that teachers who watched their own videos noticed more relevant components of teaching and learning but were less self-reflective with regard to articulating critical incidents. This seems to contradict the findings from my study.

In my study, findings showed that TCs negotiate professional pedagogical vision more intensely in the context of local examples of practice than in distal exemplars of practice. TCs had a more critical and problem-solving approach to decomposition of the practices of their peers' or their own approximations of practice, while they were more descriptive and affirmative when decomposing exemplars from the ambitious science teaching website.

Some research studies also found that analyzing one's own teaching increases the extent of emotional involvement, and allows the teachers to relate themselves to the situation more intensely (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Kleinknecht & Schneider, 2013). In my study, when decomposing their own practices, TCs tend to identify problems in the practice; they problematize the situation, describe and articulate the situation, and tried to find solutions or alternatives to the identified practice in their teaching. Thus, they negotiate professional pedagogical vision through problem solving approach in their own or peers' practice. They do not seem to have negative emotions about their own or their peers' practice. TCs' discussions of teaching facilitated by the course instructor and the classroom environment that the course instructor created may have allowed TCs' to have a critical stance in their own teaching.

Various research studies showed that it might be difficult for teachers to talk about one another's practice. They may be reluctant to critically examine the instruction (Rosenholtz, 1989),

so they may promote a conversation that is friendly and agreeable (Levine & Marcus, 2007). My findings about how TCs talked about exemplar teacher's practice support the findings from these research studies, but do not support the findings of how they talked about their peer's practice. TCs were more descriptive and affirmative when decomposing exemplars from the ambitious science teaching website. TCs tend to describe what the exemplar teacher is doing or what the students are doing without being critical to the exemplars' practice. Thus, they were in more agreement when discussing practices from the exemplars.

The difference between how they talked about their own practice and exemplars' practice can be explained through the time points of the analysis for the exemplars' practice and TCs' own rehearsal discussions. The analysis of exemplars' practice occurred earlier in the semester than the analysis of their own rehearsals. Thus, TCs may have learned to be more critical and reflective as the semester progressed. This difference could also be explained through the created classroom environment in the science teaching methods class. TCs seemed to feel safe to criticize and be criticized by each other and be open to improvement in their practices. Borko et al. notes, "the use of videos more readily exposes actual teaching practices and therefore requires a higher level of trust and respect (2008). Thus, TCs seemed to have a higher level of trust in the classroom, and feel safe to criticize each other's teaching. The current research adds to that literature in terms of providing information about which videos could be used as activities for TCs in the methods classes and how the classroom culture should be organized in order to make TCs feel safe about observing their own videos.

The findings of this research study have several implications for the practice of teacher education and professional development. The findings contribute to the understanding of TCs professional pedagogical vision around ambitious science teaching practices and how they negotiate ambitious science teaching practices in their discussions of teaching events.

Based on the findings of how TCs negotiate ambitious science teaching practices, the following implications can be suggested for teacher educators who use ambitious science teaching practices as a framework in their methods courses. In the continuum of pressing, leading and evaluating students' ideas, TCs were able to identify and recognize the differences of these practices but there were problems and difficulties in the enactment of nuanced differences between traditional science teaching and ambitious science teaching practices. How can we help them to enact these differences in the teaching and how can we support that? Windschitl et al., (2012) has developed tools for the ambitious science teaching practices. What tools can be developed to help TCs enact the nuanced differences in these practices? I wonder if we provide my coding framework as a tool or a guidebook to help TCs recognize nuanced differences between practices and help them enact the practices. Discourse tools Windschitl and his colleagues put together guide TCs to develop lessons to enact each discourse practice with their sub-practices. The coding framework is developed based on how TCs negotiate teaching practices after they enacted them in their own rehearsals or after watching model teacher's teaching. Thus, coding framework includes how TCs make meaning of those practices and how they negotiate the tensions. We can provide my coding framework as a guidebook to help TCs differentiate how they enacted these practices in their teaching. So, my coding framework can be used to analyze their own teaching after they taught their lessons, and may help TCs see the differences between practices or at least to consider looking for those differences between practices.

Findings show that TCs have some struggles differentiating between pressing questions and leading questions. Teacher educators should provide opportunities for TCs to pay attention to the questions they used in teaching and discuss the goals and purposes of those questions. Those opportunities could be created during the decomposition of practice either through decomposing their own practice or exemplars' practices.

My findings show that TCs negotiated pressing for evidence based explanations versus pressing for clarity in the explanations. That negotiation might be because of their experiences in the science teaching methods course. Teacher educators should provide more opportunities for TCs to engage their students in multiple material activities, that may help TCs to press for evidence based explanations and help their students to create evidence based explanations drawing from different types of experiences. Thus, that experience may help TCs to see a coherent content storyline that ties multiple evidences to construct an explanation for the phenomena. Making sense of material activity includes the D2 practice and based on this finding we can extend this implication to other practices as well. So, if we want TCs to learn and understand ambitious science teaching practices with meaning, then teacher educators need to engage TCs in multiple and extended experiences with each practice.

“Making sense of material activity” helped the TCs have conversations around evidence-based explanations. However, only Erika included actual data in her material activity to help students create evidence based explanations, and the discussion about evidence based explanations were limited because they did not have examples of representations of practice to refer to the evidence. The only discussion of evidence based explanation came up was during the Erika’s lesson discussion. For that purpose, teacher educators may need to be more selective about the kinds of material activities that the TCs do in their lessons. Since the experiences that teacher educators can allow for different lessons are limited in terms of the time in the semester, teacher educators need to choose them very carefully and promote to use real data or some sort of models that can be used as data so that the TCs can refer to those in pressing for explanations.

The relationship of evidence to a gapless explanation was also a point of tension for the TCs. When TCs were creating their gapless explanation, the instructor did not require them to write their explanation as evidence based, he wanted them to write very detailed and rich explanation but it does not have to be evidence based. So, teacher educators should ask TCs’

gapless explanation to be evidence based and should scaffold their gapless explanation so that TCs can see the role of evidence on students' constructing explanations. This can happen during the science teaching methods courses. TCs can create their lesson plans including their gapless explanations and before they teach their lessons, teacher educators can provide feedback on the lesson plans focusing on their gapless explanations, use of evidence or their notes to press for evidence in students' explanations. Through that feedback, TCs will be more cognizant of pressing for evidence use in students' explanations.

Based on the findings of how TCs develop professional pedagogical vision around teaching practices, the following implications can be suggested for teacher educators to organize instruction for TCs. First, knowing which practices (such as putting students in groups, creating safe environment to put students' ideas out) are developed initially and which practices (such as negotiation of contextual nature and goals of the questions, negotiation of content storyline and its presentation) are developed later in the semester provides ideas on how to organize teaching methods courses for TCs and helps teacher educators focus on certain practices before other practices. Second, findings also show that asking TCs develop material representations provided a visible discussion context for their professional pedagogical vision, so teacher educators should ask TCs to develop material representations such as lesson plans, assessments or certain tools (e.g., RSSTs) that can yield TCs' professional vision and sharable among classroom members. Third, findings suggest that TCs were more reflective and critical to their own videos compared to the model teacher's videos. Teacher educators should provide opportunities to decompose TCs' videos of teaching individually as well as collectively in the classroom through using specific prompts to focus on certain practices.

Implication for the researchers interested in investigating TCs' or teachers' professional pedagogical vision includes asking TCs or teachers to develop material representations and taking

into consideration the creation of material representations as part of their professional vision along with highlighting and coding practices. Another implication for the researchers is to investigate TCs' professional pedagogical vision through social and situative lens rather than on the individual teacher thinking. Researchers may investigate how teachers collectively develop professional pedagogical vision and use discourse analysis to determine how they accomplish that in a given context.

The research findings suggest that these activities helped TCs develop professional pedagogical vision and helped them negotiate ambitious science teaching practices. Are there teacher educator practices that are more refined and nuanced than the pedagogies of practices (representations of practice, decomposition of practice and approximations of practice) that can help TCs develop and enact these practices? What are the ambitious science teacher educator practices that can help TCs enact nuanced differences between practices?

McDonald, Kazemi, and Kavanagh (2013) argue that teacher education should redesign not only the curriculum for learning to teach but also the pedagogy of teacher education. In the math education literature, there has been a growing area of research investigating how teacher educators can create learning environments that promote TCs' development of ambitious math instruction. In those environments, teacher educators support TCs' engagement in ambitious teaching by focusing on practices that use students' participation and learning opportunities, such as eliciting and responding to students' ideas and orienting them to each other's thinking and the big ideas in mathematics.

During the methods classes, the pedagogy of teacher education includes articulating the teaching practices in detail, and engaging TCs in scaffolded opportunities to study and practice each one, usually first using videos or other records of practice, then in simulated situations with

their peers, and finally in K-12 classrooms, where they are often closely coached (e.g., Lampert et al., 2013; McDonald et al., 2013). To engage TCs in the core practices of teaching, teacher educators are trying out, for example, the practices of modeling (e.g., McDonald et al., 2013) and rehearsals (Kazemi, Ghouseini, Cunard, & Turrou, 2015) and other “approximations” of practice (Grossman et al., 2009; Lampert et al., 2013), and the use of video and other artifacts of teaching for representing and decomposing practice (e.g., Ball, 2013; Ghouseini & Sleep, 2011).

While majority of those studies focused on which activities or pedagogies of enactment are helpful for designing teacher education classrooms to engage TCs in ambitious teaching practices, other studies investigated TCs’ learning of the core practices. For example, Ghouseini (2015) investigated TCs’ enactment of ambitious aspects of teaching such as leading classroom discussions, specifically on orienting students to each other's ideas. Similarly, Freeburn (2015) investigated some key practices that constitute facilitating classroom mathematics discourse such as assessing questions and advancing questions and judicious telling in a methods course. He examined what TCs learn about those types of questions and in what ways the course activities were connected to their learning. He found that TCs constructed conceptions of those types of questions that were oriented towards focusing on and promoting students’ mathematical thinking. He also found that while there were similarities among the TCs’ conceptions of questions, TCs constructed these conceptions in individually distinct ways. Freeburn’s study has similarities to my study in terms of looking at TCs’ conceptions of specific practice and how they made sense of those specific types teacher questions.

The studies that examined TCs making sense of specific practices are rare in the math education literature too. Thus, more research about TCs’ making sense of teaching practices is needed. McDonald et al., (2013) argue, “variation in core practices within and across content areas offers rich opportunities for the field to grapple with ways of parsing practice that support

teachers' learning" (p. 381).

Limitations of the Study

Addressing limitations of the study is important for the researcher and the readers to recognize for future research as well as for judging the findings of the current study. In a qualitative study, participant selection methods can have an inherent potential for bias. Purposive, convenience and theoretical sampling strategies may produce a biased sample (Bogdan & Biklen, 2006). This study took place in one semester of a science teaching methods course with a limited number of students in one mid Atlantic university's teacher education program. It was a convenience site for the researcher.

One of the limitations of the study is the number of participants. A factor that impacted the small number of participants was there were some difficulties with some of the participants completing the course or completing all the requirements of the course due to some personal problems. Given that the research design of the study includes a single case study with embedded unit of analysis, more participants would have enriched the conversations around teaching events. If I had chosen individual TCs as my cases, then small number of participants would not have been a limitation but since I chose the group of TCs as my case, this may be considered as a limitation of the study. However, having a small number of participants is not atypical for a case study design.

During data collection process, I could not go to the field experience schools and that may have limited the study in terms of recording TCs' experiences in the schools and my understanding of how their visions are affected by their mentor teachers. During the data analysis phase, I only analyzed classroom discussions and their Studiocode analysis of teaching videos.

Thus, this may have limitations for understanding the individual TC visions regarding teaching practices. Interviews may give additional insights about how individual TCs think about ambitious science teaching practices, but interviews were not analyzed for the dissertation.

It is also important to acknowledge my biases toward how I see learning and how I analyzed it in the data. As a doctoral student in the same program in science education as the TCs, my views on teaching have been impacted in similar ways to the TCs. Being part of Penn State discourse group has also influences on my analysis as I took ethnographic data collection methods and interactional discourse analysis methods for my analysis. Coming from a perspective that appreciates interactive discourses that meaning is created in sociocultural environments, I investigated the research questions in this study. Thus, this study is embedded and influenced by those views.

Another potential issue that I need to acknowledge is I collected the data from my dissertation advisor's classroom where he was teaching the science teaching methods course. Thus, I had the privilege to have continuous conversations about the TCs and the course activities, so it helped me understand his practice and getting into the mind of the instructor. I had conversations before and after each class. Also as I started the analysis, I received constant feedback for my interpretations as he provided insider perspective. While collecting data from my dissertation advisor's classroom can have benefits, this situation may also involve some weaknesses. I might have felt pressure to convey his facilitation during the course in a positive way, given the power dynamics of a grad student and an advisor.

Future research

In this study, I used the data from the first five weeks of the instruction when TCs were in the science teaching methods course. I have different sources of data collected during the science teaching methods course. The following research projects could be potential research studies for the field.

During the analysis of professional pedagogical vision research question, I started to identify how the teacher educator facilitated the conversations and helped TCs develop professional pedagogical vision around ambitious science teaching practices. So, through continuing the analysis of the first five weeks and paying attention to teacher educator discourse, researchers can come up with ambitious science teacher educator practices. Teaching practices that teacher educators use to help TCs develop ambitious science teaching practices that are a smaller grain sized than pedagogies of practices that Grossmann and her colleagues (2008; 2009) offered. This line of research will have contribution for the broad teacher education research community.

In the continuum of future research, researchers can investigate how TCs talk about their experiences from the field in mentor teachers' classroom and how they compare those experiences to the science teaching methods course. Researchers can investigate that through TCs' interviews during the field experience as well their discussions of the field experiences in the methods course after the field experience component of the course ended. Findings from this potential research may have results regarding how TCs' professional pedagogical vision is shaped through the different context and different visions around teaching and may have implications for the arrangement and structure of the relationship of methods courses as well as field experience classrooms.

Another future research direction could be to look at TCs enactment of the rehearsals for ambitious science teaching practices and maybe focusing on the specific tensions they identified in their discussions of teaching and how those played out in their enactment. Also triangulating those enactments with their goals for the rehearsals and their reflections of those rehearsals through looking at their pre-post interviews around each rehearsal could be a way to investigate that line of research. The last potential research project would be to investigate how TCs' ideas about students' ideas emerged in their discussions as well as in the material representations including rapid student survey tools (RSSTs) from the field, their interviews, and their discussions of the teaching.

All these research projects I described above are related to the data I have already collected. For future implications of where I am going with this data and line of research includes implementing ambitious science teaching practices in my own science teaching methods classes possibly with large number of the middle school level teacher candidates in a different context. We did not talk extensively about phenomena-based teaching aspect in this research, but for future research area researchers can develop curriculum resources or editable lesson plans for the possible phenomena that TCs can use in their future classrooms where they can take those ideas and implement them in the real classrooms with the K-12 students. This idea is similar to Hiebert and Morris's (2012) idea of shared lesson plans and assessments that are co-developed with researchers that have certain visions for the science teaching and learning as a model for practice based teacher education.

This research was based on investigating a semester long science teaching methods course. Researchers can extend this research into studying the teachers' preparation and professional learning opportunities longitudinally in their student teaching semesters as well as their first year teachings as a future direction.

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Appendix A

IRB proposal first page

Institutional Review Board (IRB)
The Office for Research Protections
The 330 Building, Suite 205
University Park, PA 16802 | 814-865-1775 | ORProtections@psu.edu

Submitted by: Arzu Ozcelik
Date Submitted: July 26, 2013 11:32:26 PM
IRB#: 43485
PI: Arzu Tanis Ozcelik
Review Type: Exemption
Protocol Subclass: Social Science
Approval Expiration: -pending-
Class Project: No

Study Title

- 1>Study Title**
Examining Preservice Science Teachers' development of professional pedagogical vision in science teaching
- 2>Type of eSubmission**
New

Home Department for Study

- 3>Department where research is being conducted or if a student study, the department overseeing this research study.**
Curriculum and Instruction

Review Level

- 4>What level of review do you expect this research to need? NOTE: The final determination of the review level will be determined by the IRB Administrative Office.**
Choose from one of the following:
Exemption

5>Exempt Review Categories:

Choose one or more of the following categories that apply to your research. You may choose more than one category but your research must meet one of the following categories to be considered for exempt review.

Appendix B

IRB approval

Date: August 01, 2013

From: The Office for Research Protections - FWA#: FWA00001534
Jodi L. Mathieu, Research Compliance Specialist

To: Arzu T. Ozcelik

Re: Determination of Exemption

IRB Protocol ID: 43485

Follow-up Date: July 31, 2018

Title of Protocol: Examining Preservice Science Teachers' development of professional pedagogical vision in science teaching

The Office for Research Protections (ORP) has received and reviewed the above referenced eSubmission application. It has been determined that your research is exempt from IRB initial and ongoing review, as currently described in the application. You may begin your research. The category within the federal regulations under which your research is exempt is:

45 CFR 46.101(b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Given that the IRB is not involved in the initial and ongoing review of this research, it is the investigator's responsibility to review [IRB Policy III "Exempt Review Process and Determination"](#) which outlines:

- What it means to be exempt and how determinations are made
- What changes to the research protocol are and are not required to be reported to the ORP
- Ongoing actions post-exemption determination including addressing problems and complaints, reporting closed research to the ORP and research audits
- What occurs at the time of follow-up

Please do not hesitate to contact the Office for Research Protections (ORP) if you have any questions or concerns. Thank you for your continued efforts in protecting human participants in research.

This correspondence should be maintained with your research records.

Appendix C

Interview Questions

Interview Questions for TCs

Interview Questions before teaching

1. What topic/big idea are you teaching in this lesson? What phenomenon are you teaching?
2. What topics do you think these students need to learn to understand the phenomena?
3. What questions are you using to get student ideas? Why you think these questions will be helpful to get student ideas?
4. What Student ideas are you expecting in this topic? Why?
5. How do you think you will engage the students in science?
6. What kind of scientific practices will students engage in the lesson? How are you planning to support their engagement?
7. Do you have any concerns about the lesson? Why?

Interview Questions after teaching

1. How do you think the phenomena you used helped students to understand science ideas?
2. How did you handle student ideas? Were there anything you would respond differently?
3. Were you expecting these ideas before teaching?
4. How did you engage students in scientific practices? Were there anything you would like to do differently? Use specific practices they mentioned in the first interview.
5. Did you do what you have planned? Why? Why not?
6. What were your successes during the instruction?
7. Do you think you missed any instructional opportunities during instruction?
8. What do you think about the debrief/analysis section after the teaching?
9. How do you think these analysis sections help or constrain your thinking about teaching, student ideas, and engaging students in scientific practices?
10. What do you think about the class itself? How do you find/feel about the analysis sections? Are you comfortable with the analysis?
11. What have you learned from the analysis of your teaching?

Interview Questions for TCs during field experience

1. Could you reflect on your experiences in your mentor's class?
2. How do you define his/her teaching?
3. How do you think the school context support/constrain your mentor teachers' teachings?
4. How is your experience working in this school and with your colleagues?
5. You were in Sean's class and now you are in your mentor teacher's classroom, how is that similar or different in terms of planning and teaching the lessons?

6. How does this context shape your choices? Things you might have done if it was in Sean's class versus things you are doing in this context?
7. Interview Questions related to their experiences in the methods class
8. Reflect your experiences in your methods class
9. How do you think about Scott's teaching or the teaching you observed from Bethany?

Interview Questions for the SCIED 412 instructor

Interview 1:

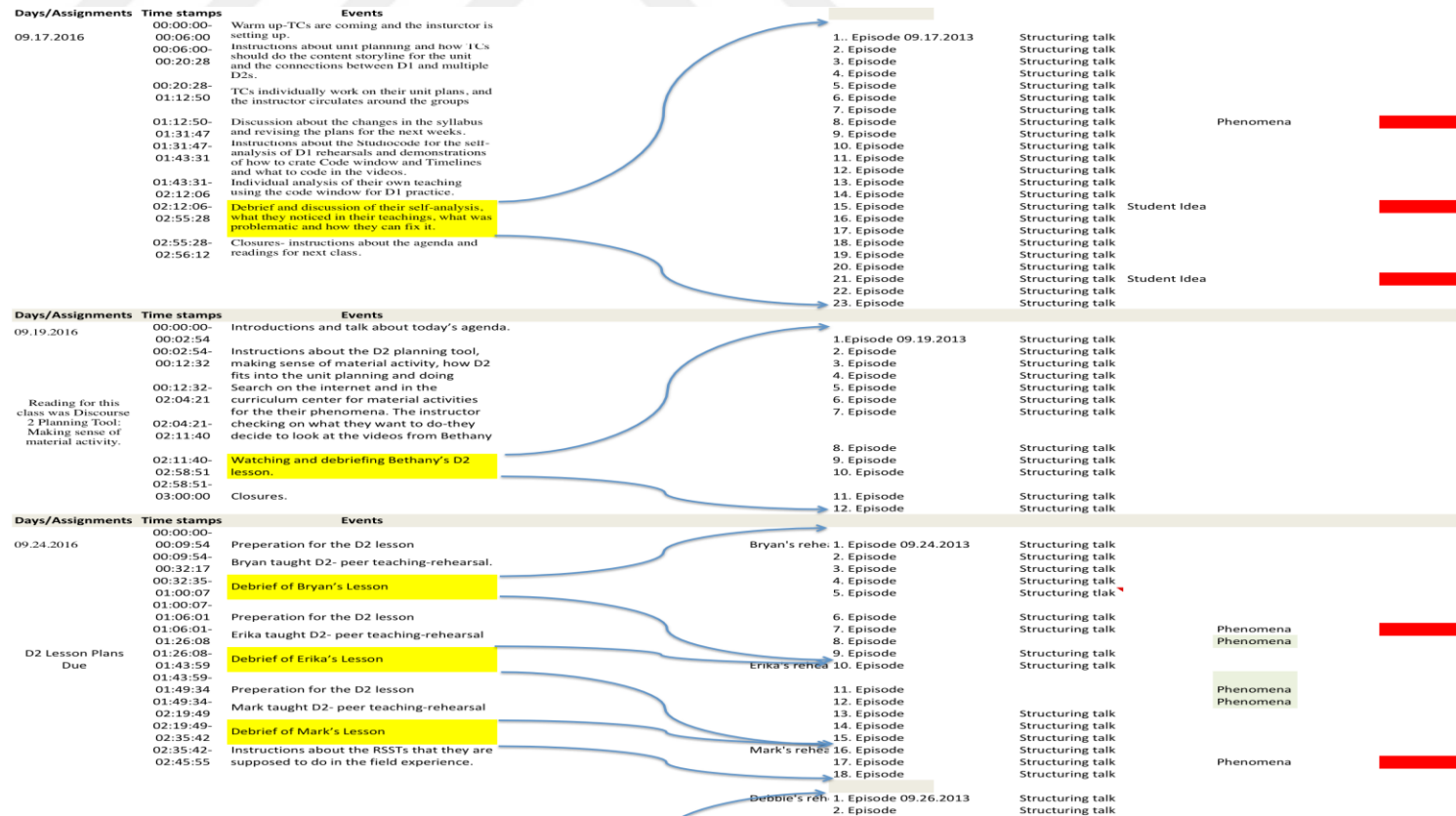
1. How do you plan the SCIED 412 course?
2. What are the main instructional routines preservice teachers will be experiencing?
3. How are you planning to support their learning to teach?
4. What are they required to read in the class?
5. What are the expectations for them?
6. How is the course laid out?
7. Do you think it is important to consider student ideas? Why? Why not?
8. How do you consider student ideas in your classes?
9. Do you think it is important to engage students in scientific practices? Why?
10. How could you engage your students in scientific practices?
11. How are you planning to press on SI and engaging students in SPs?
12. What kind of vision do you have about teaching science?

Interview questions for the CI495C instructor

Interview 1:

1. How do you plan the CI495C course?
2. What are the main instructional routines preservice teachers will be experiencing?
3. How are you planning to support their learning to teach?
4. What are they required to read in the class?
5. What are the expectations for them?
6. How is the course laid out?
7. Do you think it is important to consider student ideas? Why? Why not?
8. How do you consider student ideas in your classes? Could you give an example of how you do it?
9. Do you think it is important to engage students in scientific practices? Why?
10. How could you engage your students in scientific practices?
11. How are you planning to press on SI and engaging students in SPs?
12. What kind of vision do you have about teaching science?
13. How/what do you think about SI and engaging students in scientific practices?
14. How do you prepare your students to learn to understand student ideas in the instruction and how do you prepare them to engage their kids in scientific practices?
15. What kind of feedback you have given them in their instruction? Are there specific patterns that you saw in their teaching?

Appendix D



Appendix E

Coding Framework Table for Structuring Talk Codes

PRESSING (85)	General pressing (8)	Talk is about pressing students' ideas. TCs identify when the teacher pressed students' ideas or they reflect on when they or their peers as teachers pressed students' ideas. In those episodes, TCs have not included any purposes or justifications of pressing students' ideas.	08.29. Episode 14, 09.05. Episode 5, 09.17. Episode 4, 09.17: Episode 13, 09. 17. Episode19, 09.17. Episode 22, 09.24. Episode 4, 09.26. Episode 13,
	P1: Pressing for clarity on the word meaning (7)	Talk is about pressing for clarity on the word meaning. They identified when the teacher was pressing to make the words the students use clearer, or to get the meaning of the sentences, words, phrases the students used or to get students' reasoning when they have discussions in small groups.	08.27. Episode 6, 08.29. Episode 29, 09.10. Episode 8, 09.12. Episode 4, 09.12. Episode 12, 09.26 Episode 2, 09.26 Episode 3.
	P2: Pressing for expanding the idea students have. (Elaboration) (7)	Talk is about asking students to expand or elaborate their ideas. Pressing to expand on the ideas the students have, through asking to say more, through asking to elaborate on. In these episodes, the purpose is to get more ideas from the students. Talk is not necessarily as pressing but asking too.	08.27 Episode 2, 08.27. Episode 6, 09.10. Episode 20, 09.12. Episode 9, 09.17. Episode 1, 09.17. Episode 17. 09.26 Episode 14
	P3: Adjusting	Talk is about adjusting pressing questions for high	09.10. Episode 15, 09.26. Episode 3.

	pressing questions for different student levels (2)	school students or middle school students, so TCs talk about how the questions the teachers ask needs to change to get ideas from different levels of students, such as for some students teachers try to get what they mean and for some students teachers need to make sure they get as much as ideas as possible to help them make an explanation.	
	P4: Pressing for explanation or reasoning (16)	Talk is about teachers' pressing to make explanations. In these episodes, it is not clear how the term "explanation" is used, but most of the time, it is not necessarily normative causal scientific explanation, but TCs' talking about explaining the phenomena and explaining their ideas about the phenomena. Even though the majority of episodes include explaining students' ideas and also making explanation of what, how and why is happening sort of levels of explanation, there are a few episodes including a clear emphasis on using evidence in the explanations.	09.05. Episode 2, 09.12. Episode 4, 09.12. Episode 8, 09.17. <i>Episode 9</i> , 09.17. <i>Episode 21</i> , 09.24. Episode 3, 09.24. Episode 7, 09.24. Episode 16, 09.26. <i>Episode 5</i> . 09.26. Episode 17
	P4.1: Pressing for the levels of explanation (2)	Talk is about pressing for the levels of explanation, especially for how and why part of the explanation instead of "what" explanation.	09.10. <i>Episode 4</i> , 09.10 <i>Episode 10</i> .
	P4.2. Pressing to connect student science ideas to form the explanation (2)	Talk is about pressing students to connect students' science ideas they generated to form an explanation for the phenomena they observe.	09.05. Episode 8, 09.05. Episode 9.

P4.3: Pressing for the use of evidence in creating explanations (2)	Talk is about pressing for evidence use or data use when asking students to generate explanations.	09.24. Episode 10, 09.24 Episode 15.
P5: Pressing to create external representations of the idea (7)	Talk is about teachers' pressing students to create external representations (drawing, diagraming, modeling) of their ideas. TCs identify purposes for asking students to create external representations as formative assessment, making students' ideas and reasoning visible and help students explain their ideas more. [Those are not necessarily pressing but usually talked as asking]	08.27. Episode 2, 08.27. Episode 7, 08.29. Episode 25, 09.10. Episode 8, 09.12. Episode 26, 09.19. Episode 1, 09.24. Episode 7,
P6: Importance of asking right/better question to press (5)	Talk is about asking better or right questions to press students' ideas without leading them to wrong place or confusing them.	08.29. Episode 22, 08.29. Episode 23 09.12 Episode 13, 09.17. Episode 8, 09.26 Episode 3,
P7: Importance of Gapless Explanations and its relationship to structuring talk. (11)	Talk is about the gapless explanation and how having a gapless explanation lead teachers to be able to press students' ideas and respond to the students' ideas and thus structure the classroom talk.	09.05. Episode 2, 09.10 Episode 6, 09.12 Episode 10, 09.12. Episode 17, 09.12 Episode 19, 09.12 Episode 20. 09.19. Episode 1, 09.19. Episode 2 09.19. Episode 10, 09.19. Episode 11 09.19. Episode 12
P8: Pressing to make the phenomena more focused. (12)	Talk is about pressing students' ideas to make the phenomena more focused. This is related to how TCs structured, set up and introduced the phenomena to the students. When TCs didn't introduce the phenomena well focused and left it broad in their rehearsals, they ended up asking so many questions to press students to get where/what they want them to talk about, so this code emerged when the TCs commented on the teachers' pressing	09.10. Episode 2, 09.10. Episode 3, 09.10. Episode 5, 09.10. Episode 6. 09.10. Episode 16, 09.12. Episode 17, 09.12. Episode 22, 09.17. Episode 7 09.17. Episode 8, 09.24. Episode 17, 09.26 Episode 15. 09.26. Episode 18.

		to make the phenomena more focused in their teachings. This code includes instances of Pressing for the part of the explanation the teacher wants her/his students to focus in the lesson. And Pressing students to make the connections between concepts, science ideas and related phenomena.	
PROBING (12)	General probing (3)	Talk is about probing students' ideas. In <i>general probing</i> code, TCs did not provide justification why teachers used probing. For the rest of the codes below about probing, TCs offered some purposes of probing.	08.29. Episode 14, 08.29. Episode15, 09.24. Episode 4,
	Pro1: Probing to help make the connections to prior knowledge. (5)	Talk is about probing students to help students connect the previous learning experiences gained from prior learning experiences, labs, experiments they have done before to the concepts they are learning in the lesson.	08.27. Episode 3, 08.27. Episode 4, 09.05. Episode 1, 09.05. Episode 3, 09.05. Episode 4.
	Pro2: Probing students to get more ideas from them, probing to get deeper ideas (1)	Talk is about probing to get more and deeper ideas rather than surface level ideas from the students.	08.27. Episode 1
	Pro3: How to do probing, and choosing phrases, words to use when probing (1)	Talk is about paying attention to how the model teacher, Bethany, probed students, specifically how she phrased the questions and what words she used.	08.29. Episode 21.
	Pro4: Probing students on to say scientific terms instead of everyday language (1)	Talk is about probing students to use/say scientific terms instead of everyday language.	09.24. Episode 2,
	Pro5: Concern with	Talk is about the concern of how to probe students	08.29. Episode 24

	Probing students who say "I don't know". (1)	who say, "I don't know", how to make sure to include them in the discussions and have them offer their ideas but at the same time don't give them too much information.	
REVOICING (6)	General Revoicing (2)	Talk is about revoicing/rephrasing students' ideas, they identified teachers' revoicing students' ideas without any purposes or justifications.	08.29. Episode 21, 09.10. Episode 9,
	Rev1: Revoicing ideas instead of evaluating ideas (1)	Talk is revoicing students' ideas, but TCs see revoicing as an alternative to evaluating students' ideas.	08.29. Episode 15,
	Rev2: Revoicing to put students' ideas on better track (1)	Talk is about revoicing students' ideas to put them on better track, so TCs identified the purpose of revoicing is to put students' ideas on better track towards the normative understandings and they reflect on the difficulty of that practice.	09.10. Episode 1,
	Rev3: Rephrasing with Questions (1)	Talk is about revoicing/rephrasing with questions instead of declaratively repeating what the students said.	09.12. Episode 9,
	Rev4: Revoicing to recognize ideas (1)	Talk is about revoicing students' ideas to recognize their ideas or not to dismiss the ideas students brought up even though the ideas are wrong.	09.17. Episode 21
SUMMARIZING (6)		Talk is about summarizing students' ideas. In the episodes, they highlighted and differentiated between summarizing after each group discussion (to report what ideas come out in the group) and end of the class summaries like a wrap up – summary. Another piece of talk related to summarizing includes talk about reviewing to make connections to the previous class as well as to remind students what is relevant in previous lesson.	08.29. Episode 8, 09.17. Episode 6, 09.17. Episode 8, 09.17. Episode 19, 09.24. Episode 10, 09.26. Episode 6.
PUTTING ON HOLD (2)		Talk is about putting students' ideas on hold. When	08.29. Episode 3, 08.29. Episode 11.

		the teacher acknowledged student idea but marked it to use later in the class.	
ELICITING HYPOTHESIS (6)		Talk is about eliciting students' initial ideas, hypothesis and predictions.	08.29. Episode 8, 08.29. Episode 25, 09.17. Episode 13, 09.17. Episode 21, 09.24. Episode 16, 09.26. <i>Episode 7</i> .
ELICITING OBSERVATIONS IN RELATION TO THE PHENOMENA (2)		Talk is about eliciting observations related to phenomena under discussion and what observations would look like in relation to phenomena.	09.17. <i>Episode 5</i> , 09.17. Episode 13.
PARKING LOT (2)		Talk is about putting students' ideas in the parking lot through acknowledging the idea but not bringing up in the class discussion.	08.29. Episode 3, 09.12. <i>Episode 24</i> .
NEGOTIATION OF THE CONTEXTUAL NATURE AND GOALS OF THE QUESTIONS (7)		Talk is about questions and questioning. The classroom members negotiated context of the questions in the lesson (where they appeared in the lesson such as review), structure of the questions (including open vs close) as well as the goals or the purposes of the questions (leading vs generic) in the lesson.	09.10. Episode 8, 09.12. Episode 24, 09.19. Episode 3, 09.19. Episode 12, 09.24. Episode 1 09.24. Episode 9 09.26 Episode 6,
NOT EVALUATING BUT QUESTIONING, GUIDING AND LEADING (9)		Talk is about not evaluating students' ideas but instead guide and question them to lead them to the track she/he wanted them to go in the lesson. TCs also reflect on their negotiations of not evaluating and how to respond students' ideas.	08.27. Episode 14, 08.29. Episode 15, 08.29. Episode 16, 08.29. Episode 26, 08.29. <i>Episode 27</i> , 09.05. <i>Episode 5</i> , 09.05. <i>Episode 7</i> , 09.10 <i>Episode 7</i> . 09.10. <i>Episode 19</i>
WAYS OF EVALUATING	E1: Saying "Okays": saying okay instead of pressing or Saying okay to wrong things (3)	TCs identify and reflect on the instances of evaluating their students' ideas and types of phrases they used to evaluate the students in the rehearsals. In this one, they reflect on when they say "okay" to even the wrong ideas they heard while trying to get students say more ideas and further their thinking and talking. They also reflect	09.12. Episode 24, 09.17. <i>Episode 1</i> , 09.17. Episode 11.

		that they said okay instead of pressing students to say more about the phenomena they are studying.	
E2: Tacit/implicit feedback (Facial/ body expressions): head motion, stepping back (5)		TCs and the instructor attend to the instances of when the teachers give (or not give) implicit feedback through face/body expressions to students and how these implicit feedbacks are read by students. The implicit feedback they talked about involves facial/body expressions such as head motions, stepping backs, where (to whom) the teachers look at in the groups.	09.05. <i>Episode 7</i> , 09.05. <i>Episode 11</i> , 09.12. <i>Episode 9</i> , 09.17. <i>Episode 10</i> , 09.17. <i>Episode 20</i> .
E3: Eager to evaluate when students said something you wanted without asking their reasoning, saying “correct” (9)		TCs comment on the instances of when they evaluated students’ ideas or used evaluative phrases. In some of these episodes TCs critically reflect on either themselves or their peers’ use of evaluative phrases such as “you are right”.	09.10. <i>Episode 22</i> , 09.12. <i>Episode 1</i> , 09.12. <i>Episode 2</i> , 09.12. <i>Episode 9</i> , 09.12. <i>Episode 21</i> , 09.17. <i>Episode 18</i> , 09.19. <i>Episode 6</i> , 09.24. <i>Episode 6</i> , 09.26. <i>Episode 2</i> .
E4: Redirecting students’ ideas using declarative statements [such as "try not to think about that"] (6)		TCs reflect on the instances of when they were trying to redirect students’ ideas when students have alternative or partial understandings. They reflect on the tension they had about how to respond to the ideas. Some of the tensions they felt are whether or not to ask/press questions to get their reasoning or whether or not to redirect them using declarative statements. Some of the episodes show that the TCs see redirecting ideas alternative to evaluating students’ ideas, which shows that the TCs has taken up the idea of not evaluating and thinking about redirecting as an alternative to the evaluating. Some of the episodes include self-	09.10. <i>Episode 1</i> , 09.10. <i>Episode 19</i> , 09.10. <i>Episode 20</i> , 09.12. <i>Episode 3</i> , 09.12. <i>Episode 9</i> , 09.17. <i>Episode 23</i> .

		reflection from the TCs whereas some of them include criticism-or reflection about other teachers' teaching practices. TCs and the instructor also identify instances of TCs redirecting students' ideas using declarative statements such as saying students where to go or not to go in their explanation (coded as E4 below).	
	E5: Evaluating and then Guiding: This is not just evaluating and leaving, but proposing kids to work on something else. (1)	TCs attended to the teachers' practice of evaluating kids ideas and then proposing them to work on something else, so TC attended to the importance teacher's offering guidance to the students to work on something else instead of just evaluating and leaving. This shows up that the TCs think that giving guidance or some direction to the students to work on is important.	08.27. Episode 16
SCAFFOLDING FOR THE EXPLANATION (13)	Cueing, giving hints and when to give hints (4)	The talk is about different ways of scaffolding students in creating explanations. TCs attended to different ways or using different tools to help students create explanations for the phenomena they observed/were introduced.	08.29. Episode 17, 09.05. Episode 6, 09.26. <i>Episode 4</i> , 09.26 Episode 6.
	Using aids/structures [such as, before, during and after] to connect pieces of the whole phenomena (4)		09.19. Episode 2, 09.19. Episode 5, 09.26. Episode 21, 09.26. Episode 23.
	Asking students to use representations to show the connections in explaining the phenomena. (1)		09.24. Episode 14
	Providing data helps students make the connections in creating explanations for the phenomena (3)		09.24. Episode 13, 09.24. <i>Episode 14</i> 09.24. Episode 15.

	The ways the teachers ask questions help students connect the concepts. (1)		09.26. Episode 19.
WORKING WITH THE STUDENT IDEAS (11)	Taking ideas in students' explanation and (or not being able to) building on them in the lesson (6)	The talk is about taking students ideas in their explanations and carefully using those ideas in the lesson. This also includes instances of not knowing what to do with the student ideas or a relevant example student brought up in the lesson. TCs also reflect on the decisions they made when they focused on the piece of phenomena that student brought up rather than going into the plan she prepared or the section she wants students to talk about. This code is more about how the teacher worked with/used/orchestrated ideas in the lesson.	09.05. Episode 7, 09.10. Episode 14, 09.10. Episode 19, 09.10. Episode 20, 09.19. Episode 11, 09.24. Episode 6
	Teachers' use of language and working with students' language and their choice of words (3)	Talk is about teachers' use of language and whether or not the teacher is making students' language more scientific. TCs notice teachers' deliberate use of language, scientific terms and phrases when responding to the students' ideas after he/she elicited them in the class including changing students' everyday language to more scientific terms.	09.10. Episode 8, 09.19. Episode 4, 09.19. Episode 7,
	Responding to the wrong ideas (2)	TCs commented on how the teacher allow students have misconceptions to a certain "line" and when she should interfere and does not let them to have misconceptions and how she responds them when she hears the wrong ideas from the students.	08.27. Episode 12, 08.27. Episode 13.
PUTTING STUDENTS IN GROUPS (3)		Talk is about putting students in the small groups.	08.29. Episode 18, 08.29. Episode 19, 08.29. Episode 30.
ENTERING AND EXITING	Fading in and out-non-noticeable (2)	Talk is about how teachers enter and leave the groups, what they do and say while entering and	09.10 Episode 7, 09.12. Episode 25

GROUPS (15)	Not interrupting- Lurked, and Just listening, Not evaluating (4)	leaving the groups, and how teachers' entering and leaving the groups impact students' (groups') autonomous and dependency to the teacher.	09.10 Episode 7, 09.10. Episode 12, 09.10. Episode 16, 09.12. Episode 25
	Questioning vs not questioning (3)		09.10. Episode 12, 09.10. Episode 14, 09.26. Episode 17.
	Entering and Leaving groups- noticeably (2)		09.12. Episode 5, 09.12. Episode 25
	Student/group autonomous and dependency to the teacher (2)		09.05. Episode 11, 09.12. Episode 14.
	How teacher leaves the group and how the group make changes in their understanding (1)		09.17. Episode 15
DIFFERENCES IN GROUPS UNDERSTANDING OF THE PHENOMENA and teachers' efforts to work with one group more over the other one. (4)		Talk is about differences in between groups and thus, teachers' efforts on working with (pressing, responding to, guiding) one group more over the other group.	09.10. Episode 23, 09.12. Episode 21, 09.26. Episode 8, 09.26. Episode 12.
BALANCING TALK TIME IN AND BETWEEN GROUPS, AND HOW MUCH TO STAY IN THE GROUPS (12)		Talk is about balancing talk time in and between groups and how much to stay in one group. Balancing talk time in the groups includes teacher talking to each group member and not talking only one student. How much time is spent in each group includes the amount of time spent in the groups and the frequency of teacher visits to each groups. Balancing talk time between group members include balancing the time between groups and its'	08.29. Episode 20, 09.05. Episode 10, 09.12. Episode 14, 09.12. Episode 15, 09.12. Episode 16, 09.12. Episode 17, 09.17. Episode 2, 09.17. Episode 3, 09.17. Episode 9, 09.17. Episode 12, 09.24. Episode 10, 09.24. Episode 14.

		impacts on the groups in terms of dependency to the teacher and not being able to scaffold students when they needed the teacher's attention or help at the time.	
USE OF THINK/PAIR/SHARE STRATEGY (8)		Talk is about the use of think pair share strategy, sometimes the focus is on the individual thinking part, and other times the focus is on sharing ideas in the small groups or with pairs.	08.27. Episode 8, 08.29. Episode 5, 08.29. Episode 13, 09.05. <i>Episode 10</i> , 09.10. <i>Episode 25</i> , 09.10. <i>Episode 26</i> , 09.12. Episode 26, 09.12. Episode 27
FORMATIVE ASSESSMENT AND USE OF THE RESULTS OF FORMATIVE ASSESSMENT IN INSTRUCTION (WALKING AROUND FOR FORMATIVE ASSESSMENT, NOT TO CAUGHT UP OFF GUARD) (8)		Talk is about formative assessment. Sometimes the focus is on identifying when the teacher did formative assessment, and other times the focus is on using the information gathered through formative assessment to make decisions in the instruction in the whole class discussions.	09.10. Episode 17, 09.12. Episode 9, 09.12. <i>Episode 27</i> , 09.17. Episode 16 09.19. <i>Episode 1</i> , 09.19. Episode 7, 09.19. Episode 8, 09.19. Episode 9
EVALUATING/GIVING FEEDBACK TO EACH OTHER, DISAGREEING AND QUESTIONING EACH OTHER, CONTRIBUTING TO EACH OTHER'S IDEAS IN THE SMALL GROUPS (3)		Talk is about some of the norms required in small groups and practices that students can participate in when working in the small groups in the phenomena based teaching.	08.29. <i>Episode 31</i> 09.05. <i>Episode 11</i> 09.10. Episode 25
ESTABLISHING A SAFE ENVIRONMENT FOR STUDENTS TO PUT IDEAS	Ask them to make prediction (1)	Talk is about establishing a safe environment for students to put ideas out and talk. This code identifies strategies or ways of creating a culture for students to talk and contribute to the classroom discourse. Notice how this code emerged at the beginning of the semester when they were analyzing/observing Bethany's class.	08.29. Episode 25
	Ask them to externalize their ideas (drawing) (1)		08.29. Episode 25
	Put them in the groups (2)		08.29. Episode 25 08.29. <i>Episode 26</i>
	Not evaluate their ideas (2)		08.29. Episode 26 08.29. <i>Episode 27</i>
	Question their ideas instead of evaluating (1)		08.29. Episode 27

OUT AND TALK (4)	Put students in the groups and let them ask questions to and disagree each other. (1)		08.29. Episode 31
BRINGING GROUPS TOGETHER AND PUTTING IDEAS TOGETHER, CONNECTING DIFFERENT IDEAS (5)	Talk is about bringing groups' ideas together after they worked in small groups and asking students to present/share their ideas to make it public to other groups, and teachers' connecting different ideas in the whole-group discussions.		09.10. Episode 10, 09.10. <i>Episode 17</i> , 09.19. Episode 9, 09.24. <i>Episode 14</i> , 09.26. <i>Episode 22</i> .
HOW MUCH DEEP IN THE CONTENT, OR HOW MUCH CONTENT TO BE INCLUDED IN RELATION TO PHENOMENA (2)	Talk is about how much/deep content to include in relation to the phenomena.		09.10. Episode 24, 09.10. Episode 27.
HOW TO PRESENT SCENARIO AND WHAT RELEVANT INFORMATION TO INCLUDE AND HOW TO STRUCTURE AND SET UP THE LESSON (11)	Talk is about how to present, structure and set up the information and scenario, and what to include or exclude from the content storyline of the lesson. This is not much about eliciting or working with students' ideas but more about teachers' presenting and planning the information and how he or she sequenced and paced the information in the content storyline of the lesson.		09.12 <i>Episode 7</i> , 09.12. Episode 22 09.12. Episode 26, 09.17. Episode 14, 09.24 Episode 16, 09.24. <i>Episode 18</i> , 09.26. Episode 1, 09.26. <i>Episode 8</i> , 09.26. <i>Episode 9</i> , 09.26. <i>Episode 10</i> , 09.26. Episode 16.

Appendix F

Coding Framework Table for Phenomena Codes

Categories	Codes	Description of codes/sub-codes	Example episodes
Authentic/Real phenomena (8)	Be real thing, Connecting to real life example and students' daily experiences, relatedness (5)	Talk is about phenomena being something real and is helping students make connections to real things and phenomenon is related to students' daily experiences/lives and all these connections are in service of helping them remember later.	08.27. Episode 9, 08.27. Episode 10, 08.29. Episode 9, 08.29. Episode 12, 09.12. Episode 6.
	Challenging to talk or not challenging to talk (authenticity)/provide context for science talk (3)	Talk is about phenomena providing context for science talk and enough challenge for students to be able to talk.	08.29. Episode 10, 08.29. Episode 27, 09.10. Episode 11.
Phenomena Create Student interest (6)	Create Student interest (Student attention) (6)	Talk is about phenomena creating a student interest and attention.	08.27. Episode 9, 08.27. Episode 10, 08.29. Episode 9, 08.29. Episode 10, 08.29. Episode 27, 09.12. Episode 6.
Material activity and the Phenomena (3)	Connection between the material activity and the larger phenomena (3)	The talk is about how the material activity helped students connect it to the larger phenomena and helped students to see the big picture.	09.24. Episode 8, 09.24. Episode 12, 09.26. Episode 21.
Narrow ~~vs~~ Broad (13)	Narrow ~~vs~~ broad, Making the phenomena narrower or clearer, breaking it apart. (13)	Talk is about phenomena being narrow ~~vs~~ broad and how the phenomena should be narrowed down and what could be done to narrow it down to make it clearer in the lesson.	09.10. Episode 2, 09.10. Episode 6, 09.10. Episode 11, 09.10. Episode 16, 09.12. Episode 11, 09.12. Episode 13, 09.12. Episode 17, 09.12. Episode 20, 09.12. Episode 21, 09.17. Episode 8, 09.24. Episode 11, 09.24. Episode 17, 09.26. Episode 23
Making the focus of the lesson Apparent (16)	Focusing on the things "you" want them to focus on, Making the focus of the lesson apparent (16)	Talk is about the focus of the lesson and how to make the focus of the lesson more apparent and focusing on the things/parts of the explanation that the teacher wants students to focus on.	09.10. Episode 2, 09.10. Episode 3, 09.10. Episode 4, 09.10. Episode 11, 09.10. Episode 16, 09.12. Episode 17, 09.12. Episode 20, 09.12. Episode 21, 09.12. Episode 22, 09.17. Episode 8, 09.24. Episode 7, 09.24. Episode 11, 09.24. Episode 17, 09.26. Episode 11, 09.26. Episode 15, 09.26. Episode 23.

Appendix G

Coding Framework Table for Student Ideas Codes

Categories	Codes	Description of codes/sub-codes	Example episodes
	Negotiation of labeling Students' Ideas. (Misconception-Wrong ideas-Alternative ideas, partial understandings, productive ideas) (11)	Talk is about identifying students' ideas as misconceptions, wrong ideas, alternative understandings, partial understandings, and productive ideas.	08.27. Episode 12, 08.27. Episode 13 08.27. Episode 15, 08.27. Episode 16 08.29. Episode 5, 08.29. Episode 6 08.29. Episode 7, 08.29. Episode 29 09.10. Episode 18 09.17. Episode 15 09.17. Episode 21
Prior Knowledge (14)	Levels and types of prior knowledge and how to work with different levels of prior knowledge (5)	Talk is about the students' level of prior knowledge and how to work with students from different knowledge levels, Talk is also about students' knowledge types in terms of random knowledge the students bring about the phenomena from their daily lives (out of school experience) and knowledge they bring from previous lessons or sequences of lessons (school based). Relatedness of the student idea	08.29. Episode 4 09.10. Episode 13 09.10. Episode 15, 09.10. Episode 23 09.12. Episode 8 09.12. Episode 18
	Using prior knowledge to make explanation and required prior knowledge (4)	Talk is about using prior knowledge to make explanations and required prior knowledge to make explanations.	08.27. Episode 5, 08.29. Episode 2 08.29. Episode 28, 09.10. Episode 26
	Student's statues of prior knowledge (3)	Talk is about statues of prior knowledge; TCs wondered the statues of students' prior knowledge.	08.27. Episode 11, 08.29. Episode 1 09.10. Episode 25
	Scaffolding Students' Prior knowledge (2)	Talk is about scaffolding students' prior knowledge through introducing the representations and targeting with "guess my head" type of questions or reviews.	09.26. Episode 6, 09.26. Episode 20
	Expected/Unexpected Student Ideas/Prior knowledge (5)	Talk is about the unexpected ideas that came up in the lesson and how the teacher dealt with them and the expected ideas or prior knowledge and did not come up in the lesson.	09.10 Episode 14, 09.10 Episode 21 09.10. Episode 22, 09.26 Episode 17 09.26. Episode 18

Appendix H

SCIED 412 Course Syllabus

Week 1 - Tues, 27 Aug	Analysis of Video	
Thurs, 29 Aug	Analysis of Video	Philosophy of Science Teaching (Draft 1) Discourse Primer (T4TS) Anchoring Events (T4TS) Feynman, “What is Science?”
Week 2 - Tues, 03 Sept	Analysis of Video	NGSS, Executive Summary Models and Modeling (T4TS) Big Idea Primer (T4TS)
Thurs, 05 Sept	Analyzing/Planning for D1	Big Idea Tool (T4TS) RSST (T4TS)
Week 3 - Tues, 10 Sept	Discourse 1 (round 1)	
Thurs, 12 Sept	Discourse 1 (round 2)	
Week 4 - Tues, 17 Sept	Analysis of Practice D1	
Thurs, 19 Sept	Planning Discourse 2	D2 Planning Tool
Week 5 - Tues, 24 Sept	Discourse 2 (round 1)	
Thurs, 26 Sept	Discourse 2 (round 2)	
<i>6 weeks of CI 495C field experience in schools - No Class Meetings* (*Weekly RSST Due)</i>		
Week 12 - Tues, 12 Nov	Analysis of Practice D2 Debrief of Field Placement	
Thurs, 14 Nov		
Week 13 - Tues, 19 Nov		
Thurs, 21 Nov		Safety Portfolio Due

VITA
Arzu Tanis Ozcelik
The Pennsylvania State University
118 Chambers Building
University Park PA, 16802
axt252@psu.edu

EDUCATION

The Pennsylvania State University, University Park, PA

Ph.D. Curriculum and Instruction, Science Education; August 2011-December 2016

Dissertation: Science Teacher Candidates Developing Professional Pedagogical Vision Around Ambitious Science Teaching Practices

The Pennsylvania State University, University Park, PA

Master of Science. Curriculum and Instruction, Science Education; August 2009- August 2011

Master Thesis: Preservice Science Teachers' Use of Inscriptions in Their Peer Teaching Activity.

Karadeniz Technical University, Trabzon, Turkey

BS and M.Ed. Secondary Science & Math Education, Physics Teaching; September 2002-June 2007

PUBLICATIONS

Plummer, J. D. & **Tanis Ozcelik, A.** (2015). Preservice Teachers Developing Coherent Inquiry Investigations in Elementary Astronomy. *Science Education*, 99 (5): 932-957. DOI: 10.1002/sce.21180

Tanis Ozcelik, A. & McDonald, S. P. (2013). *Preservice Science Teachers' Use of Inscriptions in their Peer Teaching Activity*. *Journal of Science Teacher Education*, 24, 7, 1103-1132. DOI 10.1007/s10972-013-9352-1

SELECT PRESENTATIONS

- **Tanis Ozcelik, A.** & McDonald, S. P. (2017, April 22-25). Developing Professional Pedagogical Vision through the Negotiation of Ambitious Science Teaching Practices Symposium paper is submitted for the 2017 Annual International Conference of National Association of Research in Science Teaching (NARST), San Antonio, TX.
- **Tanis Ozcelik, A.** & McDonald, S. P. (2016, April 14-17). *Negotiating Tensions: Development of Ambitious Science Teaching Practices*. Paper was presented at the 2016 Annual International Conference of National Association of Research in Science Teaching (NARST), Baltimore, MD.
- McDonald, S. P. & **Tanis Ozcelik, A.** (2016, April 14-17). *Preparing novices for ambitious instruction: A look at different opportunities in learning settings*. Symposium paper was presented at the 2016 Annual International Conference of National Association of Research in Science Teaching (NARST), Baltimore, MD.
- McDonald, S., Bateman, K. M., Gall, H. D., **Tanis Ozcelik, A.**, Webb, A., & Furman, T. (2015, November 1-4). A Learning progression for plate tectonics. Symposium poster was presented at the 2016 Annual International Conference of National Association of Research in Science Teaching (NARST), Baltimore, MD.

TEACHING EXPERIENCE

The Pennsylvania State University, University Park, PA: Fall 2015, Fall 2014.

Summer Science-U Camps, University Park, PA: June-July 2010

Maraton Institution, Trabzon, Turkey: 2004-2007,