UNDERSTANDING HOW SECONDARY SCIENCE TEACHER CANDIDATES LEARN TO TEACH: ANALYZING THE ROLE OF KNOWLEDGE, PRACTICE, AND PROFESSIONAL IDENTITY

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ABSTRACT

UNDERSTANDING HOW SECONDARY SCIENCE TEACHER CANDIDATES LEARN TO TEACH: ANALYZING THE ROLE OF KNOWLEDGE, PRACTICE, AND PROFESSIONAL IDENTITY

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This study investigates the mechanism of beginning teachers' learning in the context of a university-based teacher preparation program. The purpose is to understand *how* and *why* secondary science teacher candidates from the same university-based teacher preparation program develop different kinds of practices of science teaching as their responses to deliberately designed occasions for learning. This study focuses on two key science teaching practices—(a) planning and enacting classroom activities, and (b) assessing and responding to students—that are closely connected to learning from professional communities and learning from students. Fourteen teacher candidates, 14 mentor teachers, and two course instructors participated in this study. Data included written plans and reports of teaching, candidates' teaching videos, interviews with candidates, mentor teachers, and course instructors, candidates' vision statements, and other teaching artifacts. The findings show that the candidates' ways of understanding science for teaching and their designated identities—the kind of teacher they want to be and the kind of practice they want to master—play critical roles in their learning from professional communities and from students by affecting their highlighting and interpretation of practices, resources, and advice from the communities of practices. I conclude this study by presenting a mechanism of beginning teacher learning developed from the evidence. The implications for practice and research of teacher education are discussed.

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Chapter I.

Introduction

Over the last several decades, science education communities have learned about effective science teaching practices that promote students' meaningful understanding and participation. A new vision of good science teaching was well clarified in recent influential documents (NRC, 2000, 2005, 2007) and a new conceptual framework for national standards (NRC, 2011). The 'reform-oriented practices' described in those documents address the concerns raised with traditional science teaching practices, and are to develop students' proficiency in science to prepare them as citizens in the future society (NRC, 2007). Whereas traditional teaching is focused on conveying authoritative knowledge and skills in classrooms organized around student performance for grade exchange (Doyle, 1983), reform-oriented teaching is intended to create classrooms as communities of practice that support students' scaffolded engagement in the strands of scientific proficiency. Reform-oriented teaching is based on a new perspective of science-as-practice (Lehrer & Schauble, 2006; NRC, 2007) that is fundamentally different from the traditional view that considers science as the final form of answers or the combination of content and process.

Despite the numerous efforts to encourage reform-oriented science instruction, teacher education communities still have difficulties in understanding how teachers learn of these important science teaching practices, and in providing sufficient support for them (Davis, Petish, & Smithey, 2006). The fundamental challenge for the science teacher education community resides in the fact that reform-oriented pedagogy is not yet present in most schools, as articulated by standards documents (Luehmann, 2007). The vision for good teaching advocated by university faculty is "fundamentally at odds with that of public school teachers [and] students"

(Farkas, Johnson, & Duffett, 1997), and research-based criteria advocated by the teacher education community are still subject to criticism, rather than replacing the social value advocated by the public (Kennedy, 2010a). This new vision is often perceived as "one of many" perspectives that teacher candidates can consider, and currently there is little or no sanction on the candidates who fail to meet goals or standards, especially at university-based teacher preparation programs[1]. It is not surprising that teacher candidates frequently get mixed or even contradictory messages about "good" science teaching from different professional communities during their student teaching (see Crawford, 2007; Rozelle, 2010). This is significantly different from other professional training processes, such as for lawyers or doctors. Despite the teacher education community's strong positioning about reform-oriented practices, teacher candidates have a large degree of freedom in selecting resources and ideas to craft their teaching practices in their classrooms, while valuing one 'perspective' over the other and developing different kinds of practices of science teaching. Currently it is undeniable that most teacher preparation programs organized around advocacy of reform practice continue to graduate traditional teachers whose instructional practices are focused mostly on delivering authoritative content of science and developing some skills.

Many beginning teachers teach science as they were taught, even after graduating from reform-oriented programs. To explain this trend, researchers have pointed out the powerful role of previous experiences in shaping beginning teachers' teaching practices (Eick & Reed, 2002). Teachers begin to learn about teaching even before they know they will be teachers, through their apprenticeship of observation (Lortie, 1975, 2002). When teacher candidates get into

[1] There are a few of states, including California, Connecticut, and Tennessee, that moved away from traditional teacher certification tests and use performance assessments with standardized assessment rubrics as part of the teacher licensure process.

teacher preparation programs, they bring with them a "script" (Stigner & Hiebert, 1998, p. 2) for teaching—a mental version of teaching patterns—that is formed informally as they move through twelve or more years of school. This script for teaching, which includes their views about the subject, how students learn, the roles of students and teachers, and their values, is hard to change because it has "evolved over long periods of time in ways that are consistent with the stable web of beliefs and assumptions that are part of the culture" (p. 2). Numerous research studies on science teacher learning have pointed out the impact of beliefs and values on beginning teachers' learning of reform-oriented practices (e.g., S. L. Brown & Melear, 2006; Demir & Abell, 2010; Fletcher & Luft, 2011; Kang, 2008; McBride, Bhatti, Hannan, & Feinberg, 2004; Smith & Anderson, 1999). Recently researchers, especially those from the socio-cultural research tradition, also argue that school contexts, including mentor teachers' traditional instruction, make it difficult for beginning teachers to learn reform-oriented practices (Bianchini & Cavazos, 2007; Lasky, 2005; Luehmann, 2007).

Although the notions of "apprenticeship of observation" and "script of teaching" help us to understand the continuity of traditional teaching and some factors that are involved in the process of learning how to teach, teacher educators are still puzzled about beginning teacher learning for two reasons. First, neither the notion of apprenticeship of observation nor role of contexts account for all the facts that we are observing about our teacher candidates. If these factors determine outcomes, why do some graduates who have mostly experienced traditional teaching emerged as well-started beginners of reform practices? Why do some graduates who work with traditional mentor teachers successfully learn reform-oriented practices, or vice versa? Second, the previous explanatory models do not provide mechanisms of influence. If these factors play certain roles in the process of beginning teacher learning, why are these factors important and how do they influence candidates as they learn to teach?

In fact, teacher educators have recognized the powerful roles of teachers' previous experiences and have responded to this unique challenge by designing programs to support beginning teachers' learning of reform-oriented practice as an important part of contexts. Reform-oriented teacher preparation programs focus on developing candidates' practices of teaching in school contexts by gradually increasing candidates' time in the field. In addition, such programs deliberately design occasions for learning based on evidence from the research on teacher learning (see Bianchini & Cavazos, 2007; Darling-Hammond & Richardson, 2009; Eick & Dias, 2005; Eick & Reed, 2002). Specifically, most of these programs set up occasions for learning in which teacher candidates can *learn from multiple members of communities*, such as mentors and course instructors, through their participation in and socialization with professional communities. These programs also set up occasions for *learning from their students* through formative assessment, with the hope that beginning teachers move forward from their previous experiences of traditional teaching and learn "ambitious pedagogy" that promotes students' proficiency in science. Given this unique context of beginning teacher learning, it is important to answer the following questions to tease out the processes of how beginning teachers learn to teach: How do teacher candidates who go through the same reform-oriented teacher preparation program develop different kinds of science teaching practice? Why are some candidates successful in the learning of reform-oriented practices by making use of resources and ideas provided from the program, whereas other candidates are less successful or fail to learn the kinds of practices advocated by the program? What roles do candidates' previous experience, a university-based teacher preparation program, and mentor teachers play in each candidate's learning process, respectively and collectively?

The purpose of this study is to understand the *mechanisms* of beginning teacher learning by going beyond identifying factors. I intend to understand *how* and *why* beginning teachers develop certain kinds of science teaching practices in the context of a university-based teacher preparation program. I begin by discussing two promising approaches in the field that provide some insights on the mechanisms of teacher learning and presenting my conceptual framing of the process of learning to teach, before turning to my research questions.

Conceptual Framework

Two Perspectives on Beginning Teacher Learning

The review of literature on beginning teacher learning in the field of science led me to identify three different groups of research studies: (a) cognitive and affective factor oriented research, (b) cognitive mechanism oriented research, and (c) identity oriented research[2]. I intend to build this study on the latter two groups of research studies—cognitive mechanism and identity oriented research. These two groups of research take a different 'lens' to examine the mechanisms of beginning teacher learning. Researchers in cognitive mechanism oriented research program have studied the process of beginning teacher learning by focusing on the acquisition of content-specific knowledge and practices specified by standards documents (e.g., Windschitl, Thompson, & Braaten, 2008a, 2008b, 2009, 2011). Identity-oriented research studies consider learning as the process of authoring professional identities through beginning teachers' participation in and socialization with communities of practice (Lave & Wenger, 1991; Luehmann, 2007). These perspectives are complementary rather than contradictory because they

[2] See the detail in Chapter 2

provide important insights on the mechanism of learning—cognitive self-organization or individual-in-social action (Cobb, 1994). I argue that we can develop a powerful understanding of the mechanism of beginning teacher learning by considering both perspectives simultaneously. This study conceives of beginning teacher learning as the process of developing knowledge and practices of science teaching while authoring the professional identity.

Learning as the acquisition of knowledge and practices. Both previous studies on science teacher learning and the most recent reform oriented documents (NRC, 2007, 2011) make it clear that there exists specialized knowledge required for reform-oriented teaching. Specifically, the recent reform documents propose new goals for science education; that is, developing students' proficiency in the strands of the practices of science. The new vision is based on the perspective of 'science as practice,' which is fundamentally different from previous views on science such as science as logical reasoning or science as content and process[3]. The reform document emphasizes that, "Science instruction should provide opportunities for students to engage in all four strands of science proficiency" (NRC, 2007, p. 6). Engaging students in the practices of science requires teachers' in-depth understanding of science for teaching. It has been well known that teachers' epistemological understanding about the nature of scientific knowledge and practices and their perceived goal of science instruction play important roles in the ways that they structure students' learning experiences with their instructional decisions (NRC, 2007). Whereas science is frequently presented as so-called 'the final form of answers,' or 'master narratives' in many classrooms at the K-12 and college levels, the reform-oriented documents describe science as "both a body of knowledge that represents current understanding of natural systems and the process whereby that body of knowledge has been established and is

[3] See the detail of this discussion in chapter 2

being continually extended, refined, and revised" (p.26). It is important to present science as "an integrated body of knowledge and practice" (p. 6) for students' meaningful understanding and participation, and inquiry is often suggested as one of promising ways of teaching science meaningfully (NRC, 2000, 2005).

Reform-oriented practices also require teachers' in-depth understanding about students as science learners. Understanding the role of students' prior knowledge is a core idea of learning theory (Bransford, Brown, & Cocking, 1999; J. S. Brown, Collins, & Duguid, 1989; NRC, 2005). Teachers should be able to appreciate the diverse ways of students' knowing as well as students' unique needs and provide productive instructional responses in order to enact equitable instruction (Bianchini & Brenner, 2010).

Learning as the process of authoring professional identities. Learning reform-oriented practices involves the process of authoring professional identities that often do not match either beginning teachers' initial script of teaching or the common norm in the profession (Day, Elliot, & Kington, 2005; Lasky, 2005; Luehmann, 2007). Currently the notion of identity is a complicated construct that means many different things in the field[4]. My view of professional identity is informed by discussions about socialization of communities of practice (Lave & Wenger, 1991), about the relationship of identity and practice in practice theory (Holland, Lachicotte Jr., Skinner, & Cain, 1998) as well as about narrative definitions of identity (Hall, Johnson, Juzwik, Wortham, & Mosley, 2010; Juzwik, 2006; Sfard & Prusak, 2005). Teacher candidates' practices are always socially negotiated and structured through relationships and interactions in particular contexts, rather than purely a product of their science-teaching knowledge and skills. While socializing with and participating in multiple communities of

[4] See the discussion in the chapter 2: literature review

practice, teacher candidates encounter various resources, ideas, and values about science teaching. On the one hand, candidates' practices, as the outcome of their responses to mixed ideas and resources provided for them in a social context, are grounded in their current sense of self and the tools and resources that they can draw upon. On the other hand, their practices reflect their future sense of self and practice—the kind of science teacher they want to be and the kind of science teaching they want to enact and master. Developing certain kinds of science teaching practice comes to be the process of forging identity-in-practice, 'who they are,' and 'who they want to be' as a science teacher, in a social context.

Teachers author their professional identities in a field of influence with certain *momentum*. As Wenger (1999) pointed out, identity "has momentum of its own in addition to a field of influence" (p. 154); a teacher candidate's identity bears certain momentum toward their future sense of self and practice that is most likely grounded in their previous experiences and their script of teaching. This momentum may have to do with their values, vision (e.g., religious mission), and/or their images of good science teaching, and it affects ways that candidates interact with people in "a field of influence" that is created with their participation in professional communities.

I agree that "the notion of identity cannot become truly useful unless it is provided with an operational definition" (Sfard & Prusak, 2005, p. 15). With the goal of developing powerful empirical evidence of teacher learning and the awareness of its potential for explaining the mechanisms of teacher learning, I chose the notion of "the narrative rendering of identity" (Sfard & Prusak, 2005, p. 14) or storied identities for this study. Sfard and Prusak (2005) defined learning as closing the gap between actual identity and designated identity. Whereas actual identity *is* "stories about the actual state of affairs" (p. 18), designated identity *is* "narratives presenting a state of affairs which, for one reason or another, is *expected* to be the case, if not now then in the future" (p. 18). I posit that teacher candidates' actual and designated identities are collective stories about their current and future self(s) in/and practices told by multiple people. It should be noted that identities are constructed through narrativatization of self(s) and practices when people tell stories, but practices are not equivalent to identities themselves. Whereas candidates' practices are always fluid and changeable depending on time, space, and people, 'storied identities' constructed through narrativatization of multiple people tend to capture "reifying, significant, and endorsable" (Sfard & Prusak, 2005, p. 14) aspect about a candidate and his/her practices. The notions of actual and designated identities are particularly useful in investigating beginning teacher learning, given the unique contexts of that learning. What teacher candidates actually do in a classroom, reflected in actual identities, is the complicated outcome of their interaction and negotiation with people on a daily basis, especially with their mentor teacher (see Rozelle, 2010), which I argue does not necessarily capture all the important outcomes of their learning. Candidates' designated identities—their stories about what kinds of teacher they want to be and what kinds of practice they want to master—tell us what they learn from their experiences through their highlighting and their interpretation about it along with the nature of their interaction with people in a field of influence.

Accordingly, this study investigates stories about current or future self(s) in/and practices to understand the mechanism of learning through actual and designated identities. Stories about both self(s) in/and practices told by multiple people, including candidates, their mentor teachers, and course instructors show who they are as a teacher, who they want to be, how they interpret and respond to resources and ideas provided from different professional communities, how they position themselves while interacting with multiple communities, and finally how they are recognized by others. By examining stories of current and future self in/and practice (i.e., actual and designated identities) told by candidates themselves as well as by key members of community who work most closely with candidates, I aim to understand how identity work takes place in a social context in their journey of learning to teach.

Framework for Investigating Mechanisms of Beginning Teacher Learning

Now I frame 'the outcomes' of learning, that is, what I will look at with respect to beginning teachers' learning outcome and how it will help me to understand the mechanism of learning. I propose two different types of practices. One is actual classroom practices, and the other is discursive practices of teaching, that is, interpretation of practices. The following section provides the processes by which each practice is produced and the rationales for this conceptual framing.

Beginning Teachers' Practices: Outcomes of Responses to Deliberately Designed Occasions for Learning. Teachers' classroom practices have been nominated as one of the key outcomes of teacher learning (Kennedy, 2004, 2010a) that powerfully impacts students' performance and participation (Ball & Cohen, 1999; Kennedy, 2010b). From review of research on the relationship between one or another factor and student learning, Kennedy found, "It is what teachers actually *do* that is most relevant to student learning" (Kennedy, 2010b, p. 591[italic in original]). What teacher candidates actually do in their classroom is not a simple result of their personal traits (Kennedy, 2010b). Rather, it is a combined function of both personal qualities that they bring with them and various situational factors to which candidates have to respond. In the context of a university-based teacher preparation program, a program deliberately designed for "*occasions for learning*" with a form of assignments or activities, makes their resources and ideas available for teacher candidates in order to support them to learn high quality science teaching practices. Accordingly, teacher candidates' actual practices reflect their responses to the program's deliberately designed occasions for learning.

The nature of occasions for learning, however, is not the same across teacher candidates, even from the same program. The contexts of school placements make a big difference in such occasions by affecting the types of experiences that teacher candidates have with their students and the types of advice and resources that they get from their mentor teachers. For instance, candidates who work at urban high schools that have high demands for classroom management have to respond to different occasions for learning compared to the candidates at suburban academic-oriented high schools. Mentor teachers' preferable instructional approaches, types of advice, and expectations of candidates also influence the nature of occasions for learning, along with the resources and advice provided by the program. Rozelle's (2010) study noted the differences in the nature of advice between mentor teachers and teacher preparation programs, such as immediate and localized vs. general and formal. Mentor teachers' resources and ideas for teaching are not always aligned with the ones from a reform-oriented program (see Crawford, 2007), which sometimes creates some tension that beginning teachers have to respond to. Beginning teachers select resources and ideas provided by different professional communities to produce certain types of practices as their responses to the locally created occasions for learning.

Interpretation of Practices: Representation of Teaching Expertise. I draw upon the ideas of professional vision (Goodwin, 1994; van Es & Sherin, 2008) and learning to notice (van Es & Sherin, 2002, 2008) to propose discursive practices of teaching as one aspect of beginning teacher learning outcome. Goodwin (1994) suggested *highlighting* and *coding* as the practices that participants of professional activities used to build their professional vision. Professional vision "consists of socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (p. 606). *Highlighting* is the process of attending to and identifying particular aspects of a complex social activity in situ. *Coding* involves interpreting what they attend to after picking out a specific aspect of activity. Professional vision recognized through the discursive practices of highlighting and coding reflects someone's depth of understanding of an event being seen as well as their attached cultural values. Built upon Goodwin's work, van Es and Sherin (Sherin & van Es, 2005; van Es & Sherin, 2002, 2008) proposed the ability to notice classroom interaction as a key feature of teaching expertise. They proposed three key components of teachers' ability to notice: (a) identifying what is important in a complicated teaching situation, (b) using what one knows about the context to reason about a situation, and (c) making connections between specific events and broader principles of teaching and learning (van Es & Sherin, 2008, p. 245). While claiming that in the context of reform noticing is a skill that teachers may need to develop, van Es and Sherin used the notion of noticing to investigate changes in teachers' thinking as they participated in a video club.

For two reasons, I propose that beginning teachers' interpretation of practices produced through their highlighting is one important aspect that should be considered in the investigation of the process of learning. First, the interpretation of practices shows what experiences are salient to a teacher, how it is interpreted, and what lessons they draw upon from their experiences. It shows the kinds of "feedback loops" created by a beginning teacher from their experience. The interpretation of practices can be a powerful indicator of their future practice as much as candidates' actual practices. Second, the interpretation of practice enables me to trace beginning teachers' learning trajectories including kinds of expertise they are developing. Most beginning teachers obtain some kinds of expertise after five or 10 years of teaching experiences. It has been known that there exist discernable differences in ways of seeing events between novice and experts (DeGroot, 1965; Lesgold, et al., 1988). Tracing beginning teachers' interpretation of practice through stories can provide evidence of their learning trajectories toward certain kinds of teaching expertise.

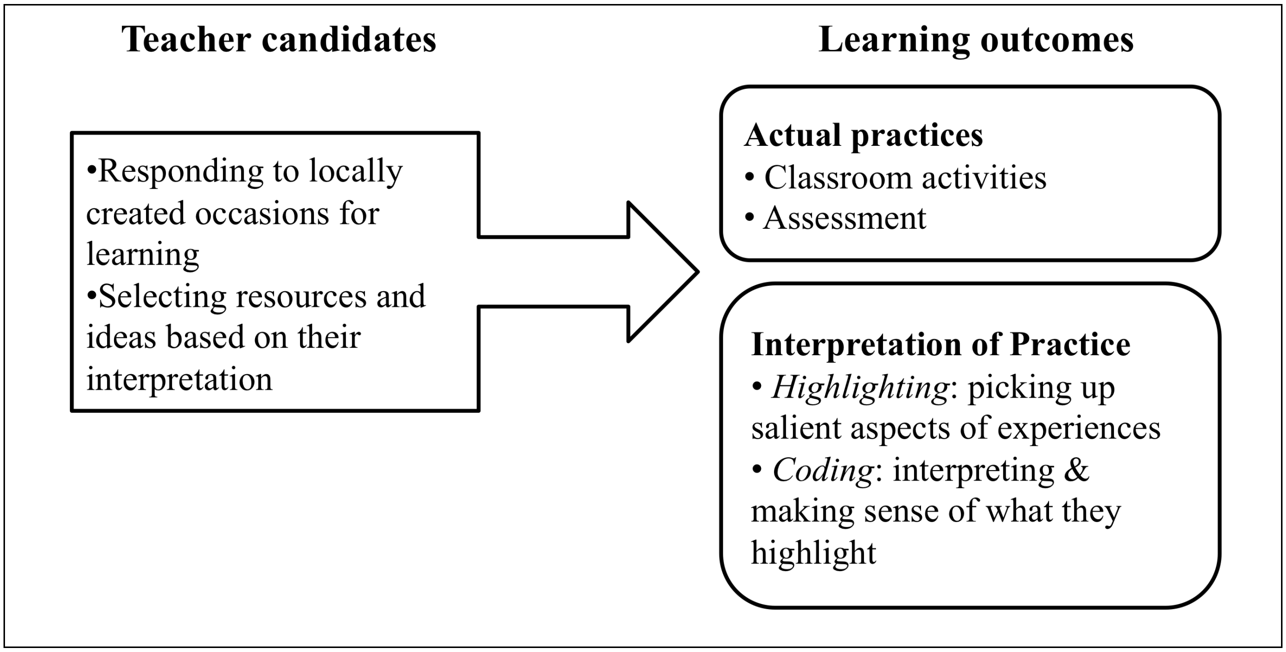

Figure 1. Conceptualizing learning outcomes: actual and interpretation of practices

Research Questions

Thus far, I have presented my conceptual framing of the process of beginning teacher learning with my theoretical perspective on beginning teacher learning. Based on this framework, I intend to study the *mechanism* of learning, *how* and *why* secondary science teacher candidates from the same university-based teacher preparation program develop different kinds of practices of science teaching as their responses to deliberately designed occasions for learning. This study focuses on two core science teaching practices emphasized by most science teacher preparation programs: (a) planning and enacting classroom activities, and (b) assessing and responding to students[5].

The specific questions are:

1. How do the candidates from the same university-based teacher preparation program respond to deliberately designed occasions for learning?
    a. How do they plan and enact classroom activities? How do they interpret and respond to resources and advice for classroom activities provided by the teacher preparation program, their mentor teachers, and their course instructors?
    b. How do they provide opportunities for formative assessment, and how do they interpret and respond to their students and their students' work?
2. What makes a candidate successful or less successful in making use of the resources and opportunities provided by the program? How do these elements influence candidates' two focus practices and their interpretations of student work, program expectations and resources, and advice from mentors and course instructors?
    a. How are candidates' practices and interpretations influenced by their knowledge for science teaching?
    b. How are candidates' practices and interpretations influenced by their identity work?

In the following section, I describe the methodology used in this dissertation, including the selection of two science teaching practices, to help readers understand and critically judge how I construct this phenomena through this research project.

Overview of Methodology

[5] I describe the rationales for selecting these two practices in the following overview of methodology

I highlight my key methodological decisions in the course of a research study for critical readership of this study before I close this chapter and move to reviewing the literature on beginning science teacher learning. This is a multiple case study with 14 secondary science teacher candidates from a university-based teacher preparation program over three years. The details of research design and research activity is described in Chapter 3. I made four methodological choices to examine the mechanisms of beginning teacher learning. Those are: (a) selecting occasions for learning about key practices of science teaching, (b) setting up comparisons of candidates in similar contexts, (c) comparing candidates on different trajectories, and (d) getting multiple perspectives on the same practices of teaching to triangulate observation and interpretation.

Selecting Occasions for Learning about Key Practices of Science Teaching

In order to examine the process of learning to teach, I decided to focus on two key science-teaching practices emphasized by most teacher preparation programs. One is *planning and enacting classroom activities*, and the other is *assessing and responding to students* (see Figure 2 and Table 1). I selected these two practices for two reasons. First, they are directly connected with the two core occasions for learning deliberately designed by most programs—learning from participation in and socialization with professional communities and learning from students—thus they enabled me to investigate the processes that beginning teachers learn from professional communities as well as from their students while engaging in these practices. While planning and enacting classroom activities, candidates have opportunities to interact with their mentor teachers and course instructors through their advice, resources, and ideas for activities. Therefore, candidates' classroom activities show how they respond to occasions for learning, in particular, from professional communities. The second practice, assessing and responding to students, is connected with the process of learning from students. By focusing on their assessment practice, I intend to examine the ways in which candidates learn from their students.

The second reason why I selected these two practices is that both classroom activities and assessment practices are indeed high-leverage practices that "the proficient enactment by a teacher is likely to lead to comparatively large advances in student learning" (Ball, Sleep, Boerst, & Bass, 2009). Both practices support work that is central to science and to helping students to improve their learning and achievement, and both are kinds of practices that beginning teachers use frequently when they teach science.

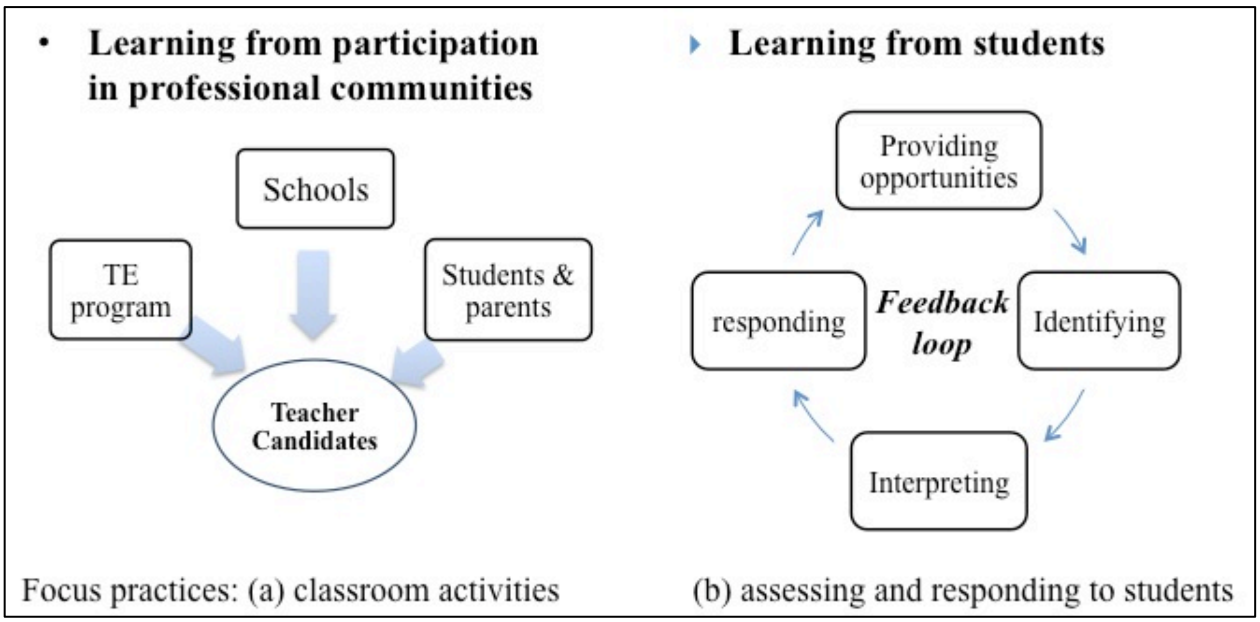

Figure 2 Occasions for learning about two key practices of science teaching

Documenting the quality of the two focus practices with empirical evidence requires parsing the complex system of activities with common language (Grossman & McDonald, 2008). I identified key aspects of each practice to characterize different types of practices observed in candidates' classrooms[6]. Whereas the aspects of classroom activities primarily emerged from the data in a way that aligned with the literature and my conceptual framework, the aspects of assessment practices were conceptualized from the literature in the first place, with consideration of the nature of available data sources (see the key aspects of each practice in Table 1).

Table 1. Two key science teaching practices

	Planning and enacting classroom activities	**Assessing and responding to students**
Dimensions for learning	Learning from professional communities	Learning from students
Elements of practices	(a) setting/highlighting/interpreting goals of lesson (b) managing/highlighting/interpreting the roles of activities (c) managing/highlighting/interpreting the roles of students	(a) Providing opportunities for students to give information about them (b) Identifying (c) interpreting (d) responding to students

Setting Up Comparisons of Candidates in Similar Contexts

In multiple case studies, comparison is recognized as "a grand epistemological strategy, a powerful conceptual mechanism, fixing attention upon one or a few attributes" (Stake, 2004, p. 457). All 14 teacher candidates' patterns of practices were analyzed during the data analysis, and I subsequently set up comparisons of six candidates in similar contexts to better understand the uniqueness and complexities of the process of learning to teach. With respect to classroom activity practices, I selected three candidates who worked at similar suburban high schools. For assessment practices, another three candidates who worked at similar urban high schools were selected. The processes of learning are expected to be influenced by contexts, but by setting up comparisons of candidates in similar contexts, I intended to focus more on the process of learning to teach in relation to candidates' knowledge development and authoring professional

[6] See the process of identifying key aspects of each practice in detail in chapter 3: Methods.

identities in similar social contexts rather than to investigate the influence of different nature of contexts.

Comparing Candidates on Different Trajectories

The choice of cases greatly impacts the nature of understanding of the targeted phenomena (Stake, 2004; Yin, 1989). When selecting six focus cases out of 14 candidates, I chose the cases that showed candidates' different learning trajectories even though they worked in similar contexts with the same support from the program. I made this choice because I think this selection provides the best opportunities to learn about the mechanisms of beginning teacher learning. By no means do I claim that that these six candidates are a representative sample of the population of teacher candidates in the program. But all six candidates that I selected in this study were candidates whom we could frequently meet and we can easily identify similar candidates every year in the program.

Getting Multiple Perspectives to Triangulate Observation and Interpretation

The last methodological characteristic that I want to note in this study is getting multiple perspectives on the same teaching event through multiple people's interpretation of practices. I selected two segments of a candidate's teaching video and used the segments in the individual interviews with the candidate, his/her mentor teacher, and course instructor to see what they highlighted and how they coded (i.e., interpret) what they highlighted. As a researcher, I also highlighted and coded the same segments of video when analyzing the data. By comparing multiple interpretations of practices from candidates, mentor teachers, course instructors, and myself, first I intended to triangulate my observation and interpretation of the practices with "rival explanations" (Yin, 1989, p. 41). Secondly, comparing the highlighting and coding between a mentor teacher and course instructors allowed me to figure out the direction of influences on candidates from the two professional communities, so as to understand the nature of locally created occasions for learning.

Significance

One contribution of this study is informing the practices and curriculum of science teacher preparation programs. Teaching, at its core, is a practice that encompasses cognition, craft, skills, and affect (Grossman & McDonald, 2008), and it has been argued that teacher preparation should be centered on core practices as a way of supporting people to develop craft and skills through targeted training and clinical experiences (Ball & Forzani, 2009; Cochran-Smith & Power, 2010; Grossman & McDonald, 2008). Understanding the mechanism of beginning teachers' learning of reform-oriented practices, including the nature of their difficulties and key elements involved in that process, enables teacher educators to re-structure the occasions for beginning teachers' learning and to find a powerful pedagogy that supports beginning teachers' learning of reform-oriented practices.

This study addresses major methodological concerns of teacher education research. Currently, insufficient empirical evidence makes it difficult for teacher educators and policymakers to make decisions about the curriculum and policy of teacher preparation programs. It is difficult to produce empirical evidence on beginning teachers' practices because of the lack of shared language for describing the features of components of practice, agreeing on measures for capturing the elements of practice (Grossman & McDonald, 2008), and capturing the substantive meanings of events with objectivity (Kennedy, 2010a). As Kennedy (2010a) pointed out, "We have faced serious technical problems in trying to translate our intuitive perceptions into precise terminology and reliable measurement scales" (p.245). This study suggests a new approach of documenting beginning teachers' development of core science teaching practice with empirical evidence. It shows ways of parsing practices of science teaching and providing potential evidence of learning, which provides researchers with the analytical tools to describe, analyze, and improve teaching.

Overview of Chapters

Having provided the reader with the contexts, the conceptual framing, and some methodological characteristics of this study, I now turn to a brief overview of the reminder of the dissertation. In chapter 2, I review the literature on teacher learning that informed the conceptual framing of this study. In chapter 3, I describe the context of this investigation and its methods. Chapters 4 and 5 present the findings about the process of beginning teacher learning through two focus practices. In chapter 4, I describe the process of learning from participation in professional communities through classroom activity practices, using three candidates' cases in similar suburban high schools. Chapter 5 is focused on the process of learning from students through assessment practices using another three candidates' cases in similar urban high schools. Chapter 6 discusses and draws conclusions on the mechanisms of learning by bringing the analyses in Chapters 4 and 5 together. Implications of this study for research and practice of teacher education are also discussed in the final chapter.

Chapter 2. Literature Review

Overview

This chapter reviews the literature on teacher learning in the field of science education. I identified three groups of research studies that explore science teacher learning with different foci. A significant proportion of the literature on teacher learning has been the studies on identifying certain core cognitive *factors* that affect their instructional practices and their students' learning. This 'factor-oriented research' has explored how other factors or interventions, such as activities in methods courses, influence on teachers' development of those cognitive characteristics such as knowledge and beliefs (e.g., Abell, 2006; Bryan & Atwater, 2002; Friedrichsen, et al., 2009; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Magnusson, Krajcik, & Borko, 2002). The second group of researchers was interested in cognitive *mechanism* of learning to teach with special attention to the practice of science specified in a new vision of science education (e.g., Windschitl, Thompson, & Braaten, 2008b; Windschitl, Thompson, & Braaten, 2009, 2011). This 'mechanism-oriented research' has examined the process through which teachers acquire knowledge and skills for science teaching. The third group of researchers, what I call 'identity-oriented research,' brings with it different assumptions on learning from a cognitive-oriented research tradition. Researchers in the sociocultural tradition consider learning as the process of forging identities through participation in communities of practice (Lave & Wenger, 1991). Whereas cognitive-oriented researchers are primarily interested in the development of some characteristics focusing on individual teachers, sociocultural researchers are interested in the interplay between the learner and the sociocultual context where learning is situated (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Therefore, they use the lens of 'identity' to explore the process of learning. In the following section, I will discuss three groups of literature on science teacher learning to draw out implications for this study.

Literature on the Development of Core Cognitive and Affective Factors for Teaching

The majority of previous research has focused on identifying one or another factors (e.g., personal characteristics of a teacher) that affect teachers' practices and students' learning, and explored how teachers acquire those factors to develop certain science teaching practices. Teachers' Pedagogical Content Knowledge (PCK), understanding of Nature of Science (NOS), and beliefs about teaching and learning are some of the constructs that have appeared most frequently in the field of research on science teacher learning.

Since Shulman and his colleagues proposed a model for understanding the specialized knowledge required for teaching (Shulman, 1986, 1987; Wilson, Shulman, & Richert, 1987), many science teacher educators have studied what allows teachers to develop their pedagogical content knowledge (PCK) and how this knowledge influences their instructional practices. In the PCK research program, this notion is conceived of as a body of knowledge distinguished from subject matter knowledge (SMK) or pedagogical knowledge (PK), although each has an influence on PCK (Abell, 2006; Magnusson, et al., 2002). The essence of PCK is "how teachers transform SMK of specific science topics into viable instruction" (Abell, 2006, p. 1134). Currently researchers in the PCK research program have specified many areas of sub-knowledge[7] to investigate how teachers acquire one or another specific type of PCK for teaching a topic, a unit, or a discipline, such as chemistry (e.g., Avraamidou & Zembal-Saul, 2010; Jong, van Driel, & Verloop, 2005; Lee, Brown, Luft, & Roehrig, 2007; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001). For example, researchers report the positive impact of university-

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[7] Magnusson, Krajcik, and Borko (2002) specified PCK as knowledge of science curricula, knowledge of instructional strategies, knowledge of assessment, and knowledge of students

based courses (e.g., Avraamidou & Zembal-Saul, 2010; Justi & van Driel, 2005), in-service workshops (e.g., Van Driel, Verloop, & Vos, 1998), or the effects of teachers' prior experiences (e.g., Friedrichsen, et al., 2009) on teachers' development of one or another type of PCK.

There are a significant number of researchers in this group who have studied teachers' development of views on Nature of Science (NOS), arguing that teachers' understanding of NOS is a critical factor in shaping their practices (Lederman, 2006). Using instruments to assess teachers' views on NOS (see Lederman, et al., 2002), they have shown the influences of particular experiences provided by the teacher education community on teachers' views on NOS, such as philosophy of science courses (Abd-El-Khalick, 2005), summer professional development programs focusing on developing communities of learners (Akerson, Cullen, & Hanson, 2009), and teacher research experiences (Schwartz & Lederman, 2002). For instance, Schwartz and her colleagues (2004) designed a science research internship course, combined with seminars and reflective activities, to encourage teacher candidates to develop views on the nature of science (NOS). They concluded that the science research internship effected desirable changes in the participants' NOS views by providing authentic contexts for their learning.

Teacher's beliefs are another construct that has been identified as one major factor that plays a significant role in shaping teachers' instructional practices (Jones & Carter, 2006). In the field of research on science teacher learning, the conceptual boundary between knowledge and beliefs is less clear "as they do not represent separate entities" (Jones & Carter, 2006, p. 1069). Abell (2006) also points out that the relation of subject matter knowledge to teacher beliefs and values and to classroom practice is less clear. Set aside its unclear boundary between beliefs and knowledge, in general, the researchers who study teacher learning focusing on development of teacher beliefs agree that a teacher's beliefs about science, science learning, and science teaching influence almost every aspect of a teacher's job, and especially their beliefs on reform-oriented instruction. Numerous studies have shown some relationship between teachers' beliefs - in particular, epistemological belief - and instructional practices (e.g., Luft, 2001; Richmond & Anderson, 2003; Zipf & Harrison, 2003); the impact of certain activities in methods courses on teachers' beliefs (e.g., Bryan & Atwater, 2002; Kang, 2008); and the roles of field experiences in developing teachers' belief and instructional practices (e.g., Crawford, 2007; Fletcher & Luft, 2011).

This group of research studies, which I call 'cognitive and affective factor-oriented research,' has contributed to the research and curriculum of science teacher education by identifying some important elements involved in the process of beginning teacher learning. The studies in this group also have suggested some potential experiences that affect the development of particular knowledge and skills of teaching, such as activities and structures in methods courses or professional development programs. There are two issues that have emerged from this research, however, in relation to understanding how beginning teachers learn the reform-oriented practices.

First, this body of literature has been less successful in providing powerful accounts of how those important elements involve the process of learning to teach in the specific social contexts where learning actually takes place. Most researchers in this group note that the ways that one factor influences classroom practices depends on other factors, such as context, placements, or teachers' subject matter knowledge, etc. For example, in Fletcher and Luft's (2011) recent study on the relationship between beginning teachers' beliefs and instructional practices in the context of student teaching, they found that beginning teachers' beliefs about teaching and learning were "impacted in different ways based on the context of the placement and the individuals" (p. 1). Crawford (2007) concluded that despite her systematic efforts toward helping candidates learn about teaching science as inquiry through her course, teacher candidates' learning is a much more complicated process that involves multiple elements playing critical roles in teacher candidates' learning. Those elements include teacher candidates' beliefs about teaching and of science, as well as mentor teachers' views, and mentors' openness or reluctance to allow teacher candidates to try out new approaches. From a review of literature on teachers' beliefs, Jones and Carter (2006) conclude, "It is becoming increasingly clear that teachers' belief systems are embedded in the larger sociocultural environment, which includes students, peer teachers, parents, administrators, families, communities, and political/government environments" (p. 1095). Abell (2006) also notes that although teacher knowledge is essential, science teacher education must honor the local and practical knowledge of teachers in the field and the sociocultural contexts that frame their work. Researchers in this group have recognized the complicated process of beginning teachers' learning that involves multiple factors, but thus far they have been less successful in giving us insights on those complicated processes.

More importantly, it is questionable whether the conceptual constructs of these studies align with the new vision of science education, as articulated in the most recent reform-oriented documents (e.g., NRC, 2007, 2010). The field of science education has evolved over several decades as we have learned more about science, science learning and teaching. It has been a continuing theme to move beyond teaching science as what Duschl (1990) calls, "final form science," because it may "leave students in the dark about the way knowledge is generated and may also distort the nature of scientific knowledge, inappropriately conveying that it is unchangeable and uncontested" (Lehrer & Schauble, 2006, p. 159). Since the 1960s, teaching the process of science along with the content has been the most popular rhetoric in the discourse about the goal of science education, and still they seem to be, especially to school teachers and curriculum designers. Science educators have problematized this process/content dichotomy because it becomes evident that learning “skills” is just as meaningless as learning facts or scientific theories in the textbook separately (Lehrer & Schauble, 2006). It may also fail to help students to understand the nature of scientific knowledge and practice that is indeed inseparable and fundamentally contingent on each other. Over the last several decades, the focus of the debate in science educators was to clarify what the essence of science *is*, the core of what we should teach. The several ‘essences’ of science, such as scientific concepts (i.e., knowledge), reasoning (i.e., skills), and epistemology (e.g., nature of science), were identified and appear in the previous National Science Education Standards (NRC, 1996), and have been reflected in the research on science teacher learning as demonstrated above.

The most recent reform documents (e.g., NRC, 2007) and a new framework for science education (NRC, 2010), however, propose new goals for science education with consideration given to our current understanding of science, research on science learning, as well as the need for preparing future citizens in our society. In these documents, the goals of science education are stated in a significantly different way from the previous standards, that is, developing students’ scientific proficiency in the four interwoven strands. These documents state that students who are proficient in science (NRC, 2007, p. 36):

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.

It should be noted that the four strands of scientific proficiency are not the core or essence of science that we expect to see as the outcomes of development that are internal to individuals. These strands are *practices* of science, that are "patterns of activities that are initiated and embedded within goals and thoroughly saturated with human meaning and intentions" (Lehrer & Schauble, 2006, p. 161). This perspective of 'science as practice' (Lehrer & Schauble, 2006; NRC, 2007) is fundamentally different from the traditional view of science as focusing on the development of individual characteristics, such as acquiring knowledge, skills, and an understanding of the nature of science. Lehrer and Shauble (2006) discuss how the science education community re-conceptualizes the view of science and moves forward from the previous perspective:

> The science-as-practice image suggests that science spans multiple epistemologies and practices. Moreover, perhaps what is important with respect to development is not characterizing changes that are internal to individuals, but understanding how individuals are initiated into and participate in these variable ways of knowing and doing science. From an educational perspective, the goal in that case would be to consider which forms of practice provide the greatest educational leverage, and then to understand how to assist students in beginning to participate (Lehrer & Schauble, 2006, p. 160).

Undoubtedly, the success of reform depends on teachers' capabilities of engaging students in the practices of science, which require teachers' in-depth understanding of 'science as practice.' The reform document states, "science instruction should provide opportunities for students to engage in all four strands of science proficiency" (NRC, 2007, p. 6).

Given the current reform movement in science education, the factor-oriented research programs raise some important questions. There is no doubt that reform-oriented teaching requires specialized knowledge for teaching, especially, teachers' in-depth understanding of science as practice. However, the current PCK research program in science conceives of PCK as a distinct body of knowledge different from subject matter knowledge (SMK) (Abell, 2006). Researchers in this program tend to be more interested in the transformation of SMK (because it is a distinct body of knowledge) than characterizing the nature of specialized knowledge for teaching that is fundamentally integrated with understanding of science itself. It seems to me that the distinction among subject matter knowledge, pedagogical content knowledge, and pedagogical knowledge in this research program may generate a distorted understanding of science teaching as much as the dichotomy of scientific content and process does. In the case of the Nature of Science (NOS) research program, above all, the underlying assumption of NOS as the core subject for science teaching is questionable in the new standards. Researchers in the NOS program distinguish NOS from science processes or scientific inquiry, emphasizing that "NOS refers to the epistemological underpinnings of the activities of science and the characteristics of the resulting knowledge" (Lederman, 2006, p. 835). Given that the integrated understanding of knowledge and practices of science is a critical element for reform teaching, this essentialistic argument of NOS as a distinct entity that is separated from the practice of science (i.e., inquiry) makes its power as conceptual construct for explaining teacher learning even less promising.

In summary, the previous research studies in this group inform me that there exists certain specialized knowledge that powerfully affects teachers' instructional practices. These studies also suggest that the process of learning to teach is a complicated one that involves multiple elements with some characteristics of both teachers and contextual factors. Despite the fact that some researchers are aware of the complicated roles of multiple elements, so far researchers in this factor-oriented group are struggling to provide powerful evidence-based explanations about the dynamic interaction of those multiple elements in the process of learning how to teach. In addition, the conceptual constructs of this research seem to be less successful in capturing either important characteristics of teachers or practices of teaching advocated by the most recent reform-oriented documents.

Literature on the Cognitive Mechanisms of Learning to Teach

There is another body of literature that studies the mechanisms of beginning teacher learning focusing on acquisition of content-specific knowledge and practices of science teaching. Windschitl and his colleagues have been exploring beginning teachers' learning of reform-oriented with special attention to the practices of science as articulated in the new vision of science teaching (see Windschitl, 2002, 2003, 2004; Windschitl, Thompson, & Braaten, 2008a; Windschitl, et al., 2008b, 2009, 2011). Whereas factor-oriented research studies tend to focus on certain core characteristics of teachers (i.e., knowledge, skills, epistemology of science) that need to be developed, this group attends to both practices of science and of science teaching in its investigation of beginning teacher learning. For instance, in one recent study, Windschitl and his colleagues (2008b) designed 'a system of learning activities' that intended to foster teacher candidates' participation in material and discursive activities characterizing the work of scientists, that is, what they called "model-based inquiry" (Windschitl, Thompson, & Braaten, 2008a). The focus of their investigation was to understand *how* beginning teachers engage in the practice of science teaching as scaffolded by the program, and *how* it affected beginning teachers' practice of science teaching. Their research questions demonstrate their attention to the mechanisms of beginning teacher learning as follows: "In what ways does an instructional focus on scientific models and model-based investigations influence how beginning teachers think and talk about the epistemological role of models in inquiry? In what ways does an instructional focus on models influence beginning teachers' use of models and modeling with their own students? (p. 312)" Rather than arguing certain causal relationships between the experiences provided by the program and beginning teachers' epistemological understanding or their practice, Windschitl and his colleagues concluded that their instructional approaches provided "conditions" for beginning teachers' learning of model-based inquiry.

In another recent study about beginning teachers' learning through 'collaborative inquiry into practice', Windschitl and colleagues (2011) further investigated the process of learning what they called 'ambitious pedagogy.' They identified two groups of teacher candidates who had different habits of mind and views of the relationship between teaching and learning (i.e., simplistic view vs. problematized view). They described how these two groups of candidates responded to learning opportunities differently, such as selecting different kinds of artifacts from classroom tasks, differences in the depth of analyses of student works, and the ways in which they represent their dilemmas to their peers. They conclude that those candidates having a problematized view benefit most from the resources provided by the program because they can "learn from the collaborative examination of records of practice (p 15)."

For this group, the focus of inquiry is clearly not examining certain core characteristics of individual teachers required for reform-oriented teaching. What makes it different from the factor-oriented research that focuses on cognitive and affective factors is that this group intends to understand the mechanisms of learning—the ways in which beginning teachers participate in practices of science as well as science teaching. The attention to practices is well aligned with the new goals of science education, that is, engaging students in the strands of scientific proficiency.

Literature on the Development of Teacher Identity

Recently, the idea of identity is getting new attention in the field of teacher development and teacher learning with the awareness of the complex dialectic between learning and its sociocultural context (Sfard & Prusak, 2005). There is a growing body of literature that uses identity as an analytical lens for teacher learning (Enyedy, Goldberg, & Welsh, 2006; Gee, 2000; Hall, Johnson, Juzwik, Wortham, & Mosley, 2010; Helms, 1998; e.g., Luehmann, 2007; Richmond, Juzwik, & Steel, 2011). Sociocultural and socioconstructive researchers argue that studies that solely focus on knowledge, understanding or other purely cognitive constructs in teacher education are limited because they leave "the novice teachers alone to figure out how to develop, integrate, and reconcile emotions and physical aspects with the understanding involved in becoming a teacher" (Luehmann, 2007, p. 827). Sociocultural researchers are concerned about the process of the cultural shaping of learning, the relations of people in communities, and the process of learners becoming a part of a community of practice (Gutierrez & Rogoff, 2003; Holland, William, Skinner, & Carole, 2001; Lave & Wenger, 1991; Ma, 1999; Sfard & Prusak, 2005; Stigner & Hiebert, 1998). From sociocultural perspectives, learning is considered an active and social process. It is situated in circumstances and settings (Brown, et al., 1989; Resnick, 1987), and is a process of socialization in which learners develop identities-in-practice while participating in communities of practice (Brickhouse, 2001, Lave & Wenger, 1991). Thus, researchers in this tradition propose to replace the traditional discourse on schooling with talk about the "construction of identities" (Lave & Wenger, 1991, p. 53).

Studies that examine teacher identity aim to understand the mechanisms underlying human actions, in other words, to explain why different teachers act differently in the same situation such as reform-oriented movements of teaching (e.g., Day, Elliot, & Kington, 2005;

Flores, 2006; Hong, Oliver, & Vargas, 2009; Lasky, 2005; Luehmann, 2007). By using the notion of identity, researchers try to understand similar patterns emergent from different teachers' teaching practice and their development (see Enyedy, et al., 2006; Lasky, 2005; Luehmann, 2007), and how one's experience across multiple cultural communities of practice impact one's professional practices, values, and/or beliefs, and what form it takes.

Sociocultural researchers highlight the similar features of identity and professional identity. Luehmann (2007) reminds us of the four common characteristics of identity. First, identity is socially constituted, that is, one is recognized by self and others as a kind of person because of the interactions one has with others. Second, identity is constantly being formed and reformed, though the change process for one's core identity is long term and labor intensive. Third, identity is considered by most to be multifarious, that is, consisting of a number of interrelated ways one is recognized as a certain kind of person, participating in social communities. Finally, identity is constituted in interpretations and narrations of experiences (Luehmann, 2007, p. 827). In general, identity is viewed as a fluid, dynamic, relational, recursive, and discursive process (Beijaard, Meijer, & Verloop, 2004; Hall, et al., 2010; Juzwik, 2006; Richmond, et al., 2011; Sfard & Prusak, 2005) in this tradition.

Researchers, however, have also struggled to operationalize the definition of identity so as to capture the complex interplay between learners and its sociocultural context. It may be true that "the notion of identity cannot become truly useful unless it is provided with an operational definition" (Sfard & Prusak, 2005, p. 15). Beijaard, Meijer, and Verloop (2004) remind us that more attention should be paid to the role of context in professional identity formation, and in what counts as 'professional' in teachers' identity. One approach to documenting identities is to consider every aspect that seems to relate to identity. For instance, Enyedy, Goldberg, and Welsh

(2006) are aware that "the notion of professional identity lies at the intersection between one's personal history and individual psychology on the one hand and one's cultural history and community of practice on the other hand" (p. 71). Arguing that identity is a complex construct, yet extremely important to understand the practice of teaching as a profession, Enyedy et al. (2006) include beliefs, goals, and knowledge as the constructs of identity, though point out that it is not limited to them.

Another approach to operationalizing identity development is the narrative definition of identities (Hall, et al., 2010; Juzwik, 2006; Richmond, et al., 2011; Sfard & Prusak, 2005). Sfard and Prusak (2005) define identities as "collections of stories about persons or as those narratives about individuals that are *reifying, endorsable, and significant"* (p. 16). While rejecting the notion of identities as extra-discursive entities that one merely "represents" or "describes" while talking, Sfard and Prusak claim that narratives themselves present them as discursive counterparts of one's lived experience. Researchers who share this narrative definition of identity tend to examine what a teacher, or others, tell them about the teacher's practice assuming that it will reveal the complex dialectic between identity-building and other activities (see Richmond, et al., 2011). Narratives or teachers' stories about themselves and practices become the essential part in most recent investigations on identity. In many empirical studies, identities or professional identity is constructed from the thematic analysis of teachers' stories about themselves. For instance, Leuhmann and Tinelli (2008) studied teacher professional identity development with social networking technologies in the context of a year-long graduate level seminar at a university. They define the professional identity as "being recognized by self or others as a reform-minded science teacher" borrowing from Gee's (2000) definition. The development of professional identity is identified by looking at the emerging themes in the contents of the blogs such as wrestling, displaying competence, sharing emotions, encouraging, etc. Similarly, Lasky (2005) analyzes teachers' professional identity through thematic analysis of stories about themselves from the interviews. The narrative definition of identity seems to have potential to provide some insights concerning teachers' different actions and development trajectories in social contexts.

In summary, sociocultural studies provide a new vision of learning suggesting that the notion of identity allows us to better understand the underlying mechanism of teachers' change of practice. Despite some meaningful attempts at defining and capturing teacher identity, the review of empirical studies on teacher identity indicates that the field is still looking for better ways of capturing teacher identity that reveal the complex dialectic between a teacher and social contexts.

Conclusion

I identified three groups of research studies in the field of research on science teacher learning in this review of the literature: (a) cognitive and affective factors-oriented research, (b) cognitive mechanism-oriented research, and (c) sociocultural identity-oriented research. Considering the goal of understanding mechanisms of beginning teachers' learning of reform-oriented teaching, I draw upon the following implications for this study.

First, researchers in science teacher education have been successful in identifying some important elements that play significant roles in shaping beginning teachers' classroom practices, but they have been less successful in understanding the mechanism of learning—why those factors are important and how they work together in actual contexts. In order to provide appropriate and substantial support for beginning teachers' learning, we need to know more than the fact that it is a complicated process that involves multiple elements.

Second, the reform-oriented teaching manifested in most recent standards requires teachers' in-depth understanding of science as practice in order to engage students in the strands of scientific proficiency. The change of the goals of science education in the standards documents reflects the movement toward participating in the practices of science beyond developing knowledge of a core or essence of science. Thus far, the research on science teacher learning has been dominated with what I called factor-oriented research that is organized around the development of core or essential characteristics of science teaching. Considering the new goals of science education, teachers' understanding of the view of 'science as practice' needs to be better attended in the research on teacher learning.

Third, both cognitive mechanism-oriented and sociocultural identity oriented research seem to be promising in exploring the process of beginning teacher learning. Examining the process of acquiring knowledge and practices of reform-oriented teaching will help me to understand the mechanisms of learning in-depth in relation to teachers' cognitive development. The notion of identity is a useful analytical lens that potentially allows me to explore the mechanism of learning in social contexts. But the construct of identity needs to be operationalized with the consideration of the unique challenge of beginning teacher learning. Therefore, I intend to build my study on these two groups of research studies (mechanism- and sociocultural identity oriented) in order to understand the mechanisms of beginning teacher learning comprehensively and in-depth.

Chapter 3.

Contexts and Methods

This investigation is a multiple case study (Stake, 2004; Yin, 1989) with 14 secondary science teacher candidates in a university-based teacher preparation program for a research period totaling three years. I examined secondary science teacher candidates' mechanisms of learning with special attention to the roles of knowledge and professional identities by setting up comparisons with six focus cases. In this chapter, I begin by describing the university-based teacher preparation program as one main context of the candidates' learning. Next, I describe the methods in detail, including participants, data collection, and data analysis. The limitations of this study are discussed at the end.

Research Context: A University-Based Teacher Preparation Program

The Green teacher preparation program is a reform-oriented five-year program at a large Midwestern University. Teacher candidates typically get into the program in their junior year and take basic courses along with the experience of tutoring in the field. They take a series of four content-specific methods courses from the senior year to the intern year (see Table 2 below). Candidates are placed in nearby schools early in their senior year, and then placed in a different school once again for their internship year. Thus, most candidates experience two different mentor teachers over two years. The program is designed to gradually increase candidates' experiences in the field as they move through the program. Candidates observe four hours per week at their school placements during their senior year, and they teach between two and five lessons in each semester. During their internship in the 5th year, they spend four days a week, from Monday to Thursday, at the field site as a full-time intern, and they take methods courses on Fridays except during the (guided) lead teaching periods[8].

Table 2. Research context: A five year reform-oriented teacher preparation program

Level	**Seniors (4th year)**		**Full time Internship (5th year)**	
Semester	**Fall**	**Spring**	**Fall**	**Spring**
Teacher education program	Science methods seminar I	Science methods seminar II	Science methods seminar III	Science methods seminar IV
School-based experiences	Observation (4h per week) Co-planning & co-teaching (Two single lessons)	Observation (4h per week) Co-planning & co-teaching (Two single lessons & One 3-day lesson)	Observation Teaching one focus class Two guided lead teachings (2 weeks per each)	Lead teaching (10 weeks)
Occasions for learning: Classroom activities	Planning and enacting two single lessons	Planning and enacting two single lessons & one 3-day lesson[9]	Planning and enacting daily lessons & units	Planning and enacting daily lessons & units Inquiry/application activity sequences
Occasions for learning: Assessment practice	Clinical interview Analyzing student responses	Designing assessment items & analyzing three focus student responses (one per semester)	Designing assessment items & analyzing three focus student responses (two per semester)	Designing assessment items & analyzing three focus student responses (twice per semester)

Interns select one class hour, and teach this 'focus class' throughout the whole internship period. They teach one more class period besides their focus class during the first two-week period of

[8] (Guided) lead teaching is the period when interns' teaching load in the field increases by adding one or two more classes to the general teaching load during the non-(guided) lead teaching period. It was designed by the program to periodically increase or decrease the teaching load in the field in order to assist their learning to teach effectively by engaging them in the cycle of planning, teaching, assessment, and reflection.

[9] Candidates teach three consecutive lessons for three days

guided lead teaching (GLT), and they teach two more classes during the second GLT period in the fall semester. Finally, they assume full responsibilities as a lead teacher during 10 weeks of lead teaching in the spring semester. Teacher candidates are provided opportunities for interacting with their course instructors and their peers regarding their planning, teaching, and assessment through the assignments and discussion in the methods courses.

Designed occasions for learning: Planning and enacting classroom activities. Teacher candidates are provided several targeted opportunities of planning and enacting classroom activities while getting advice from both their mentor teachers and their course instructors through 'Lesson/unit plan and report' assignments[10]. Similar to other teacher preparation programs, the assignment for classroom activities is structured to support candidates' development of classroom activity practices by helping candidates' thoughtful planning and reflection before and after teaching. During the occasions that are named "co-planning and co-teaching," typically candidates get access to resources and ideas of school professionals, including their mentor teacher. Whereas mentor teachers' advice is mostly provided through informal conversations, worksheets, or activities, course instructors provide written comments and suggestions on candidates' ideas for classroom activities both before and after their teaching. In addition, candidates have opportunities to discuss their ideas of classroom activities with instructors and their classmates in their methods courses, before and after their teaching.

Designed occasions for learning: Assessment practices. Candidates are requested to design two to three formative assessment tasks/items tied to their proposed learning objectives in their lesson plans, and to enact them both before and after their teaching,[11] whenever teacher

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[10] See the template for lesson/unit plan and report in appendix 1

[11] See the instruction for this assignment in appendix 2.

candidates engage in planning and reporting that teaching assignment from the senior to the internship year. Therefore, a candidate gets at least nine occasions for learning about assessment practices over two years. Typically, a candidate has opportunities for analyzing and discussing students' responses to their assessment questions with instructors and peers in their methods courses. A candidate has to select three focus students who are at different achievement levels, and then develop a written report based on evidence of students' learning.

It should be noted that the occasions for learning in this program are focused more on formal assessment practices such as written work or planned interviews than an informal assessment practices such as questioning and responding during instruction. Formal assessment practices presented with their written work or stories of practices give information on all elements of assessment practice.

Methods

Participants

Teacher candidates. A total of 14 teacher candidates from three cohorts in a reform-oriented teacher preparation program at a large Midwestern university participated in this study for two years (see Table 3 below). Participants were selected from a pool of volunteers in a way that represented the teacher candidate population of the program, considering their school contexts, major, gender, and school level. I selected four candidates from three consecutive cohorts during the period of data collection, 2008-2010. The first four candidates from cohort I—Monica, David, Teresa, and Susie—were interns (5^{th} year) during the first year of study (2008-09). The second four candidates, from the cohort II—Leslie, Shannon, Mary, and Kevin—were seniors (4^{th} year) at that time. Two of them, Leslie and Shannon, continued to participate in this study in the next year (2009-10) during their internship period, and another two candidates, Adam and Alisa, replaced Mary and Kevin due to the distance of their internship placements from the research site for the latter. The third group of four candidates, from cohort III—Lori, Lynn, Stella, and Scott—participated during the second year of data collection (2009-10) as seniors.

Table 3. Participant selection

Academic year	2008-9	2009-10	Status during data collection
Cohort I	Monica		Intern
	David		Intern
	Teresa		Intern
	Sarah		Intern
Cohort II	Leslie	→ Leslie	Senior/Intern
	Shannon	→ Shannon	Senior/Intern
	Mary		Senior
	Kevin		Senior
		Adam	Intern
		Alisa	Intern
Cohort III		Lora	Senior
		Lynn	Senior
		Stella	Senior
		Scott	Senior

Table 4 shows the 14 candidates' profiles, including gender, major, school context, and stages of program. Among the 14 candidates, 10 candidates were female and four were male. Seven out of 14 candidates majored in Biology, three in Chemistry, two in Physics, and one in Earth science. The contexts of their schools (i.e., urban vs. suburban) were evenly balanced during the process of selecting participants. The characteristics of the 14 candidates were fairly consistent with the characteristics of all the secondary science teacher candidates in the program.

Mentor teachers. Fourteen mentor teachers who worked with the teacher candidates participated in this study. The mentor teachers had from six to 38 years of teaching experience when they worked with these candidates, and all of them had experiences working as a mentor teacher more than two times before they worked with these candidates in this project. Among 14 mentor teachers, eight had worked with the program several times, and four mentor teachers graduated from the same teacher preparation program. The mentors were each interviewed about candidates' practices, their own practices, and the nature of their relationship and interaction with their candidate.

Table 4. Profiles of the 14 teacher candidates

Academic year	Pseudonym	Gender	Major	School context	Stages of program
Cohort I	Monica	F	Bio	Suburban HS	Intern
	David	M	Bio	Suburban HS	Intern
	Teresa	F	Bio	Urban HS	Intern
	Sarah	F	Chemistry	Urban HS	Intern
Cohort II	Leslie	F	Bio	Urban HS Urban HS	Intern/senior
	Shannon	F	Chemistry	Urban HS Suburban HS	Intern/senior
	Mary	F	Chemistry	Suburban HS	Senior
	Kevin	M	Physics	Suburban HS	Senior
	Adam	M	Bio/Phys	Suburban HS	Intern
	Alisa	F	Earth	Urban MS	Intern
Cohort III	Lori	F	Bio	Urban HS	Senior
	Lynn	F	Bio	Suburban HS	Senior
	Stella	F	Bio	Suburban MS	Senior
	Scott	M	Physics	Urban MS	Senior
3 cohorts (2009-10)	14 Teacher candidates	F: 10 M: 4	Bio: 7 Chemistry: 3 Physics: 2 Earth Science: 1	Urban: 8 Suburban: 8	Intern: 8 Senior: 8

Course instructors. Two science methods course instructors, Dr. R and Dr. G, were interviewed in the same way as the mentor teachers. Dr. R had taught the science methods course for more than 10 years in the program, and for Dr. G, it was her fourth year of teaching the methods courses. Due to the cohort system of the program, typically a course instructor works with the same cohort for two consecutive years, from the senior to the internship year, which provided both the instructors and the candidates opportunities of building a close working relationship. Both Dr. R and Dr. G worked with the candidates for two years while teaching four consecutive science methods courses.

Focus Case Selection

All 14 teacher candidates' practices were analyzed to find patterns of practices, but six focus cases are described in detail in the findings section in order to have depth of analysis. The six focus cases were selected considering the contexts of the school placements (i.e., urban vs. suburban), the nature of mentor teachers' instruction (i.e., conceptual, reform-oriented vs. didactic, traditional), and characteristics of the student classroom communities. I selected three interns—David, Monica, and Adam—who worked at similar suburban high schools but developed different kinds of classroom activity practices. With respect to assessment practice, another three candidates—Leslie, Susie, and Teresa—were selected. These three candidates worked at the same or similar urban high schools in the same school district that had similar level of challenges in managing the classroom, but they each developed different kinds of assessment practice. I will describe the details of the six focus cases and their contexts in the following section.

Classroom activities: Three suburban candidates' cases. Three interns—David, Monica, and Adam—shared many common features with one another. These three candidates were all biology majors, and taught either 9th or 10th grade biology in the unit on genetics at similar academic-oriented suburban high schools in their internship year (5th year) (see Table 5). The schools had a relatively high percentage of white students (66%, 84%, 90%), and a low percentage of students who get free or reduced lunch (9 to 19 %). One key difference among the three candidates was the kinds of resources and ideas for classroom activities provided by their mentor teachers. Two of them, David and Adam, worked in a so-called "best scenario condition," where their mentors and teacher preparation program provided consistent ideas and resources for reform-oriented science teaching. Their mentor teachers, Mrs. M and Mr. V, graduated from the same teacher preparation program 12 and 7 years ago, respectively. Both mentors were highly regarded mentor teachers by the program, and they modeled reform-oriented practices for candidates. Another intern, Monica, worked with Ms. S, whose practice was mostly didactic. Ms. S had strong reservations about inquiry teaching. Planning and enacting classroom activity practices involve selections of resources and ideas for activities provided by professional communities. Therefore, the difference among mentors' preferred instructional approaches and their positioning with respect to the program created important differences in the nature of occasions for learning for each of the candidates. The three candidates developed different kinds of classroom practices while responding in a substantially different way to their occasions for learning.

Table 5. The three focus cases for classroom activity practice

Candidates	David	Monica	Adam
Ethnicity, gender	White male	White female	White male
Major	Biology	Biology	Biology
School setting	Suburban high school	Suburban high school	Suburban high school
Subject to teach	9th grade biology, the unit of genetics	9th grade biology, the unit of genetics	10th grade biology, the unit of genetics
Stage of program	Intern	Intern	Intern
Mentor	Mrs. M (graduated from the program)	Ms. S	Mr. V (graduated from the program)

Assessment practices: Three urban candidates' cases. I selected three urban candidates, Leslie, Teresa, and Susie, as focus cases for assessment practice, on the assumption that the nature of student communities in their classroom might play a critical role in candidates' learning from students. The placements for these three candidates commonly had fairly diverse populations of students, large class sizes, and limited resources. The West high school, where

Leslie and Susie worked, had about 55 percent non-white students, and about 58 percent of the students were eligible for free or reduced lunch. Teresa worked at the Central high school that had 63 percent non-white students, and about 51 percent of the students were eligible for free or reduced lunch. Teachers at both West and Central had been suffering from a severe budget cut. The three candidates taught either 9^{th} grade biology or chemistry. Susie and Teresa were in their internship year (5^{th} year) but Leslie was in her senior year (4^{th} year) (see Table 6). The three mentor teachers were all experienced teachers who had collaborated with the program for several years. Their approaches to teaching science were so-called 'traditional,' but they were reasonably successful teachers in these challenging urban high schools. In summary, Leslie, Susie, and Teresa shared most contextual factors that potentially would involve in their learning of assessment practices. Even so, they developed different kinds of assessment practices while responding in different ways to their occasions for learning.

Table 6. The three focus cases for assessment practice

Candidates	**Leslie**	**Susie**	**Teresa**
Ethnicity, gender	White female	Asian female	Asian female
Major	Biology	Chemistry	Biology
School setting	Urban high school (West high school)	Urban high school (West high School)	Urban high school (Central high school)
Subject to teach	9^{th} grade biology, the unit of genetics	9^{th} grade chemistry, Chemical reaction	9^{th} grade biology, the unit of genetics
Stage of program	Senior (4^{th} year)	Intern (5^{th} year)	Intern (5^{th} year)
Mentor	Mrs. F (graduated from the program)	Mrs. B	Mrs. R (graduated from the program)

Data Collection

Multiple data types were collected to document candidates' mechanisms of learning the two focus practices. The primary sources of data were candidates' *teaching episodes*. A teaching episode was a unit of data collection produced through candidates' guided engagement in the teaching cycle—planning, teaching, assessment, and reflection. Various artifacts around the teaching cycle were generated by candidates as they responded to the deliberately designed occasions for learning with a form of written reports or videos. One of teaching episodes included a set of interviews that were conducted with a candidate, his/her mentor teacher, and course instructor using the candidate's teaching video. In addition, candidates' vision statements and extra interviews with candidates using a clinical interview video were also used as sources of data.

Teaching episodes. Each candidate produced two or three teaching episodes per semester. I selected one episode per semester for each candidate as a primary data source, and used other episodes as complementary data. Typically, data from one teaching episode included written plans and reports of teaching. Candidates were required to include their teaching video in one teaching episode each year. Each year, I collected at least two teaching episodes for each candidate, including the one that had a teaching video. The different types of data included in the teaching episodes are described in detail as follows.

A. Plans and reports of teaching. Each teaching episode includes a written plan and a report. The "plan" has the descriptions of lesson objectives, classroom activities, and assessment items. The "report" includes candidates' stories about their teaching (e.g., stories of what happened during the lesson), three focus students' responses to both their assessment questions and their instruction, and ideas for improvement. These written data showed both actual practices and 'narrativatized' practice. The plans and reports of teaching were used as the major source of data for analyzing assessment practice. The assessment questions in their plans showed the first step of assessment practice—providing opportunities for students to give information about themselves. Their written analysis of three focus students' responses to their assessments showed what candidates identified about their students and how they interpreted it. Finally, their stories of ideas for improvement included candidates' responses to students (i.e., the last element of assessment practice). The narrativatized practices of classroom activities were used as the complementary source for triangulating the patterns of actual practices identified from the teaching video. In addition, candidates' stories about the two focus practices were used for analyzing candidates' knowledge and identities.

B. Candidates' own teaching videos. Candidates videotaped at least one lesson at their school placement while developing one teaching episode. Teaching videos were analyzed to characterize candidates' actual practices of classroom activities. These videos were also used for interviews with candidates, mentor teachers, and course instructors.

C. Interviews using teaching videos with candidates, mentor teachers, and course instructors. I conducted individual interviews with all 14 candidates, the14 mentor teachers, and the two course instructors, using candidates' self-made teaching videos. Interviewing using videos has been suggested as an effective approach to understand teachers' reasoning behind their science teaching practice and their professional vision (Enyedy, Goldberg, & Welsh, 2006; Sherin & van Es, 2005; van Es & Sherin, 2008). Furthermore, interviews provide opportunities for candidates to tell stories about self(s) and practices of science teaching, either currently or designated practices in the future in their classroom. It also allows other important members of communities who work most closely with candidates to tell stories about candidates, his/her practices, and the nature of interaction and relationship with candidates. Candidates' stories about self and practices, in particular their interpretation about practice, resources, and ideas from different professional communities were used for analyzing candidates' learning of the two focus practices, their knowledge, and identities.

The interview was semi-structured; typically one interview took between 60 and 70 minutes. I selected two short segments of videos before the interviews. Each segment was three to seven minutes long; one segment captured characteristics of classroom activities (i.e., the focus practice I), and the other showed candidates' interaction with students, a key part of assessing and responding to students (i.e., focus practice II). During the interviews, questions were asked before and after watching the two segments of videos. The important part of this interview was to provide opportunities for interviewees to highlight and code (i.e., interpret) the two focus practices of this study in response to my both open and structured questions. Examples of questions for highlighting and coding include: (a) What do you notice in the video? Is there anything that stands out to you? (b) What do you like or dislike about it and why? (c) Is there anything that you would like to do differently? If so, why? (see all the questions in the interview protocol in Appendix 3). Besides the highlighting and coding of the focus practices, I also asked about (a) school contexts, (b) relationships with students, mentor teachers, course instructors, and other members of communities, if any, in relation to their practices (e.g., how to work when you plan a lesson), and (c) current and future self (s) as a teacher. The same or similar questions were asked of candidates, mentor teachers, and course instructors in order to compare what they highlighted and how they coded (i.e., interpreted) what they highlighted with respect to the two focus practices of this study.

D. Artifacts of teaching episodes. Other artifacts about teaching episodes provided by candidates or mentor teachers were used as complementary sources of data, such as worksheets, PowerPoint presentation slides, examples of students' work, or models used in the videotaped lessons.

Other data sources. Besides the teaching episodes that have multiple sources of data generated by multiple members, there were other important sources of data that were used to triangulate patterns of practices identified from the main teaching video. Some of these data were analyzed to understand the mechanisms of learning—the roles of candidates' knowledge and professional identities in the learning process. Those data included candidates' vision statements and interviews with candidates using a clinical interview video.

E. Candidates' vision statements: Statements of good science teaching and teaching philosophy. Teacher candidates developed statements of good science teaching at different stages of their teacher preparation program as a part of their course assignments. Depending on course instructors, some candidates produced "vignettes of good science teaching" that included exemplary teaching episodes that they experienced or wanted to see in their classroom, along with their analysis. Teaching philosophy statements produced at the end of the internship year were also added to the data if available. All these data included candidates' stories about self(s) and practices at different stages of their program. These data were especially useful to see candidates' vision of good science teaching, and their designated identities—what kind of science teacher they wanted to be and what kind of science teaching they wanted to master.

F. Interviews with a clinical interview video. During the first year of data collection, I conducted other individual interviews with the eight teacher candidates from cohort I and II, using one video. This video showed a faculty' member's clinical interview with a sixth grade student, Jeremiah. In the video, Jeremiah had rich personal experiences of gardening with his father and knowledge about plants, but dismissed the school knowledge associated with the term "photosynthesis" by saying, "I don't know a lot about photosynthesis. I did not pay attention to that part." During the individual interviews, the candidates watched and responded to Jeremiah.

This interview, by using the same video, created a 'controlled' environment where candidates were provided with exactly the same information about a student, Jeremiah, through video, and had opportunities of identifying, interpreting, and responding to him[12]. This interview was used as complementary data to triangulate candidates' patterns of assessment practices that emerged from their own teaching episodes.

Data Analysis

The purpose of this study was to understand the mechanisms of candidates' learning of the two science teaching practices—the practices of classroom activities and assessment. In this data analysis I examined the processes by which candidates developed certain kinds of practices as they responded to occasions for learning. The model of beginning teachers' mechanism of learning was developed through the examination of the processes of both acquiring knowledge and of authoring professional identities as framed in the conceptual framework.

In the first stage of data analysis, I analyzed all 14 teacher candidates' cases to find patterns of the two focus practices of this study—the practices of classroom activities and assessment. Considering the emerging patterns of practices, general characteristics of candidates' understanding of science for teaching, school contexts, and other elements that are involved in mechanisms of learning, I selected the six focus cases[13]--the three candidates at similar suburban high school contexts for classroom activities practices, and the other three at similar urban high school for assessment practices—for the second stage of data analysis that was about model building. In the second stage, I examined their knowledge and professional identities to explain how and why the candidates developed certain kinds of science teaching practice following the

[12] See the interview protocol at Appendix 4

[13] See the rationale and the detailed process of selecting six focus cases in the section on participants, pages 54-57

conceptual framing. In the following section, I describe the detailed process of data analysis at each stage.

Stage I: Finding patterns of the two focus practices. The two focus practices of this study—classroom activities and assessing and responding to students—needed to be specified with a "common technical vocabulary" (Grossman & McDonald, 2008, p. 186) in order to characterize patterns of practice in a valid and reliable way. This specification of the focus practices should align with both the conceptual framework and the empirical evidence existing in the data. The specification and data coding were conducted iteratively at the first stage of data analysis. The major sources of data for finding patterns of candidates' practices were (a) candidates' teaching video, (b) interviews about the teaching video, and (c) the written plan and reports of the videotaped lesson from one teaching episode. The data from other teaching episodes were also analyzed to complement the patterns of classroom activity practices that emerged from the main teaching episode. For the assessment practice, candidates' interviews with a clinical interview video were analyzed as supplementary data sources as well. The detail of the process of analyzing data for each focus practice is described in the following section and summarized in Table 7.

Planning and enacting classroom activities. One teaching episode included multiple sources of data about the same classroom activities enacted by candidates. The data included: (a) teaching video, (b) a written plan and report, (c) the candidate's interview about the videotaped lesson, (d) a mentor's interview about the videotaped lesson, and (e) a course instructor's interview about the videotaped lesson. The data were analyzed with four steps: (a) developing the coding schemes for each focus practice, (b) data coding, (c) finding patterns of practices, and (d) triangulating and checking reliability. The patterns of classroom activities practice emerged from one teaching episode were triangulated using other teaching episodes. Overall data analysis was conducted with the help of Nvivo 8, a computer software program for assisting qualitative analysis.

Table 7. Data analysis of the two focus practices

	Classroom activity practices	**Assessment practices**
Major data source	Teaching video Written plan and report Candidates' interview Mentor's interview Instructor's interview	Written plans and reports of multiple teaching episodes Candidates' interview Teaching video
Supplementary data source	Written plans and reports of other teaching episodes	Interview with a clinical interview video
Elements of practices for data analysis	(a) Goals of lesson (b) Roles of activities (c) Roles of students	(a) Providing opportunities for students to give information about them (b) identifying (c) interpreting (d) responding
Unit of analysis	An account about three elements of classroom activity practices. One account consists of one or multiple sentences.	Accounts generated from one student response that have information about candidates' noticing and responding to students

*A. Developing coding scheme***.** To characterize candidates' practices of teaching, I first examined each candidate's written plan and report and interview transcript. As I read through written plans and reports of teaching and interview transcripts, I identified the places that included candidates' stories about classroom activities. At this initial stage, I developed analytical memos linked to each data source from the 14 candidates' teaching episodes using NVivo. The analytical memos included relevant segments of data, analytical summaries, and my initial observations and comments about classroom activity practices. Next, I developed the "standardized descriptors" of each type of data in order to code the analytical memos using NVivo software. The standardized descriptors represented the main content of each segment of data, such as “objectives”, “sequences of activities”, “ideas for improvement”, and “relationship with mentor teachers” (see Table 8).

Table 8. Examples of standardized descriptors

	Plan and report	Teaching video

Examples of Standardized descriptors	• Classroom activities
	    o Objectives
	    o Sequences of activities
	• Assessment items
	• Making sense of students' responses
	• Ideas for improvement
		• Introduction of the lesson
		• Relationship with the mentor
		• Concerns
		• Comments about the lesson
		• Teaching materials
		• Goals of the lesson

Three elements of classroom activities commonly appeared in the two types of data across most candidates’ cases. These elements were (a) goals of the lesson, (b) roles of activities, and (c) roles of students. I decided to use these elements to characterize candidates’ classroom activity practices because of their alignment with research on reform-oriented science teaching and their strong empirical presence in this source of data.

Data were first coded with the standardized descriptors using NVivo. The result of this coding allowed me to see the contents of one descriptor from all candidates on the same page, and thus to easily compare and characterize different kinds of classroom activity practices across candidates. For example, with respect to the descriptor of “Goals of the lesson,” whereas a candidate’s account was focused on students’ content understanding (e.g., “finding patterns from data and formulating a new explanation”), another candidate’s account was focused on social aspects of learning (e.g., “getting them to work together”). I developed two levels of “codes” that captured the characteristics of proposed goals in candidates’ stories of practices. One is “descriptive codes” that directly come from the data and characterize candidates’ accounts, such as “getting them to work together,” and the other is “interpretive codes” that group similar characteristics of descriptive codes together, such as “content understanding”, “social aspect of learning", and "motivational/behavioral aspect"[14]. These two levels of code helped me to address the issue of balancing objectivity and subjectivity in the later process of checking reliability. During the data coding, considering the interpretive code linked to the multiple descriptive codes allowed the coder to code the data capturing the meaning of the words in the context of teaching, rather than simply relying on the words themselves. This was important because many candidates appropriated the program language in their own meaningful way without understanding the underlying meaning of it during the interview.

B. Data coding. Candidates' interview transcripts were coded again with the final coding scheme for classroom activities using NVivo 8. The coding scheme was iteratively revised whenever moving to another candidate's case. The unit of analysis in this coding was an account about any of the three elements. One account consisted of one or more sentences. I coded candidates' teaching videos using the same coding scheme. The written plan and report were used to triangulate the consistency of the results of coding of both teaching video and the interview transcript. With respect to the six focus cases, mentor teachers' and course instructors' interview transcripts were coded in the same way in order to compare their accounts of classroom activities with candidates' accounts, with respect to goals of lessons, roles of activities, and roles of students.

C. Finding patterns of practices from the results of coding. The number of codings was counted and converted into percentages in a spreadsheet to find the overall patterns of practices across different types of data in each candidate's case. The percentage chart showed which aspect of goals of lesson, roles of activities, and roles of students were highlighted more than others relatively in both teaching videos and their accounts.

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[14] See the coding scheme for classroom activities in appendix 5.

D. Inter-rater reliability and triangulation. The coding schemes were regularly discussed with one faculty member at weekly meetings. Another doctoral student in the science education PhD program coded samples of data to check the reliability of my coding. The initial inter-rater reliability was below 50% because of the different level of interpretation in the process of coding data between two researchers. As I described above, the greatest challenge in this process was how much the researcher codes the account relying on the words in the accounts themselves. Coding the data relying on words that were captured in the descriptive codes made the result of coding objective and reliable, but it failed to capture the meaning attached to the words because candidates often meant different things even when they used the same program language (e.g., inquiry, explaining). This reflects the difficulty of "capturing the substantive meanings of events rather than just the events themselves" (Kennedy, 2010, p. 245). In order to balance objectivity and meaningfulness, I developed 'interpretive codes' in addition to the existing 'descriptive codes,' and had the second researcher recode data using the new coding scheme. The coding scheme was continuously revised until we reached to over 80 % reliability. Candidates' patterns of practice were identified from the multiple data sources within one focus teaching episode, and then the patterns were triangulated with the data from other teaching episodes.

Assessment practices. The process of analyzing assessment practices was very similar to the one for classroom activities, except that the elements of assessment practices were specified from the prior conceptual framework. As described in the theoretical framework in Chapter 1, assessment practices were examined with respect to (a) what kinds of *opportunities* candidates provide for students to give information about their learning either formally or informally, (b) what they *identify* (i.e., highlight) about students from those opportunities, (c) how they *interpret* (i.e., code) what they identify, and (d) how they *respond* to students. Candidates' suggestions and ideas of modification for improvement showed their instructional responses to their students as well as the lessons that they drew upon from their experiences. The coding scheme for assessment practices was developed with respect to these four elements through the same process[15].

The major sources of data for assessment practices were (a) written plan and reports and (b) the candidates' interviews about their lessons. Written plans and reports included candidates' assessment questions or tasks, the description of three focus students and their responses to the assessment questions, candidates' analysis of students' work, and ideas for improvement. Candidates' interview transcripts included their accounts of students and students' responses to their instruction. The unit of analysis of this coding was *the accounts generated from one student response*. Data showed that one student response usually generated one cycle of assessment practice, from identifying to responding. If candidates summarized or pointed out the pattern of student responses, that account was also counted as one unit of analysis.

All 14 teacher candidates' assessment practices were analyzed using sets of data from candidates' two teaching episodes. For the three focus cases of assessment practice, I also analyzed another interview with candidates using a clinical interview video. I coded this interview using the same coding scheme for assessment practice to triangulate patterns of assessment practices that emerged from candidates' own teaching episodes.

Stage II: Building the model on the mechanisms of learning through the analysis of knowledge and professional identities. The results of the first stage of data analysis showed patterns of practices for 14 candidates' classroom activities and assessment. Overall the

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[15] See the coding scheme for assessment practice in appendix 6.

candidates were separated as two sub-groups who were either successful or less successful in making use of resources and ideas from the program to develop reform-oriented practices. As described in the above focus case selection and in the overview of methodology of chapter 1, I selected the six candidates who showed different learning trajectories even though they shared many characteristics with one another and worked in similar contexts. While selecting the six focus cases, I also set up comparisons of candidates in similar contexts—three suburban high school cases and three urban high school cases in order to focus on the process of candidates' knowledge development and authoring professional identities as framed in the conceptual framework. With respect to the selected six cases, I analyzed candidates' understanding of science teaching and their professional identity to develop the explanatory model of the mechanisms of beginning teachers' learning.

Candidates' knowledge for science teaching. Candidates' knowledge was analyzed from their highlighting and coding in their stories of science teaching. While telling their stories, candidates picked up the salient aspects of their experiences (i.e., highlighting) and interpreted it (i.e., coding) in a certain way. Candidates used their knowledge to make sense of what they noticed (Sherin & van Es, 2005). Accordingly, candidates' stories of practice, in particular their interpretation of the practices and resources reflected their understanding of science and teaching science. The major sources of data were each candidate's interview and written reports of teaching from two or more teaching episodes. Candidates' vision statements were also analyzed as supplementary data sources.

The analysis of candidates' knowledge for science teaching was guided by the four strands of scientific proficiency described in the most recent reform documents. As the learning goals or outcomes of science education, these documents describe students' scientific proficiency in the four strands as the following (NRC, 2007, p. 36):

Students who are proficient in science:

5. know, use, and interpret scientific explanations of the natural world;
6. generate and evaluate scientific evidence and explanations;
7. understand the nature and development of scientific knowledge; and
8. participate productively in scientific practices and discourse.

The core question for examining teacher candidates' understanding of science for teaching is how candidates understand the meaning of student proficiency in science. In order to analyze the ways in which candidates understand science for teaching, I identified the four elements of knowledge for teaching from the strands of scientific proficiency while considering its presence in actual data (see Table 9). The four elements are: (a) the meaning of understanding science, (b) the roles and the relationship of key components of science, including observation, experiences, data, pattern finding, scientific models, or theories in the process of developing students' scientific knowledge, (c) the relationship between scientific knowledge and practice in their instructional representation, and (d) the relationship between the classroom learning community and scientific community with respect to the roles of participants in each community.

Using this framework, I examined candidates' highlighting and coding in their stories about science teaching. In particular, I closely examined their interpretation of practices in terms of candidates' senses about goals of instruction and its effectiveness with regard to student learning. The six candidates' knowledge were analyzed individually, and then cross-examined. I found two different ways of understanding science for teaching from this cross-examination.

These two different ways of understanding science for teaching were characterized with respect to the four elements.

Table 9. The four elements of knowledge for teaching

The four strands of scientific proficiency	The four elements of knowledge for teaching
students who are proficient in science: 1. know, use, and interpret scientific explanations of the natural world; 2. generate and evaluate scientific evidence and explanations; 3. understand the nature and development of scientific knowledge; and 4. participate productively in scientific practices and discourse.	(a) the meaning of understanding science (b) the roles and the relationship of key components of science, including observation, experiences, data, pattern findings, scientific models, or theories, in the process of developing students' scientific knowledge (c) the relationship between scientific knowledge and practice in their instructional representation (d) the relationship between classroom learning community and scientific community with respect to the roles of participants in each community.

Professional identities. In this study, professional identities were conceptualized as collective stories about a candidate in/and practices told by multiple peoples. Professional identities consist of two types of stories: (a) the stories about their current self in/and practice (i.e., actual identities) and (b) the stories about their future self in/and practice (i.e., designated identities). Whereas actual identities reflect candidates' current practices based on their current available tools, personal resources, the nature of interaction and relationship with people in social contexts, designated identities reflect their aspiring practice and resources if they do not have now then in the future. It should be noted that candidates' understanding of science for teaching is not a separate entity from their professional identities. Rather, candidates' understanding of science for teaching is one of their key resources that determine the kinds of practice that they are *currently* capable of engaging in, which is reflected in their actual identities. Candidates' practices are reflected in the collective stories about current self(s) in/and practices, but the practices themselves are not the same with the actual identities. Rather, practices are reconstructed through a story-teller's narrativatization.

The data showed that the stories about self in/and practices were organized around the four elements: (a) goals, (b) classroom activities, (c) students, and (d) roles of and relationship with people. These elements guided my analysis of both their actual and designated identities. For actual identities, the interviews with candidates, mentor teachers, and course instructors conducted at the last stage of the program or after graduation were used as the major sources of data. I also analyzed other complementary data that included any stories of candidates' current self(s) in/and practices, that were (a) written plans and reports, and (b) interviews using a clinical interview video. For designated identities, candidates' vision statements were used as the primary data sources. Candidates developed vision statements (e.g., accounts of good science teaching, teaching philosophy statement) at three different stages of the program: (a) at the beginning of senior year (4^{th} year), (b) at the beginning of internship year (5^{th} year), and (c) at the end of internship year. The three vision statements were coded and compared to examine any changes in their aspiration throughout two years[16]. Candidates' interviews with teaching video conducted at the end of the internship year were used as supplementary data source for analyzing candidates' designated identities.

Building the model about the mechanisms of beginning teacher learning. In order to develop the explanatory model about the mechanisms of beginning teacher learning, specifically, how candidates produce certain learning outcomes (i.e., actual practices and interpretation of practice) as their responses to occasions for learning, I examined the patterns of each candidate's two focus practices in relation to their highlighting and coding, their understanding of science for

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[16] See the result of coding of designated identities in appendix 12.

teaching, and their actual and designated identities. I also examined across the six candidates' cases while comparing and contrasting the similarities and differences.

As I noted before, candidates' understanding of science for teaching was not a separate entity from their professional identities. Both of the conceptual constructs were analyzed from their stories about self in/and practices. Candidates' ways of understanding science for teaching was one important personal resource that enabled them to engage in their current practices. Therefore, understanding of science for teaching was reflected in their actual identities. Despite the inherent conceptual overlapping between the notions of knowledge and professional identities of this study, both conceptual constructs were useful because each of them allowed me to examine the mechanisms of learning from the different perspectives. By taking the analytical 'lens' of candidates' understanding of science for teaching, I focused on examining individual candidates' internal cognitive process while candidates respond to the occasions for learning and their effects on the development of certain types of practices. The analytical 'lens' of professional identities allowed me to examine the process of developing certain types of practices through candidates' interaction with activities and people in social contexts.

Subjectivities

As a qualitative researcher, I recognize that any observation and interpretation that I made were filtered through my own professional vision and biases that were formulated with my own experiences, values, and knowledge. I am an Asian woman who used to be a science teacher at two low resourced public schools in Republic of Korea. I had six years of middle school and high school teaching experience in that country. Through the struggles of teaching science at the early stage of my career as a science teacher, I was convinced that the traditional science teaching did not provide students meaningful and powerful learning experience. I came to strongly believe that preparing a quality teaching force is the key to make actual changes in classroom. My personal journey of learning how beginning teachers learn started a long time ago, even before this project. While a graduate student, I learned about the structure and characteristics of the teacher preparation program by observing science methods courses and shadowing university field supervisors' work. During the first year of data collection, I took on the role of university field supervisor for six interns, including Monica. Although David, Teresa, and Susie were not the interns that I was supervising, I was able to hear many stories about them, including their progress and struggles in the field, from both their field supervisor and course instructor through weekly instructor meetings throughout the whole year. During the second year of data collection, I taught the senior-year methods course; the four senior participants in this study—Lori, Lisa, Scott, and Stella—were my students. I was not formally related to either Leslie or Adam through the program, but my close relationship with their course instructors and field supervisors allowed me to encounter pieces of stories about them, though this was rare. My roles and relationships with the candidates certainly influenced my interpretation as well as the candidates' responses, because I knew them and the contexts that they had to deal with. I was actually a part of the context that candidates had to respond to, and I was aware that all the participants recognized this when they responded to my interview questions.

I addressed the issue of subjectivities with multiple layers of triangulation. First, I used multiple data sources to find patterns of practices. The patterns were triangulated with other teaching episodes. Second, I gained multiple perspectives from multiple people on the same segments of teaching video, including teacher candidates, course instructors, mentor teachers, and myself. By comparing the interpretation in their narratives on the same teaching episodes, I was able to compare and triangulate my interpretation with others. Third, I set up comparisons of cases at similar contexts, and I was a part of their common context. Finally, I conducted a formal inter-rater reliability check of my coding results with another graduate student with a sample of data.

Limitations of this Study

There are two limitations that should be noted in reading the findings of this study. The first concerns the data collection, and the other involves the data analysis. Two teaching episodes per one candidate were collected each year as the primary sources of data. The patterns of classroom activity practices, that is one of two focus practices of this study, were analyzed from the one main teaching episode that included candidates' teaching video, the written plan and report, interviews with the candidate, mentor teacher, and course instructor. This teaching episode was the one that was taught at the last stage of candidates' internship year. Then, this pattern of classroom activities was triangulated with other sources of data or the other teaching episodes. Regarding the analysis of the patterns of classroom activities, the results would be more reliable and valid if multiple sets of complete teaching episodes had been collected and analyzed. Also, multiple teaching episodes might allow me to trace the changes of practices throughout one or two years. The process of data collection requires time and energy from both researchers and candidates. It also increases the amount of work for analyzing data. Finding a balance between producing reliable and valid evidence of candidates' learning and having reasonable time and energy is tricky but important for future investigations.

The other limitation concerns the process of checking the inter-rater reliability of coding. Only a small sample of data could be coded by the other graduate student using the coding scheme that I developed due to the constraints of the resources. A broader reliability check with two or more other researchers would make the results of coding more reliable.

Chapter 4.

Findings I: Planning and Enacting Classroom Activities

Overview

This chapter examines the process by which secondary science teacher candidates develop certain kinds of practice of classroom activities as they respond to deliberately designed occasions for learning. I analyzed 14 teacher candidates' classroom activity practices manifested in both their actual practices (i.e., teaching video) and their narratives of practices (i.e., interview). The results indicate that only five candidates were clearly successful in making use of the perspectives and resources of the program as they planned and enacted classroom activities; the other nine candidates were less successful in making use of the program's ideas and resources to plan and enact classroom activities in a way that supports students' meaningful understanding. I selected the cases of the three teacher candidates who worked in similar suburban high school contexts. I closely examined the ways in which they responded to the occasions for learning in relation to their understanding of science teaching and professional identities (i.e., actual and designated identities). The three cases showed that candidates' understanding of science for teaching affected (a) what they highlighted about their experience and classroom activity practices, (b) how they coded (i.e., interpreted) what they highlighted, and (c) their selection of resources, ideas, and advice provided by the professional communities. Despite the fact that the program deliberately designed occasions for candidates to learn from professional communities, candidates' responses were profoundly constrained by their understanding of science teaching in how they highlighted and interpreted experiences, practices of classroom activities, resources, and advice from the professionals. Candidates selected resources, ideas, and advice based on their interpretation of them; thus candidates who had initially different ways of understanding science for teaching from the program were less likely to make use of resources and ideas from the program.

Candidates' professional identities, in particular their designated identities, also affected their learning from their mentor teachers and their course instructors as they engaged in classroom activities practice. Candidates positioned themselves as a learner of science teaching in certain ways depending on their perceived gap between actual and designated identities, which affected their ways of interacting with the professionals.

This chapter begins by presenting the 14 teacher candidates' patterns of classroom activity practices. Then the cases of three focus candidates—David, Monica, and Adam—are described in great detail. The description of each case is structured in three parts: (a) stories about the candidate, (b) the nature of occasions for learning for the candidate, and (c) the candidate's responses to the occasions for learning. By presenting the stories about candidates and their practices told by multiple people, including candidates themselves, their mentor teachers, course instructors, and myself, I intend to help readers to see candidates' actual identities—their current self(s) in/and practices constructed through collective stories. Because I purposefully selected three suburban candidates' cases who worked in similar suburban high schools, the differences in the nature of occasions for learning were mostly associated with resources provided by their mentor teachers and their preferred instructional approaches (e.g., reform-oriented vs. traditional). The patterns of classroom activities of one teaching episode taught at the last stage of their program were analyzed in both their actual practices (e.g., teaching video) and their narratives on practices (e.g., teaching video interview). Candidates' narratives on their practices were compared with their mentor's and course instructor's narratives in terms of what they highlighted and how they coded (i.e., interpreted) what they highlighted.

The descriptions of the three cases are followed by my analysis of the three candidates' understanding of science for teaching and their designated identities across two years. Finally, the process of learning to teach is discussed in relation to their understanding of science for teaching and authoring professional identities.

Fourteen Candidates' Patterns of Classroom Activity Practice

Two patterns were found in candidates' classroom activity practice as the result of data coding[17]. One group of candidates, consisting of five of the 14 candidates, highlighted and interpreted the goals of classroom activities, the roles of students, and the roles of activities with the focus on students' conceptual understanding of content. Their classroom activities provided meaningful opportunities for students to interact with both content and other students. The other group, nine out of 14 candidates, focused primarily on procedural or motivational roles in their highlighting and interpretation of the three focus aspects—the goals of the lesson, the role of students, and the role of activities. Their classroom activities passively engaged students in the process of reproducing canonical scientific knowledge without making connections between observations and scientific models or theories (see Table 10). In the following section on the three focus cases—David, Monica, and Adam—I describe (a) stories about the candidate, (b) the nature of occasions for learning for the candidate, and (c) the candidate's responses to the occasions for learning.

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[17] See Appendix 7: The results of coding about classroom activities

Table 10. Fourteen candidates' classroom activity practices

	Classroom activities supporting students' meaningful conceptual understanding of materials	**Classroom activities focusing on delivering content as the final answers**
Candidates **Interns** **Seniors**	**Monica**, Susie, **Adam**, Leslie Leslie, Scott	**David**, Teresa, Shannon, Alisa Mary, Kevin, Stella, Lynn
Goals	Actively engaging students in scientific practices Developing safe and comfortable learning environment	Teaching the content (i.e. the correct answer) and process/skills (i.e., critical thinking skills, problem solving skills, scientific method)
Roles of students	Actively interacting with both content and their peers Developing their own knowledge from data	Actively engaging in tasks Finishing the work following the direction
Roles of activity	A selected activity provides meaningful opportunities for students to make connections between observations and scientific theories/models.	A selected activity motivates students and helps them remember the information better by visualize or illustrate the content.

The Case of David

David is the candidate who was provided with consistent resources and ideas from both his mentor and the program, but who failed to demonstrate his learning of reform-oriented teaching. To begin with, I present stories about David told by himself, his mentor, and his course instructors. The stories were organized around the four elements: (a) goals, (b) classroom activities, (c) students, and (d) relationships with people. Next, the occasions for learning locally created for David in Mrs. M's classroom are described. In the latter part, the patterns of David's classroom activities in both actual practice (i.e., teaching video) and narratives of practice (i.e., his stories about practices during the interview) are presented with the results of coding. David's highlighting and coding (i.e., interpretation) of the classroom activities in his teaching video were compared with the highlighting and coding of his mentor and course instructor.

Stories about David

David was a white male intern who majored in biology and had a minor in chemistry. He wanted to be a high school biology teacher, and he had a firm vision about good science teaching when he got into the program in his senior year. David was concerned about relevancy, and he believed that science is fun and interesting when we can relate it to students' everyday lives. In his vignette of good science teaching that he wrote at the very beginning of his senior year, David described a mitosis and meiosis lesson in his high school AP biology course as "One of the best examples of science teaching that I can remember." As demonstrating his designated identities in this vignette, David highlighted that the teacher activated students' prior knowledge to make connections, made every subject exciting by relating it to their everyday lives, did not make students bored by giving a short lecture, got students to have some fun by actually acting out the [mitosis and meiosis] processes as a class, and finally helped students to remember the information. David stated, "Since everyone was having so much fun with it, we all learned it very well. Acting it out gave us all really good connections to remember the information, too."

Throughout the internship, David enjoyed teaching and did not encounter any troubles with students at the academic-oriented high school in a university town. In his stories about self, David described himself as a "laid back", "relaxed," and "free flowing" teacher for his students during the interview:

David: More laid back…I don't know, kind of like, I like…kind of relaxed…I'd say I'm a teacher who expects students to do what they're supposed to be doing. Like, they're supposed to meet me half way and, you know, do the things I want them to and, and if they do, then there's not really going to be too many problems or anything like that.

While offering lots of freedom to students, David expected that students should "hold their responsibility to pay attention," and "If they're not paying attention that's their choice." In general, students were respectful to David. David was clear about his expectations about grading, which most students of this school were concerned about. In his methods course, David was a "relaxed" participant who often made jokes. The course instructor, Dr. R, described David as the candidate who did not take teaching very seriously, while expressing her concern about his attitude. She said that David "was so flippant about things."

Dr. R: I had concerns about several things. One was not about his practice. It was about his attitude without practice cause I early on just didn't think that he took teaching very seriously. It was just because he was so flippant about things. I mean he has a good sense of humor. He's a joker. But sometimes that leaked into some of… I think that he was very confident about his ability. He thought he could be a fine teacher. I don't think he thought the program would do him a whole lot of good you know. I think that he thought of himself as somebody who was a pretty good teacher coming in.

While working with his mentor, Mrs. M, David was "laid back," which made Mrs. M concerned about his planning. Mrs. M stated, "My number one concern is planning, and then the subset of that would be content knowledge to be able to relate to ninth grade kids."

Mrs. M: The planning portion, I didn't really feel like it was a strong relationship. He would take a look at what my materials were, and then he would design his lessons, but very rarely did I see lessons early. So that was a real struggle, trying to be able to figure out entirely where are you going with this? You've seen what my plans are and you understand the content, but how are you going to relate that to kids?

David was aware of the difference in their approaches to planning, and pointed it out as one key difference between himself and his mentor. David interpreted it as the matter of personal propensity, such as organized vs. flexible, that comes with experience for the most part:

David: With my planning, I don't plan as far ahead as Mrs. M does. She does a lot of things where she'll plan really far ahead with the genetics that we're doing right now…And I like that, I just haven't planned far enough ahead to actually set something like that up, but - that's a difference there. I think that she's more organized in knowing what she wants to do and I think that will come with experience too, obviously, but - I think that Mrs. M likes to make sure that all of her classes are on the same pace, and I - I am more flexible as far as - like, if one class is not understanding something, like, allowing them to get a day behind so that I can re-teach something.

David also highlighted his mentor teacher's approach of "re-teach for all three classes, so that they're all at the same pace" as another difference between himself and his mentor, and negatively interpreted his mentor's approach because it took out the time for covering the vast amount of content required by the standards.

Despite both course instructor and mentor teacher being concerned about his "content knowledge to be able to relate to students," David thought that he and his mentor were pretty similar in that they "both like to tell stories, like personal stories that relate to things and allow the students to do that too," except the fact that his mentor had more stories due to her longer experiences.

During the interview, Dr. R said, "[David] felt like he knew how to work with students, he felt like he knew his content, he never, he never, in as far as I could see in all the stuffs he turned in, he never doubted his understanding of content." It was evident that David was less interested in seeking out resources and advice from both his mentor and course instructor while positioning himself as a confident candidate as being illustrated in Mrs. M's following comments:

> Mrs. M: Just in terms of behavior, he was very closed. In terms of what you would see, his physical stance was with his arms crossed. Kind of staying at a further distance from me, and just saying, "Okay, okay, okay," and not really asking the 'why' part. It was very short, like, "I've heard you" and that was it. Body language alone was very telling, at least for me.

It should be noted that the interviews with Mrs. M and Dr. R were conducted after David graduated from the program. The stories about David and his practices told by Mrs. M and Dr. R were constructed from their memories of their year long or two-year experience of working with David, rather than those were the narratives constructed from one time observation of David and his practices in one particular teaching episode presented by a teaching video. While characterizing David as "a confidant traditional teacher who emphasizes procedural display kinds of things from your students, Dr. R said, "That's not just from this video, but from other kinds of things that I see", "If we get procedural display from him, it's not surprising."

The Nature of Occasions for Learning for David

David's mentor, Mrs. M was a 12-year veteran science teacher who graduated from the same teacher preparation program. She got her master's degree in the area of educational technology at the same university. Mrs. M had broad mentoring experiences with candidates and beginning teachers, including seniors and interns from the program, undergraduate students at the nearby community college, and new teachers at her school.

Mrs. M was a highly regarded mentor teacher who provided candidates with a good model of science teaching practices advocated by the program. Mrs. M did not teach directly from the textbook in her biology course. Her instruction started from content expectations, which she translated into learning objectives for students. She said, “We start with content expectations for us to read, and then we write an objective sheet.” Mrs. M carefully selected a classroom activity by considering “what you do with it, and why it is important, and what’s follow up.” There were many “pieces” that she had to consider, and “the selection of activity has to fit all those pieces.”

> Mrs. M: Then you take that activity – what does that activity help you do? Does it help you understand the structure of DNA? Okay, does it not? You first have to make a decision – does it help or does it not? If it is something that’s going to be meaningful to help the kids make their understanding, okay, that's fine. But what are you going to do with it? Use it as an introductory piece? Do you use it after they’ve learned something and use it as their practice? Or do you use it as a way of assessing where it went. I think it’s the selection of the activity and what you do with it and why it is important. And what’s the follow up? You've done the activity, now what? What does that mean? So the selection of the activity has to fit all those pieces.

Mrs. M described activities as “a frame of references” that all students of her classroom commonly were able to have. She said, “[Students] all have the same experience and you can work from that experience and visit it multiple times if you need to.”

Mrs. M's instruction was focused on students' ideas and their conceptual understanding. She asked students many "series of questions to get there," and continuously assessed students' understanding before, during, and after her lessons to respond to them immediately. Therefore, in David's case, both the program and mentor teacher advocated and modeled reform-oriented science teaching practice coherently, and made the ideas and resources available to him. David was in a good position to learn reform-oriented practices from communities of practice without tension between the two important communities that he had to be involved with.

David's Responses to Deliberately Designed Occasions for Learning

David's classroom activity in the teaching video: Actual practice. The topic of the lesson in David's teaching video was DNA replication in the unit of genetics. David used small plastic models and a packet of worksheets[18] that he got from his mentor teacher in this lesson. Students had learned about the structure of DNA by using a plastic model in the previous lesson. In this lesson, David's purpose was for his students to understand the process of DNA replication using the same plastic DNA model. He opened up the activity by stating the goal of the lesson, "learning how DNA is replicated."

T: Today's going to look a lot like yesterday, except we are going to be learning a new concept about DNA, and how DNA is replicated. It will be using the model that we were using yesterday. We are going to use those examples and go through a few notes. And then the questions that are in that packet that I handed you yesterday, the packet with the directions, how to do this activities, I want you to answer those, and have those get to me tomorrow.

S1: What?

[18] See Appendix 8: David's worksheet of his DNA replication activity

S2: One second, what?

T: So the packet that has directions for this activity within it yesterday and today. There are three questions on the first page and two on the second page. I want you to turn in tomorrow. And then the last reminder, you don't have to write this agenda, [it's] just reminder. If you did do your extra credit opportunity that was Midwestern University lecture, if you listened up the lecture, if you want to turn the extra credit in the first lecture, that's due today. So if you didn't go to it, then obviously doesn't need to do. … [The class is getting noisy]

T: I want you guys to work with the people who are sitting next to you today.

[David gets some students who do not have a seating partner to move their seat]

T: I am going to pass out the DNA pieces. I want you to start from the second page of the packet. [The class is noisy. David passes out the DNA pieces]

T: Hold on a second! Guys! When you are building this, all right, follow the direction on the second page. What I want you to do is, since you already know how to build DNA, when you are making this small piece of DNA to start with, I think you should be able to make this in 15 minutes. So go through the replication as much as you can, and then we are going to talk about it. When you are done with your replication, raise your hand. I will come over, and I will compare my DNA with yours to see if you are correct. So you have until 9:55am in order to get this done.

While introducing the day's activity, David highlighted the procedural aspects in terms of both the goal of lesson and roles of students. He gave students the task of building a model by "following the directions" on the packet, and then showing him if their model is "correct."

After about five minutes of short introduction, the students started working with their partner. The key activity of this lesson was "DNA replication modeling." As indicated in the introduction, students followed the direction on the packet and simulated the process of DNA replication using the plastic DNA model for 15 minutes. When they finished it, they called David and showed their model to him. In 15 minutes, David got students' attention back to him, and he went over the replication process in front of all students using his correct model for about five minutes. He had students correct their model if it was wrong. After wrapping up this modeling activity, he gave a PowerPoint lecture about the DNA replication process for 23 minutes. David explained in detail the DNA replication process, including the basic components of DNA, the purpose of replication, the process of zipping and unzipping, and the function of enzymes in the process (i.e., helicase, DNA polymerase). Students quietly listened and took their notes during this lecture. During his lecture, he sometimes asked questions of students. If one or another student gave the correct answer that he looked for, he moved to the next point.

T: So we had an original [DNA]. We made two. What happens to the actual halves of the DNA strands that were originally there? Is there all the same DNA strands? Is there one on each?

S: There is only one strand in each copy.

T: Right. It was split and the DNA was built in the middle, so there is only one strand in each copy. There is one old strand in each copy. Okay? This will be what we call the DNA template strands, so the strands that we use to build a new DNA, Okay?

S: [quiet]

T: And then one new strand in each copy. [show his model of DNA] So in your copies of DNA, this would be the same in any DNA you think of being replicated, one of the strands is old copy, and one of the strands is the brand new copy of DNA, Okay?

S: [quietly writing down the information on the PowerPoint presentation on the notes]

About three minutes before the bell, David showed a short web-based animation that simulated the process of DNA replication. He said, "What I want to do to finish up class today, as we went through the replication and we modeled it, I just wanted to show you one more animation. Just so you can have seen it in one different way. Without having to touch it, you concentrate what's actually happen." Students watched the animation, showing their interest after listening to the long lecture.

Goal of lesson, roles of students, and roles of activity in David's teaching video. The analysis of the teaching video showed that this lesson was focused on delivering procedural scientific knowledge—the process of DNA replication [code G-b: reproducing factual information or canonical knowledge]. There was only one moment when the teacher talked about the goal, at the very beginning of the lesson. David said, "Today's going to look a lot like yesterday except we are going to be learning a new concept about DNA, and how DNA is replicated." And then the rest of the lesson was devoted to students getting through the process using a hands-on activity, comparing it with the 'right' model that the teacher made, and getting through the process step by step with the PowerPoint lecture. The major roles of students in the activity coded through the analysis include (a) following directions, (b) remembering information, and (c) paying attention to the teacher. The major roles of activity coded in the analysis include (a) making science interesting, (b) getting students to remember the new information, and (c) visualizing the concept. The modeling activity served as the representation of the invisible phenomenon, but the connection between the model and real world examples was not addressed very well, either through teacher's explanation or questions to students in the video (see Table 11). Overall, this activity engaged students in reproducing canonical scientific knowledge—the process of DNA replication—by following the directions with the provided worksheet.

Table 11. David's teaching video

Focus aspects	Interpretive/descriptive codes
Presented Goals	• Reproducing factual information/ canonical knowledge (G-b1) • Getting some skills or procedural knowledge (G-b2)
Roles of students	Relating to procedural/behavioral aspect • Following directions (S-b1) • Filling out worksheets or taking notes (S-b2) • Paying attention (S-c3) • Giving answers to the teacher's questions passively (S-b4) • Getting things done (S-b5) • Reproducing the process (S-b6) • Remembering information (S-b8)
Roles of activities	Relating to procedural/motivational aspect • Simply visualizing concept without making connection across scales or phenomena (A-b5) • Solidifying the concept by confirming canonical knowledge (A-b6)

David's classroom activity in interview: narratives of practice. The same two segments of David's teaching video were used for interviews with David, Mrs. M, and Dr. R. Their narratives on David's classroom activities were coded in terms of highlighted goals of the lesson, highlighted roles of students in the activity, and highlighted roles of activity. Their interpretations about the highlights were analyzed as well (see Tables 12, 13, and Figure 3).

A. Goal of the lesson. Despite that David, Mrs. M, and the course instructor all talked about the goal of this lesson relating to the "process of DNA replication," David highlighted and coded (i.e., interpreted) the goal in a different way from both Mrs. M and Dr. R did. David's goal was "for [students] to be able to explain how replication happens, the steps in replication." He also said, “My specific goals were to have them go through the directions, so that they could model how replication is happening, so that they would have that experience before we talked about it in a lecture.” Mrs. M said, “I think that he is trying to accomplish that there's a process. If you use these models, you will know what that process is.” The course instructor also highlighted, “I think his goal is, he wants them to understand replication, what’s the purpose of replication.” David interpreted that students having experience before he gave his lecture was effective and appropriate because “It gives them something to link those definitions and steps [of DNA replication] that we talk about in the lecture.” David said,

> David: So [students] could actually, like, while we’re going through the lecture, they can be, like “Oh, okay, this is when I did that part of the modeling.” “This is when I unzipped the DNA. I pulled the two strands apart.” So, *to give them something hands-on and visual to relate to what we’re going through in the notes*. *The point is to give them experience that they can build patterns from.* So, like, to give them the experience of actually modeling, so that they can provide answers for, like, why that’s happening or how that’s happening, while we’re going through the notes of how replication actually works.

David’s highlighting of the goal was mostly focused on reproducing the procedural aspect of knowledge (i.e., explain the steps in replication) as well as procedural aspects of students’ activity (i.e., go through the direction). He interpreted it positively because students can “build patterns from” the experience, so they can provide answers for why and how replication is happening during the later lecture. However, both the mentor teacher and the course instructor interpreted that this goal is “problematic” or “faulty” because it does not help students to actually develop meaningful understanding about DNA replication. Both Mrs. M and Dr. R drew upon their observations of David’s practices throughout the year to interpret what they highlighted while telling their stories. Mrs. M started making her comments saying, “Based on what I see and what I remember from last February…”

> Mrs. M: Based on what I have seen, what the kids are going to get out of this? …What's the process? What's the point? Is it really right or wrong? Can't you be somewhere in the middle? … I think there's just more in there, that's troublesome to me.

Dr. R interpreted negatively pointing out the similarity of this lesson to the other episode that she remembered. She said, “just like doing the digestive system is doing something else.”

> Dr. R: I mean I think his goal is, he wants them to understand replication what’s the purpose of replication, but I don’t know. First of all, if all they’ve had is DNA structure, I don’t even know if they have any sense of, you know, what’s the purpose of replication…I mean, why does that happen and maybe he started that way. But if he didn’t, it just doesn’t seem like there is this driving question, 'why would I care about replication?' … If the idea is, if the goal is, “I want them to be able to tell me what replication is” and maybe [I would ask him to] “show me.” Then he probably is maybe if he does enough of this stuff with them. Maybe he’s achieved his goal, maybe. I think the goal is faulty, um and his uh his assumptions about students understanding and their learning are faulty.

It should be noted that David appropriated much of the program’s language, such as “give them experience that they can build patterns from” or “modeling” in his own meaningful way to label his practices. However, both his mentor teacher and course instructor were skeptical about the appropriateness of the goal in relation to students' meaningful understanding of the content.

B. Roles of students. All three parties highlighted the students' roles in the activity focusing on students' behaviors such as "following the directions", and "taking notes," even though Mrs. M and Dr. R expressed their strong disagreement about the appropriateness of these roles in relation to students' learning. For example, David said, "You try to get through it, but then it's frustrating because, you know, you have kids in the class who are not at the same point you are when you're talking about it, so - and one thing that I dislike is, students don't know how to follow directions." Mrs. M also highlighted that "following directions" was the major expectation of students in this activity while expressing her disagreement. Mrs. M said, "I don't know if the kids would necessarily be able to just pick up a set of directions and read it, and then know what to do with it and then try to figure out why they just did it." Both the course instructor and the mentor teacher expressed their concerns about students' passive roles, specifically not using students' ideas. They interpreted that students' ideas were not valued, and students did not have ownership of the knowledge. For instance, Mrs. M characterized the nature of scientific knowledge and the role of students in David's lesson in one sentence: "There are certain things that [students] need to know, and this is what they are." Dr. R said, "I don't think his students ever owned the knowledge. It was always what he wanted them to know and he gave them the package for it."

Dr. R: *There wasn't really a sense of the students' idea*. Oh even though he knew that he should think about student ideas, I think he had some, you know. Another one of these things that he recognized what the program valued. He knew that we valued students' ideas, he knew that we valued questioning, he knew that we valued inquiry, he knew that we valued careful planning. I mean a whole variety he was quite aware of that. He was a very good diagnostician in that respect. But I think he, he used so, it was more about form and not function as he would enact these things, which on the surface might have been interpreted by some people as being inquiry or you know reform minded teaching or that he was really listening to kids ideas. But I never really felt like he pulled that all the way through. It was like he would ask questions or try to use examples of real life stuff that he thought the teenagers would be interested in. *But I never really felt like it was integrated into the meat of what he was teaching cause he still had these very canonical kinds of things he wanted them to understand.*

C. Roles of activity. There was a big discrepancy between David's highlighting and interpretation and both Mrs. M's and Dr. R's with respect to the role of his modeling activity. David highlighted the role of the activity focusing on its procedural/motivational aspects, such as "get students excited", "get them to remember new information better", and "visualizing the concept." He was very positive about this activity because "it gives them something to link those definitions and steps, too, that we talk about in the lecture", and "giving them something that they can remember…the new information."

David: The hands on activity before that doesn't necessarily tell them exactly how it works, but *it gives them something to link those definitions and steps, too, that we talk about in the lecture*, so, you know, in the lecture, when I say "the DNA is unzipped", then they've already did that. They didn't necessarily realize that it was called DNA unzipping, but they can be like "oh yeah, that's when I did this." And when we went through the lecture, they have their models in front of them, so that they can do it as we're going through the notes too. But, just giving them something that they can remember in their head that they did and, you know, remember—using that as a way to remember the new information.

However, both Dr. R and Mrs. M's interpretation about the roles with respect to students' learning were quite different. Dr. R said, "There is too big a gap." "I never really felt like the kids were building the knowledge." Similarly, Mrs. M said, "Based on what I have seen, what the kids are going to get out of this?"

Dr. R: I would bet that David thinks by having [students] do this themselves, maybe not how it is following directions that's fine, the fact that they are doing something making something is gonna, make what he's saying more 'relevant.' They're, they're getting some ownership out of this activity. I can't see it. But I could see that he might see it cause it's hands-on, it's doing something, just like doing the digestive system, is doing something. But then he's just gonna give them a lecture afterwards and somehow it's magically all gonna fit into place cause he'll be able to take that activity and map his power point onto that thing that they just made. I don't see it. I think there is too big a gap, and I don't think it's the right order at all.

Mrs. M: Based on what I see and what I remember from last February, yeah, [David might think that] "by having kids use things, that means they learn things. The note part – in the end, I'm right. There are certain things that you need to know and this is what there are."…Based on what I have seen, what the kids are going to get out of this? They know they have to model. They know they're either going to be right or wrong, and they know they have questions that they have to answer. But aren't those kind of three separate things? That whole sequence is kind of a concern.

In addition, both Dr. R and Mrs. M highlighted both the authoritative nature of scientific knowledge presented in this lesson and David's model of students' learning—his understanding about how students learn science—and they negatively interpreted its impact on students' learning through his instruction. Dr. R pointed out that David had the "canonical kinds of thing he wants his students to understand," so it prevents his students from having real ownership of the knowledge. Mrs. M also expressed her concerns repeatedly about David's positioning with respect to scientific knowledge and students as an authoritative source. Dr. R said, "His assumptions about students' understanding and their learning are faulty." Mrs. M pointed out David's problematic assumption "by having kids use things, that means they learn things" from her point of view. In summary, all three watched the exact same teaching video, but David highlighted different aspects of classroom practices and interpreted what he highlighted in a substantially different way from the way that his mentor and course instructor did. Table 12 compares and contrasts the highlighting and coding (i.e. interpretation) among David, his mentor, and course instructor. The number shows the total number of units coded in each category of descriptive codes. Both Table 13 and Figure 3 were generated from the coding results of David's interview transcript. Table 4.4 shows the results of interpretive codes—which aspects were more or less highlighted by David in his accounts on the classroom practices. Figure 3 shows the relative percentage calculated from Table 13. Once again, this figure shows which aspect was relatively more or less highlighted in David's accounts with respect to goals, roles of students, and roles of activities.

Table 12. David's narratives on his classroom activity practice

	Candidate (David)	**Mentor (Mrs. M)**	**Course instructor (Dr. R)**
Highlighted Goals	Identifying (procedural) (2)	Identifying (procedural)	Identifying (procedural)
Highlighted role of students	Following the direction (3) Filling out the worksheet or taking notes (1) Paying attention (3) Giving answers to teacher (1) Getting things done (4) Figuring out answers (2)	Follow the direction (2) Taking notes (1) Understand the purpose of activity (1)	Following the direction
Highlighted role of activities	Getting students excited (1) Getting students to remember new information (1) Visualizing the concept or content (3) Giving students experience that they can build knowledge on it (3)	Visualize the concept (1) Get them to do something (1)	Get them to do something
Coding	This activity is useful because it actively engages students and helps them remember the steps of DNA replication process.	It is doubtful if students understand either the purpose or the process of DNA replication. It is problematic to present science as authoritative, the right answer Not using students' ideas; students do not have ownership of their knowledge David's model of student learning is problematic—just because having students use things, does not mean they learn the materials	

Table 13. David's highlighting of classroom activities at interview[19]

	Goals	**Role of students**	**Role of activity**
Content understanding	0	2	3
Social	0	0	0
Procedural/behavioral	2	12	5

[19] Each number in the table shows the total number of coding

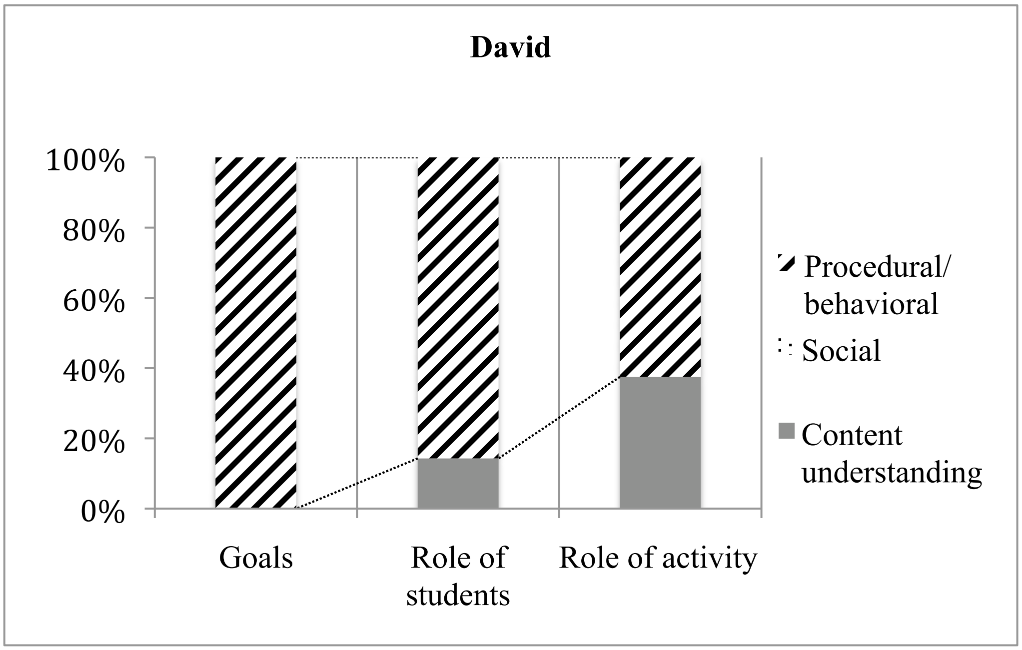

Figure 3. David's highlighting of classroom activities [20]

Summary of David's case. Despite the fact that David was in a good position to learn reform-oriented practices while providing consistent ideas from both his mentor and the program, the analysis of both the teaching video and the interviews indicated that David was not successful in planning and enacting classroom activities as advocated by both his mentor and the program. His actual practice as manifested in his teaching video provided students with limited opportunities for engaging in science by having them simply reproduce the canonical scientific knowledge following his directions. In David's narratives about his classroom activity, he highlighted the goals of the lesson, the roles of students, and the roles of activities, mostly focusing on procedural or behavioral aspects rather than content understanding and the social aspect of students' learning. He interpreted what he highlighted positively in relation to students'

[20] The chart is developed from the coding results in the table 4.4. This chart shows which aspect was relatively more highlighted in David's accounts with respect to goals, roles of students, roles of activity

understanding of the concept, which was contradictory to both his mentor teacher's and course instructor's interpretation about it. The mentor teacher and course instructor constantly drew upon their observations of David's practices to construct their narratives. Interestingly, there were a couple of times that David appropriated terminologies from the teacher preparation program to highlight and interpret certain roles of the students or activity. Despite this "labeling" of his procedural practices using the language of the reform-oriented practice, both his mentor teacher and course instructor expressed their strong concern about David's practices, pointing out that his practice did not provide opportunities for students to learn science meaningfully.

The Case of Monica

Stories about Monica

Monica was a white woman who had a bachelor's degree in Zoology and Aquarium science when she got into the teacher preparation program. Monica's goals as a teacher were helping students understand science in a cognitively challenging but socially and emotionally supportive classroom learning community. The teachers that Monica liked the most were the ones "that challenged you a little bit, but then found ways to challenge you and make you feel successful still." One of the words that she liked to use in her classroom was "a community of learners." Monica wanted her students to feel "accepted for who they are" through the support system in her classroom that she created. Her lunch hours were always crowded with students who tried to get extra help from her. She was busy greeting and talking with students before and after her classes. She often began her lesson celebrating a student's birthday, other special events, or recognizing students' personal and/or small accomplishments.

As described above, one strong component that repeatedly resonated in Monica's current and future stories (i.e., actual and designated identities) was developing a comfortable social environment where everyone was cognitively challenged but could be successful. It was also a point of difference between Monica and her mentor teacher highlighted by Monica. Although Monica was always respectful to her mentor teacher, she wanted to be a different kind of teacher from her mentor teacher who was "very by the book", strict and harsh to students. Monica thought that "there is only so much I can do" by creating a relaxed environment.

> Monica: I try to make it not intense and like – you know, my mentor is a lot – she's very by the book, and there are things I probably shouldn't let my kids get away with sometimes, like they'll not be taking notes. But honestly, sometimes in my opinion, it's more work to – if they're not going to take notes and I've reminded them a couple times at that point there's only so much I can do. So I hope that it's a little bit of a relaxed environment for them. I like to think that it's comfortable.

Monica was an active participant in her methods course during her internship year. She volunteered to share her stories at the school with other interns during discussion, raised many questions, and contacted her course instructor and her university supervisor to get extra feedback on her lesson plans or resources for teaching. Her course instructor, Dr. R said, "Monica asked a lot of questions both before she would plan, but also while she was teaching. She would sometimes write me an email or when we saw each other in class, she really wanted to talk about some things."

Throughout her time in the program, Monica had struggled to teach science "differently" from the way that she had learned science as a student. She said, "I don't feel like up until college, none of my classes really focused on inquiry or application as far as I can remember. Like as a student you're not really thinking about that." During the interview, Monica told interviewers, “I get tired of lecturing and [students] don’t like lecturing. My first lesson I taught to seniors, I lectured the entire hour. Their teacher must have threatened them because they were really good.” It appeared that there was big a gap between what Monica was capable of in her current practices (i.e., actual identities) and her aspiring practices (i.e., designated identities). Monica actively sought out resources for teaching from other interns, course instructors, the Internet, etc. For instance, she voluntarily visited a chemistry intern’s classroom next to hers to observe her teaching a few days during her busy internship period, and incorporated strategies that she found useful into her own instruction. Monica’s mentor, Ms. S, described Monica as “a researcher.” Ms. S said, “She was quite a researcher, so she was really good about going out and trying to find something new.” Ms. S also said, “Monica is really good at taking suggestion.” While reflecting on her teaching practices over two years during the interview, Monica was pleased about her changes. She said, “[If] I did look back at one of my senior year mini-lab tapes, wow! [now] I do look different than that, so I was happy with that.” Monica’s story suggested that she perceived some gap between her current practices and what she would like to do, and she worked hard to close the gap while participating in both the teacher preparation and school professional communities.

The Nature of Occasions for Learning for Monica

Monica’s mentor, Ms. S had about ten years of teaching experience. At this school, she was teaching biology and human biology. Her classroom was always clean, orderly, and organized. Ms. S used a time watch in her instruction to remove any downtime and make transitions efficient. If the bell rang, students had to finish their work and move to the next activity following Ms. S’s direction. Ms. S’s approach to science teaching was basically didactic, though she used interesting labs or activities sometimes. The key thing that Ms. S would look for when she designed or selected classroom activities was “relevancy,” meaning whether the activity would make her lecture clear and confirm the story, and so help students to remember it better. She said, “I know when I’m lecturing and I want [the activity] to tie in directly to my lecture. So, does [the activity] enhance what I'm saying or is it just fluff? I don't want to do a craft just to do a craft, but if it is demonstrating a concept that I'm talking about, then it gives them a better idea.” For instance, in her lesson on DNA structure, students did a cut and paste activity to make DNA. Ms. S stated, “That was useful because we’re talking about the structure. [Students] can manipulate it and things that you touch, you tend to remember more. You have a picture of what you did in your hand. So I thought that directly related, rather than just making a DNA model to make a DNA model.”

Ms. S’s classroom activity practice was very different from the one advocated by the program. Ms. S was well aware of the conflict between hers and the program’s ideas. Mrs. S did not hide her critical position on inquiry practice, while framing it as “The University’s discovery.”

> Ms. S: In the introduction, I would want to introduce objectives – what are we trying to learn? That's where I'm not really familiar with the Midwestern University discovery, discovering patterns on their own. If you give them an objective, are they not discovering a pattern on their own because you've already kind of told them it? You know? I would usually introduce a lesson with what I want them to get out of the lesson and then at the end, go back and ask those questions or somehow evaluate.

The “discovery” was problematic to Ms. S because the lessons take a long time to create and to carry out. Furthermore, to Ms. S, “It was hard to watch when the kids weren’t getting the pattern." Ms. S admitted that she did not use the inquiry approach in her classroom. She said, "I don't use it…it's not my style and it's uncomfortable to do something that's not your style...Yeah, and all of the Midwestern university is learning it this way, and I didn't go to the Midwestern university, so I didn't learn it this way. But I think it is a good approach."

Throughout the internship, Monica got contradictory messages about science teaching practices from her mentor teacher and the program. Monica was in a difficult position where she had to 'please' both her mentor and the course instructor, who advocated different kinds of practices in order to be a successful intern.

Monica's Responses to Deliberately Designed Occasions for Learning

Monica's classroom activity in teaching video: Actual practice. The videotaped lesson was planned as a part of Monica's methods course assignment. In this assignment, candidates had to plan, teach, and report an "inquiry activity sequence." Monica selected this teaching video, among others, because she liked this lesson, and she felt "it was better than others."

The topic of the lesson was incomplete/co-dominance in genetics. Students had learned about Mendel's law of dominance in previous lessons, and in this lesson Monica wanted her students to understand incomplete/co-dominance genetic phenomena through students' inquiry activity. Monica found the activity idea from the Internet, and revamped it through her conversation with peers and course instructors. All teaching materials, including pictures and worksheet[21], were created by Monica. She opened up the lesson with "bell work" (warm-up activities) while making a connection with previous lessons and clearly stating her lesson objectives:

[21] See Appendix 9: Monica's worksheet of her incomplete/co-dominance activity

Monica: We are going to start with bell work today. There are some pictures on the smart board. Last week, a little bit before, we talked about dominant and recessive inheritance patterns, so something is always dominant over something else, Mendel's law of dominant. *Today we are starting to look at some patterns that don't necessarily follow that rule*.

The journal question on the board was "How do the phenotypes of the following organisms differ from the dominant/recessive inheritance pattern?" The five example pictures of crossbreeding that do not follow the Mendel's law appeared on the screen (see Figure 4).

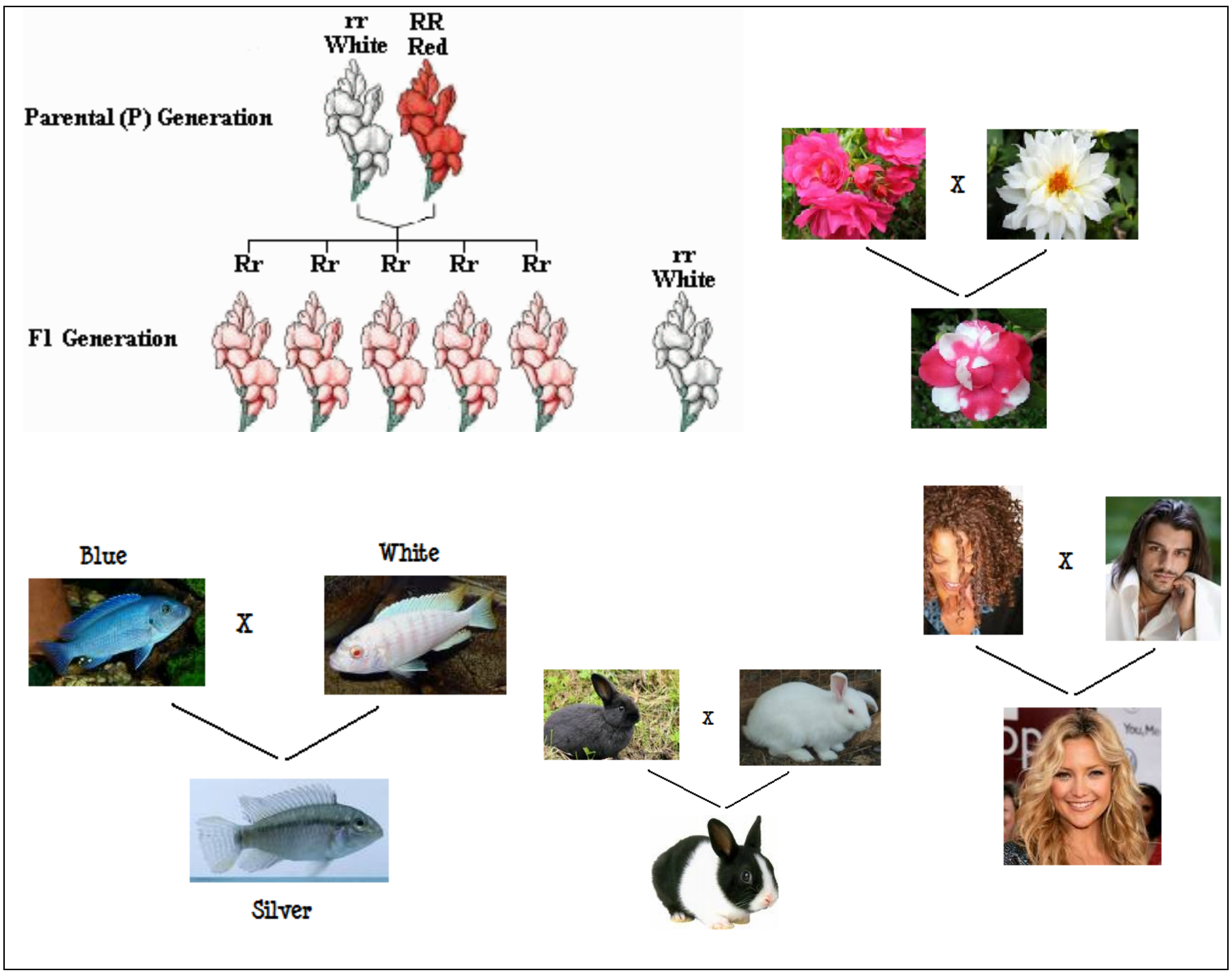

Figure 4. Monica's classroom activity: Incomplete inheritance (For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation)

Three questions were posted with these pictures: A. What are some important phenotypic patterns that you see in these pictures? B. What questions do these pictures bring up? C. Talk to your table partners. What are some questions that your table partners had?

Students observed the five pictures that showed that the offspring did not exactly show one parent's trait, or showed a mixture of traits. They formulated questions from their observations individually, and then they discussed their individual observations and questions with peers in the table group for about five minutes. Monica got them to share their observations and questions with the whole class after the individual and small group work, through whole class discussion.

It should be noted that the first stage of inquiry framed in the inquiry framework (NRC, 2000) is formulating questions. Monica brought five real world examples of incomplete/co-dominant inheritance into her lesson at the beginning of the sequence, and guided students to scientific practices, such as making observations, formulating questions from the real world examples, and finding patterns based on their prior knowledge about Mendelian genetics.

Following about five minutes of bell work, Monica introduced the day's activity, Easter egg genetics lab. The outside of the egg represented the organism's genotype, and the jellybeans inside represented the organism's phenotype. Each half of the egg represented one allele (e.g., if the egg has two red halves, the genotype is RR). The worksheet included three different crossing scenarios such as purple vs. green flowers, red vs. white fur, and blue vs. orange feathers, with very student-friendly words and pictures.

To begin with, students reviewed the key concepts and terminologies such as genotype and phenotype with Monica.

T: The main activity for today is the Easter Egg Genetics Lab. Pull out the worksheet of the Easter Egg genetics lab. [Students pull out their worksheet] So in this lab the outside of the egg represents the organism's genotype. Give me an example of "genotype," Abby?

S: ummm…

T: give me an example of genotype.

S: ummm..

T: [calling out one student] Would you help her out?

S: Capital A, Capital A?

T: Capital A Capital A [AA], okay. Sidney, what is another example of genotype?

S: ummmm.. little b little b?

T: [nodding her head] Little b little b [bb] is another example of genotype. Okay. These eggs, the outside of the egg represents the genotype from the alleles. When we write a genotype, how many alleles…. have?

S: [students raise their fingers]

T: Not one, I see fingers are up two while held up. It should be two. There is two alleles, big A big A [AA]. That's two alleles. Big B, little b, two alleles. How many halves of my easter egg has?

S: Two!

T: Ooo! Yeah! So each half represents the allele. If you look at the purple and green, the very top of the page, what letter is representing the color purples then?

S: Big B

T: Big B, so what letter is representing the green then?

S: little b

T: Okay. [Showing an egg] so what is this egg representing?

S: Big B little b

T: Big B little b [Bb]. Yeah, half purple, half green...The inside of the egg has jellybeans. The color of the Jellybean represents the phenotype. So what is the phenotype of this individual?

S: purple

T: So the phenotype of this individual is purple. So when you look at your lab sheet, there are going to be multiple spots that you need to write down the genotype and the phenotype. So what should the genotype look like for the purple plants? So genotype is the letter combination, the phenotype is the color that you see. So genotype on the outside, phenotype on the inside.

After this brief review and introduction of the activity, Monica modeled herself what students should observe with the eggs using two eggs. Then students got to work with partners and filled out the worksheet for 17 minutes. During this time, they examined the genotype and phenotype of the offspring that were represented as eggs, figured out the expected genotypic and phenotypic ratio using a Punnett square, compared it with the actual results of observation, and found patterns in the given examples. It should be also noted that Monica guided students to connect what they found in this activity with Mendel's model that was presented in a previous lesson, by specifically asking the question, "How does this type of inheritance relate to Mendel's Law of Dominance?" She also guided students to do this modeling activity with their every day experience through the question, "Can you think of any examples of this type of inheritance that you've seen before? If so, what have you seen?"

Students went over the worksheet with Monica as a whole class after finishing their group work. Monica asked students to compare the example that follows Mendel's law of dominance with the other two examples that do not follow it. Students found that there are genetic phenomena that do not follow Mendel's laws, and they talked about similar phenomena or examples from their everyday experiences. They revisited the five pictures from the bell work, and they talked about the questions that they formulated using the idea of incomplete and co-dominance. Finally, Monica gave an example of co-dominance, ABO blood type, before the bell.

Goals of lesson, roles of students, and roles of the activity in Monica's teaching video. The classroom activity in this teaching video was coded using the coding scheme (see the detail in Table 14).

Table 14. Monica's teaching video

Focus aspects	Interpretive/descriptive codes
Presented Goals	• Inquiry: Developing explanations about the phenomena or solving problems by reasoning through data (G-c2)
Roles of students	Oriented to content understanding • Formulating questions (S-c6) • Making observation and finding patterns (S-c4) • Coming up with explanations grounded in data/evidence (S-c7) • Developing own knowledge/building own ideas (S-c8) Oriented to social aspect of learning • Sharing ideas and communicating with others (S-s1) • Working together (S-s2)
Roles of activities	Oriented to content understanding • Representing the phenomena or models to make connections between observation and scientific model/theory (A-c2) • Getting students to observe and find some patterns (A-c3) • Giving students experience that they can build knowledge on (A-c4) • Making connection with previous or next lessons (A-c5) Oriented to social aspect of learning • Getting students to work together and help one another (A-s1)

The results of coding showed that Monica presented a high-level cognitive goal (i.e., developing explanations about the genetic phenomena), and students in her classroom took active roles with both content understanding (i.e., formulating questions, observing and finding patterns, and coming up with explanations grounded in data) and the social aspects of learning (i.e., sharing and communicating ideas with peers, working together). The activity that modeled the incomplete/co-dominant genetic phenomena helped students find patterns that were not explained by previous scientific theory (i.e., Mendel's law), so that students investigated a new scientific explanatory model that explained new patterns.

Monica's classroom activity in interview: Narratives of practice. Monica, her mentor, Ms. S, and Dr. R's narratives on the same segments of teaching video were analyzed. The analysis was focused on what they highlighted and how they interpreted (i.e., coded) what they highlighted with respect to the goals of the lesson, the roles of students, and the roles of activity (see the results of coding in Table 15, 16, and Figure 5 below).

A. Highlighted goal of lesson. Monica, Ms. S, and Dr. R highlighted the inquiry aspect of this lesson, though they described it using different terminologies. Whereas both Monica and Dr. R used languages from the program, such as "inquiry", "observing and finding patterns," to highlight her goals, Ms. S labeled it as "discovery." Ms. S pointed out that it was a pattern of Monica's approach throughout her internship year saying, "She would often try to incorporate that where the kinds have the experience and they find their own patterns."

> Ms. S: I know MSU patterns in discovery. She would often try to incorporate that where the kids have the experience and they find their own patterns and then you ask your questions about what you saw or you try to come up with a rule for what you see in the world. So they're coming up with their questions.

In addition to the inquiry goal, Monica emphasized several times during the interview that she tried to develop a safe learning community where students work together.

B. Highlighted roles of students. Both Monica and Ms. S highlighted the role of students that is connected with content understanding through students' engagement in science practices, such as finding patterns from observations and figuring out answers. Again, interestingly Ms. S described students' practices in the activity as "solving riddles." Monica also highlighted the role of students that involved procedural or behavioral (e.g., following the direction, filling out the worksheet) aspects as well as social aspects. Monica liked this activity because students could share their ideas and work with their peers together. Like her highlighting of goals, she pointed out several times how this interaction among students would be beneficial to their learning. Similar to Monica, Dr. R highlighted students' engagement in scientific practices for content understanding, such as making observation and finding patterns.

C. Highlighted roles of activity. Interestingly, the roles of activity highlighted by Monica and Dr. R were quite different than those highlighted by Ms. S. Whereas Ms. S mainly highlighted the roles that involve motivational or procedural aspects, such as making it fun and interesting, motivating students, visualizing the concept, and helping students remember information, Monica and Dr. R highlighted the way that this activity represented incomplete/co-dominant phenomena and the connection with real world examples.

D. Competing discourses and different interpretation about the same video. Monica interpreted the classroom activity of her video very positively, because the activity helped students to "develop their own knowledge":

> Monica: The strength is that [students] develop their own knowledge, and that's so much better I've found than me telling them things because I can tell it to them as many times as they want and they take tests, and they haven't come up with a way to remember it, so they haven't actually learned it.

Dr. R also interpreted this activity positively saying, “that is a pretty reasonable beginning of an inquiry-based investigation.”

> Dr. R: I think that what she's trying to do is remind them of the basic pattern that they've already established about dominance and recessiveness, and then say, “Okay, now that you understand that, now we're going to change things up a little bit and there's going to be something a little different in terms of both the alleles and then the look and ratio of the offspring.” And that's a different pattern. Then they have to come back around and figure out what might explain the differences in the patterns. So I think that's a pretty reasonable beginning of an inquiry-based investigation.

Ms. S, however, interpreted that this activity was good because it gave a visual and “something to remember.”

> Ms. S: I think it demonstrates the concept well. You know, you could have blue and blue together and they're blue or you could have yellow and yellow together and they're yellow, or you could have a yellow and a blue together and they're green. I think it gave a visual and something they could touch rather than just talking about purple flowers and white flowers. I think it gave them something to remember.

The following Table 15 and Table 16 show the results of descriptive and interpretive coding, respectively. The chart in figure 5 shows the relative percentages calculated from Table 16. It demonstrates which aspects were more or less highlighted by Monica in her accounts on classroom activities with respect to goals, roles of students, and roles of activity.

Table 15. Monica's narratives on her classroom activity practice

	Candidate (Monica)	Mentor (Ms. S)	Course instructor (Dr. R)
Highlighted Goals	Inquiry (2)[22] Developing a safe learning community (1)	Inquiry (discovery)	Inquiry
Highlighted role of students	Following the directions (1) Filling out the worksheet or taking notes (1) Observing and finding patterns (6) Reasoning through data (1) Figuring out answers (1) Developing their own knowledge/building their own ideas (1) Sharing ideas and communicating with others (2) Working together (3)	Observing and finding patterns Figuring out answers (solving riddles)	Observing and finding patterns Figuring out answers Developing their own knowledge
Highlighted role of activities	Representing the phenomena that are difficult to observe to make connections (3) Getting students to find some patterns (2) Getting students to work together and help one another (3)	Get students to observe and find some patterns Visualize the concept (4) Make it fun and interesting (2) Motivate students Help students to remember	Representing the phenomena that are difficult to observe to make connections Getting students to find some patterns
Coding	Activity helps students to develop their own knowledge	It gave a visual and something to remember	Reasonable start; would be good to use real world examples

[22] The number in the parenthesis shows the total number of coding

Table 16. Monica's highlighting classroom activities at interview

	Goals	Role of students	Role of activity
Content understanding	2	9	5
Social	1	5	3
Procedural/behavioral	0	2	0

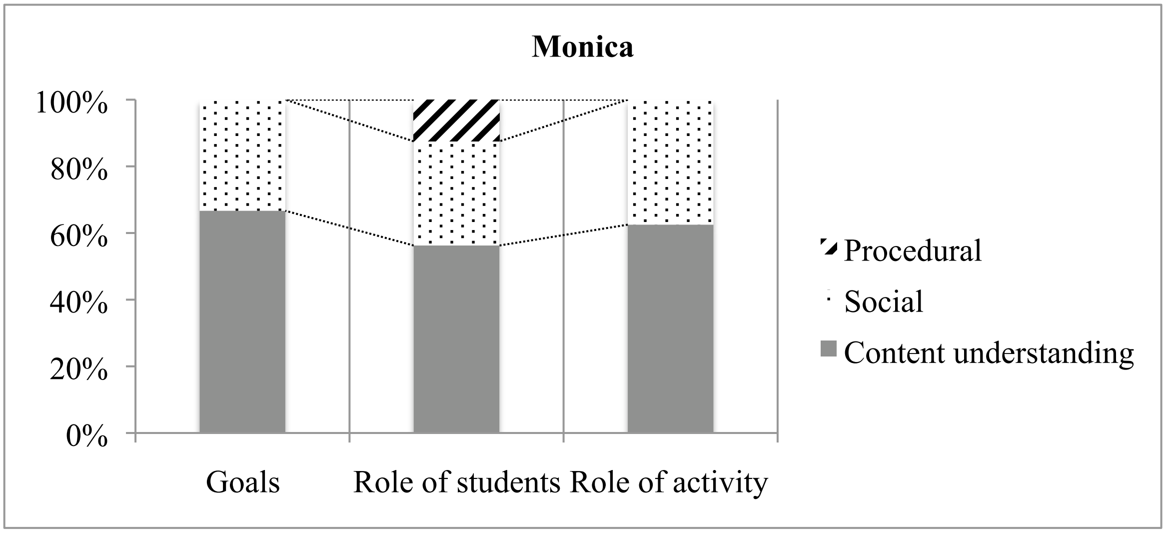

Figure 5. Monica's highlighting classroom activities

Summary of Monica's case. Although Monica was in a difficult position where her mentor provided conflicting ideas and resources about classroom activity practices to the ones from the program, the results of data analysis indicated that she was successful in making use of both resources and demonstrating her capability of planning and enacting ambitious classroom activities as advocated by the program. In addition, Ms. S's comments suggested that Monica had made her efforts to engage students in scientific practices throughout her internship year. Both Monica's teaching video and the interviews indicated that Monica set high-level cognitive goals and provided opportunities for students to play active roles in developing their understanding of content and interacting with both content and other students meaningfully through the activity. Furthermore, her narratives on the classroom activity suggested that Monica was sensitive about the social environment in students' learning process, and she developed good knowledge and skills for planning and enacting quality classroom activities as advocated by her teacher preparation program. Monica's highlighting and interpretation about the classroom activity were fairly similar to her course instructor's, but those were significantly different from her mentor teacher. They used different language to "label" practices featured in the same teaching video. Whereas Ms. S mostly highlighted the procedural or motivational aspect of roles in her narratives on classroom activity and expressed her discomfort with this type of inquiry activity, Monica highlighted and interpreted positively and enthusiastically how the activity supported both content understanding and students' social interaction.

The Case of Adam

Stories about Adam

Adam was a white male intern who desired to be a biology teacher at the secondary level. He graduated summa cum laude with an associate's degree in computer networking from a community college. He had some work experiences in technology-related fields, such as technical support for a virtual university and an Internet provider. Adam was certified to teach biology and integrated sciences from the program four years after his graduation from community college. During his internship, he taught biology and conceptual physics with his mentor teacher, Mr. V, at a suburban high school.

Adam had a vision of teaching "the fundamentals of science" and incorporating it with biology content to begin with, although his ideas became more sophisticated with time. Early on in his senior year, he highlighted the "scientific method", "asking questions", "formulating their own hypothesis," and connecting what students learn with their lives as qualities of good science teaching. Later in his internship he stated, "My students not only learn biology and the fundamentals of science. They develop the ability to question, observe, and explain the world around them. The knowledge that they learn will be realistic and have a goal that can be applied to their lives." Adam's mentor, Mr. V, identified Adam as someone who always struck him as "having a real strong science mind." He said that seeing the patterns is "inherent" in how Adam learned about science, and Adam projected his way of understanding science onto the students.

> Mr. V: Adam enjoys science a lot. So with his understanding of science, he's able to see the patterns and put them together. That's his approach to understanding it, and then he projects that on the kids. I think it's inherent in how he thinks about things. It's like how a teacher will have a certain learning style that they learn with or learned best with, so they tend to use that a lot more. It's the same way with him. He learned science by seeing patterns, and so then he made that a theme to point that out to kids.

To Adam, "the most important part of teaching science" was having students be able to do the activities, such as "working on a problem and trying to solve it by making observations and drawing conclusions."

With his strong orientation to the fundamentals of science in his stories, Adam highlighted students' active roles through student-to-student interaction with the least amount of a teacher's help. He interpreted this type of independent-active role positively in the sense that students "take an ownership over their learning" and "it can be a lot of fun for the students to be able to think about the material and it removes science as not just an accumulation of facts." Although both his mentor teacher and his course instructor highlighted the students' active roles in Adam's practices, their interpretations were slightly different from Adam. Both Mr. V and Dr. G's were skeptical about students being successful in activities without enough the teacher's guidance. Mr. V said, "Adam had a harder time going out and offering help without seeming like he was, if that makes sense…Adam was good when the students approached him but he wasn't necessarily always seeking out those questions from them." Similarly, Dr. G said, "But what we talk about a lot in our methods class is that if you want these students to find patterns, sometimes you have to help them. You can't just do a free for all."

During his internship, Adam worked very closely with Mr. V. Adam thought that Mr. V was close to what he imagined to be the ideal teacher. Adam said, "Mr. V is really good. His level of connection… the way he makes a bond with his students is one of the parts of teaching that I want to approach." Mr. V said, "Adam always had a real interest in figuring out what was going on and just sitting and learning about how you structure a whole unit. He always seemed to be soaking it all in." With a strong wish to be a good science teacher, Adam worked hard to learn and improve his practices. Mr. V said, "Adam was pretty open to constructive criticism. He has a real focus of wanting to be a good teacher and realizing some deficiencies and some strong points that he has now and really wanting to work on those to improve them. If we would talk about something, you could see him trying to implement them in the classroom."

It appeared that Adam was less interested in participating in his methods course and utilizing resources from the program, although he "was in line for the program in a lot of ways" using the course instructor, Dr. G's words. Dr. G said, "Adam did the assignments, but he didn't necessarily buy in to filling everything out the way we wanted it filled out…he would participate…but he wasn't one of the more involved students."

The Nature of Occasions for Learning for Adam

Adam's mentor, Mr. V was a 7-year experienced science teacher who graduated from the same teacher preparation program. He had his internship at this school eight years ago, and used to be a student of David's course instructor, Dr. R. Mr. V had been working as a mentor teacher for several years. Similar to Mrs. M, Mr. V was highly regarded by the program as a mentor teacher who understood and modeled reform-oriented science teaching practices for candidates. In his instruction, Mr. V carefully guided students' thinking to build their knowledge through classroom activities embedded in real-world scenarios. With respect to selecting classroom activities, Mr. V stated, "Trying to have hands on things that help students build ideas is kind of the theme of my activities." In addition, Mr. V believed that creating a comfortable learning environment by building a relationship with students is critically important to teach science in a reform-oriented way. He said,

> Mr. V: You've got to break down some of the formalities that would be more traditional if you want to get kids to be able to work well with each other, respect the classroom and the stuff you've got here, and then to offer up ideas to you as a teacher. They need to be able to trust you and building that relationship is important.

Mr. V always greeted students in the hallway, talked with them before, during, and after class, in and outside of the classroom. Whenever students did group work at the lab table, he sat with students and made himself available to students. He knew every single student as an individual, including their home background, what they liked or disliked, what they did over weekend, etc. For instance, during the interview, he told the interviewer in detail about students in Adam's teaching video, who the student was, what she liked or disliked, and what her pattern was in classroom, etc. Adam said, "The way that [my mentor] makes a connection to students is very admirable."

The science department of Adam's school had a long history of collaboration with the teacher preparation program. Many teachers had worked as mentor teachers, or had experiences collaborating with university professors through teaching methods courses, conducting research, or developing curriculum materials together. This school was conceived by the program as one of the 'ideal placements' for teacher candidates, where candidates would be able to experience the kinds of science teaching practices advocated by the program and could access high-quality resources coherently. Mr. V pointed out the role of this unique school context in candidates' development saying, "I think interns here have it a little different":

> Mr. V: It's a big theme of our department, teaching kids through inquiry and using constructivism, and having them working in groups to come up with answers and stuff…I think interns here have it a little different. We have tons of activities here. We have so many people who teach biology, so that there are a lot of things for them to use. So it's hard to bring in something that doesn't work well.

While working as an intern at this school, Adam was in a good position to learn reform-oriented science teaching practices. He had access to high-quality resources that were not normally available to many other interns. He was also provided with consistent ideas about and resources for science teaching practices from both his mentor teacher and the program.

Adam's Responses to Deliberately Designed Occasions for Learning

Adam's classroom activity in teaching video: Actual practice. The topic of the lesson in Adam's teaching video was pedigrees in genetics. Adam videotaped this lesson during his spring lead teaching period. It was the first day of pedigrees, following the unit on inheritance. In this lesson, Adam wanted to introduce the idea of pedigrees with the story of the Lion King, including symbols and representations for using a pedigree in the following lessons. The idea of classroom activity for this lesson was originally from the department of this school.

After this short introduction to the activity, students moved to the lab tables in the back of the classroom. There were two sheets on every table that showed the Lion King's pedigree (see the Figure 6). The key activity of this lesson was "examining the Lion King's family pedigree." Students looked at it and talked about it with their peers for seven minutes to figure out answers to the five questions on the sheet. The five questions were either about finding some patterns in the pedigree (i.e., write down any patterns you notice about the diagram) or figuring out the meanings of each symbol and the representation of pedigree (i.e., what does the green line represent?).

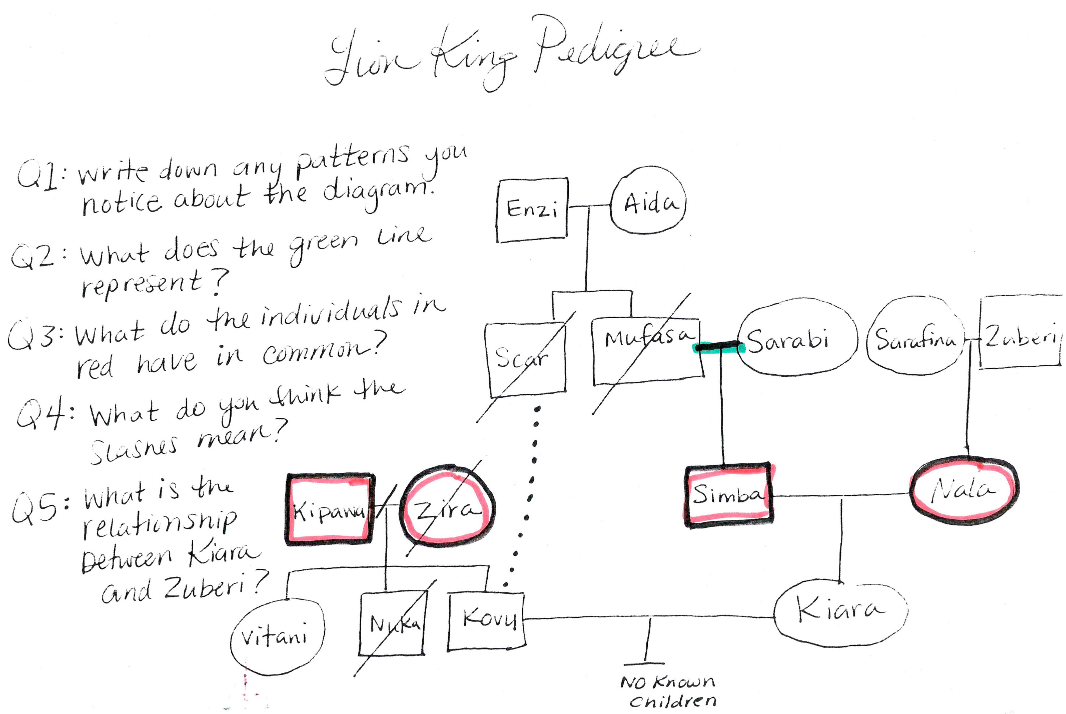

Figure 6. Adam's activity: Lion King Pedigree (Figured drawn by Adam)

Students came back to their seats from the lab table after figuring out their answers to the five questions, and then Adam went over them for about eight minutes. Adam passed out 'pedigree notes.'[23] This note showed one big pedigree that consisted of three generations, and prompts such as "affected males, affected females, normal males, parents and children, siblings, twins, etc." For 22 minutes students listened to the teacher's explanation about pedigree and symbols, identified equivalent symbols or individuals in the pedigree, and filled out the note.

Adam passed out another worksheet, 'complete the pedigree.[24]' Students wrote the genotypes by examining the phenotypes of the pedigree while listening to the teacher's explanation for about 15 minutes.

Table 17. Adam's teaching video

Focus aspects	Interpretive/descriptive codes
Presented Goals	High level cognitive goal • Application: (G-c1)
Roles of students	Oriented to content understanding • Observing and finding patterns (S-c4) • Figuring out answers (S-c7) Oriented to social aspect of learning • Sharing ideas and communicating with others (S-s1) • Working together (S-s2) Oriented to behavioral aspect of learning • Following the direction (S-b1) • Filling out the worksheet or taking notes (S-b2)
Roles of activities	Oriented to content understanding • Representing the phenomena or models to make connection between observation and scientific model/theory (A-c2) • Getting students to observe and find some patterns (A-c3) • Making connection with previous or next lessons (A-c5) Oriented to social aspect of learning • Getting students to work together and help one another (A-s1)

Adam's classroom activity in interview: Narratives of practice. The analysis showed that in general Adam's highlighting and interpretation about the goals of the activity, roles of the students, and the roles of the activity were consistent with his mentor, Mr. V and his course

[23] See Appendix 10: Adam's worksheet A—Pedigree notes

[24] See Appendix 11: Adam's worksheet B—complete the pedigree

instructor, Dr. G. All three of them highlighted how this lesson would provide the foundation for the following lessons by making connections with previous lessons. They also highlighted how students actively engaged in the activity for understanding content, and the ways in which the activity provided opportunities to interact with other students and make connections with other scientific models (i.e., Mendelian genetics) and examples (multiple genetic traits). Interestingly, both Mr. V and Dr. G commented on the insufficient scaffolding for students' engagement in the activity (see Table 18, 19, and Figure 7).

A. Goals of the activity. The key activity of this lesson was the Lion King pedigree activity. After watching the segment of video showing this activity, all three of them described the goal as setting up some foundations for the following activities by teaching the symbols of the pedigree. They particularly highlighted the connection of this lesson with following activities regarding students' understanding of genetic phenomena. Adam said, "To establish the foundations for using a pedigree, to interpret later pedigrees." Mr. V said, "I think he wants the kids to be familiar with how a pedigree is set up, what the symbols are and then I'm assuming he talks about and goes through an example where he has them identify the genotypes." Similarly, Dr. G said, "Probably his idea was to get them to understand that circles are females, squares are males, horizontal lines means married, a vertical line means children. So he was probably trying to get them to find patterns in a pedigree on their own."

Adam: [The specific goal of this lesson was] to establish the foundations for using a pedigree, to interpret later pedigrees. So later I would show them different inheritance patterns and how they look on pedigrees. I'd also want them to learn about inbreeding and show them an example of an inbreeding pedigree, as well. Just showing them, starting out with that, I thought without them knowing what these different symbols meant, they would be lost. This was just to establish the idea of pedigrees.

Mr. V: I think he wants the kids to be familiar with how a pedigree is set up, what the symbols are and then I'm assuming he talks about and goes through an example where he has them identify the genotypes. They usually like doing pedigrees, so I think it makes it fun to do. I think he was probably able to get a lot of student interest.

All of them positively interpreted the appropriateness of this goal. Adam also said that most students understood the idea of pedigrees, thus this lesson was successful in achieving its goal.

B. Roles of students. All three interviewees commonly highlighted students' roles, focusing on both cognitive and social aspects in relation to their sense-making process. They highlighted that students engaged actively in this pedigree activity, such as "observing and finding patterns" from the given pedigree and "figuring out the answers by themselves." They also highlighted the social environment where students could interact with each other, such as "talking to one another to solve the problems", "telling stories, and yet still be on task." Whereas Adam interpreted the role of students positively and productively for the most part, both Mr. V and Dr. G expressed their concerns about lack of actual scaffolding provided by Adam, although they interpreted the planned roles of students in this activity positively. Dr. G said, "I like that he trusted the students to be able to find patterns…what I didn't like is…I don't think it was clear to the students what they were supposed to do when they broke out into their lab groups … It seemed almost like a free for all." Mr. V said, "Adam was good when the students approached him, but he wasn't necessarily always seeking out those questions from them."

C. Roles of activity. The role of the activity highlighted by Adam was strongly focused on content understanding, how this activity would support students' understanding of representations of genetic phenomena using pedigrees. The story of the Lion King was one example that most students were familiar with. By answering the five analytical questions about the pedigree of the Lion King's family, Adam thought that students came to understand the symbols of pedigree (e.g., gender, generation, genetic traits), and how patterns of genetic traits can be represented through pedigrees.

Adam: I believe that [students] need multiple examples of pedigrees, not just one. They need to see many different types and to see how many different traits are inherited. It's also good if you tie it to some traits that they've seen before. We just did Mendelian and non-Mendelian inheritance, so tying the traits that they learned from before to how they fit in as a family. It helps them build that connection.

Similarly, Mr. V highlighted the role of this activity focusing on students' content understanding. He pointed out how Adam tried to connect pedigrees with some real world examples or genetic phenomena. Mr. V interpreted this activity positively because it engaged students actively (i.e., "rather than just him telling them what [pedigrees] are") and meaningfully (i.e. "[Adam] is definitely hitting on some of the key things that we want to do"). He commented that the familiar story of the Lion King motivated students to participate in the activity. Mr. V said, "It's nice when you get students talking about things with their peers and figuring out answers themselves. I think it's a good activity."

Mr. V: Well, I think he's doing a good job of getting the kids to look at a pedigree and come up with the patterns that are there, rather than just him telling them what they are. So he seems to be getting the kids involved. He's using "The Lion King," tying it in with something they're familiar with so they are going to be a little more engaged because of it. It seems like he's definitely hitting on some of the key things that we want to do.

Mr. V also pointed out that Adam's instructional approaches of this episode was fairly consistent throughout his internship year. Mr. V said,

Mr. V: kids see a pattern and they figure it out in order to build that knowledge…Adam seemed to get that early on in the year. It seemed a little more inherent in what he was thinking…so for him, seeing patterns was something that he did himself, and then that made him a little more aware of getting students to see those.

Dr. G highlighted both the motivational function as well as content understanding (i.e., "giving students some freedom in discovering the patterns").

In summary, all three of them highlighted and interpreted the goal of the lesson, the role of the students, and the role of the activity in a fairly similar way for the most part. Their highlighting and coding included students' content understanding, their social interaction in their learning process, as well as the motivational aspect. Interestingly, however, Mr. V and Dr. G made similar comments on the scaffolding provided by Adam in relation to the roles of students. Both of them liked students to play active roles in this activity, but they pointed out that it would be hard for students to be successful without substantial supports from Adam. Table 18 and Table 19 show the results of descriptive and interpretive coding, respectively. The chart in figure 7 shows the relative percentages calculated from Table 19. It demonstrates which aspects were more or less highlighted by Adam in his accounts on the classroom activity with respect to goals, roles of students, and roles of activity.

Summary of Adam's case. The result of data analysis showed that Adam's highlighting and coding about the classroom activity were consistent with his mentor teacher and his course instructor for the most part. All three of them highlighted the high level of the conceptual goal of the lesson and the way that the activity provided the foundation for students to understand genetic phenomena. They also highlighted the role of students, focusing on cognitive and social aspects of learning. However, both the mentor teacher and the course instructor were concerned about the lack of scaffolding that supported students' active roles provided by Adam. This result indicated that Adam was fairly successful in classroom activities except for providing substantial scaffolding that supports students' successful engagement.

Table 18. Adam's narratives on his classroom activity practice

	Candidate (Adam)	**Course instructor (Dr. G)**	**Mentor (Mr. V)**
Highlighted Goals	High level conceptual goal (1)	High level conceptual goal (1)	High level conceptual goal
Highlighted role of students	Thinking and analyzing critically (4) Going through thought process (1) Making connection among concepts (1) Observing and finding patterns (4) Drawing conclusion/figuring out answers (1) Understanding the purpose of activity and make connections (1) Communicating and sharing ideas with peers (2) Working together (3)	Observing and finding patterns by themselves (2) Figuring out answers (1) Building their own knowledge (1) Communicating and sharing ideas with peers (2)	Observing and finding patterns
Highlighted role of activities	Representing the phenomena for making a connection among OPM (2) Making connection with previous or next lessons (2) Get students to see the value of learning the concept (1)	Making content interesting (2) Getting students to do something (1) Representing the phenomena for making connection among OPM (1) Getting students to find patterns (1)	Making content interesting
Coding	Overall successful, positive	Appropriate goals, and roles of activities; Positive about students' active roles but be concerned about the lack of scaffolding	

Table 19. Adam's highlighting of classroom activities at interview

	Goals	**Role of students**	**Role of activity**
Content understanding	1	12	4
Social	0	5	1
Procedural/behavioral	0	0	0

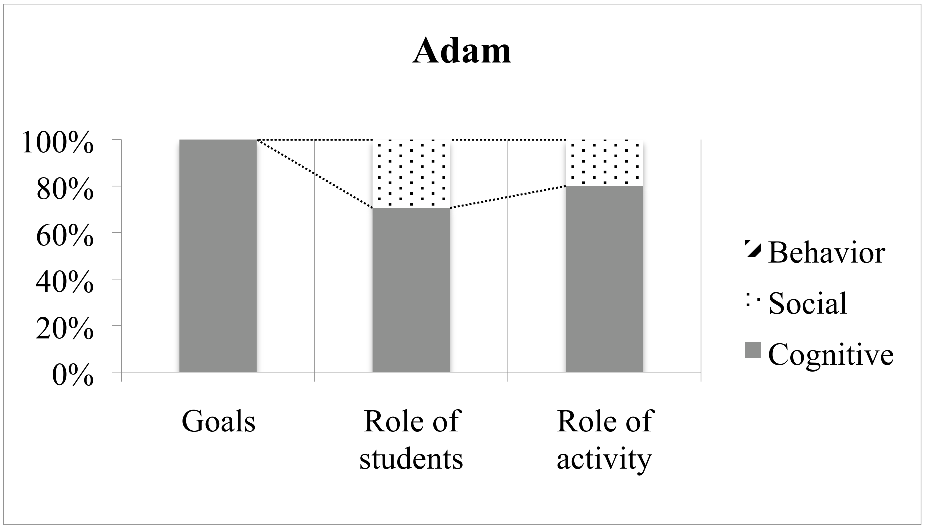

Figure 7. Adam's highlighting of classroom activity

Classroom Activity Practices and Candidates' Understanding of Science for Teaching

David, Monica, and Adam talked about the topics of their teaching video in substantially different ways, although all three taught a lesson from the same unit (i.e., genetics) in biology. I found that the ways in which Monica and Adam understood science for teaching were fundamentally different from David's. Whereas Monica and Adam understood that scientific knowledge is integrated with scientific practice by appreciating observation and scientific models or theories, David saw science as authoritative knowledge that consists of a story of or about phenomena. In the following, David's ways of understanding science for teaching are compared and contrasted with Monica's and Adam's (see Table 20). Supplementary data sources, including candidates' written reports of teaching other lessons and their statement of good science teaching, were analyzed along with the teaching video interviews.

Table 20. Candidates' ways of understanding science as content for teaching

Narrative Ways of Understanding Science for Teaching (Two-dimensional Model): David	In-depth Understanding of Science for Teaching (Three-dimensional Model): Monica and Adam
• Considering science as stories of/about phenomena or scientific models; the answer, 'why' part, explanation • Achieving scientific understanding by making connections between or among stories ("seeing the connection") • Content vs. process (e.g., scientific method, problem solving skills) • Scientific community as authoritative source of scientific knowledge • Making connections among topics considering causal (logical) relationship	• Appreciating the relationship between observation and scientific models/theories • Achieving scientific understanding by making connections between observation and theory • Integrated understanding of scientific knowledge and practices • Scientific community as a model for students' classroom community • Situating a topic in a unit with the consideration of big ideas, key phenomena or patterns of a unit

David's ways of understanding science: Two-dimensional narrative model. The data indicated that David understood science as a subject for teaching in a very different way from both Monica and Adam. The four main characteristics of David's understanding were the following: (a) seeing science as stories of/about phenomena and the reason why it happens, (b) achieving scientific understanding by making connections between/among stories, (c) understanding scientific community as the authoritative source of scientific knowledge that he has to cover, (d) making causal connections of a topic with others in a unit to answer "why" questions.

a. Seeing science as stories of/about phenomena & the reason why it happens. David narrated the content as stories of and/or about phenomena and the right answer to 'why' questions. For instance, with respect to his lesson on DNA replication, the content of this lesson was the story of DNA replication, why it is replicated. While introducing the context of this lesson during the interview, David listed the topics that he covered in the unit. The growth of the human body or cancer is an important phenomenon that can be better understood using the scientific models of DNA structure, replication, and the cell cycle. David tended to describe each topic as stories *of* something out there (e.g., DNA), or stories *about* things that happen (e.g., cancer, DNA replication), rather than appreciating important observations, patterns, and scientific theories concerning the topic. David said,

> David: This was, this unit was just structure and function of DNA and replication and, like, the cell cycle. So, we talked about the cell cycle. And then, after, like the next unit that followed was, we did a cancer unit. So, like, in this unit that included replication, we did, like, replication and mitosis, cell cycle, like all in one unit. So, [students] learned cell division, mitosis and then, you know, DNA replication's role in that and why it's replicated. And then after that, we went onto a unit, a cancer unit, because they know how mitosis works, they're able to realize what will happen next when things go wrong with the cell cycle, which they just got done learning about. (David, from interview with teaching video)

As demonstrated in David's narratives, he worked hard to make a coherent story of cells, DNA, and cancer, how a cell is divided, how and why DNA is replicated, and what will happen when something goes wrong—the story about cancer. In another lesson on sex-linked inheritance that was framed as a 'inquiry' lesson by David, he described the content as the answers to three "why" questions: "What genetic aspect about men would make them more likely to have a hereditary disorder than women?" "Why would it not be possible for a man with one of these disorders to pass the same disorder on to a son?" "Why were Queen Victoria's daughters able to escape having hemophilia while her son was not able to?" There was only one correct answer to each question in his inquiry lesson, which was basically the 'story' of sex-linked inheritance. David stated, "The correct answer to this would be that Queen Victoria can only donate one of her X chromosomes to each child." Students' reasoning that did not match with the canonical scientific explanation was "wrong," so it should be cleared up.

> David: The only thing that people got mixed up a little was that they would put the trait for hemophilia on the Y chromosome of a male as well as the X, which is wrong. The trait is only carried by the X [chromosome], and that is why men are more likely to have the disorder because they only get one X to determine that…I think we cleared up the Y chromosome confusion enough that we didn't have to talk about it any extra during the next class" (David, from inquiry lesson report)

To David, the content of science consists of many stories that scientists developed, just like pieces of puzzles. When all the pieces are put together in the right spot, students get to see the "picture of it." The picture is something that is developed by the scientists, and is the right answer that students need to know. However, if the pieces are not connected very well, they are all over the place on the puzzle plate, so students fail to see the connection and lose their interest. David worked hard to tell a coherent story in order to help students '*see'* the picture.

b. Achieving scientific understanding by making connections between/among stories. From David's point of view, making connections between/ among stories in answering "why" questions was the core for achieving understanding. For instance, during the interview, David argued that two types of cell division, mitosis and meiosis, should be taught separately, because "they're for completely different reasons." From David's point of view, to best achieve understanding, the topic (i.e., story of something out there) should appear when it comes to its 'turn,' where one story is logically connected with the next story (e.g., a problem with mitosis can cause cancer), just like a piece of puzzle should be connected with the correct next piece.

David: I like doing it that way because I think that in a lot of textbooks, they teach mitosis and meiosis together. They're similar, but they're for completely different reasons. I mean, mitosis is to split body and cells and, you know, to make identical cell copies of each other. Meiosis is to make sex cells, so, I mean, there's not really to teach that until you're going to get closer to genetics, because it has more to do with genetics. So mitosis, and then problems with that would lead to cancer. And cancer is something that the students loved talking about because all of them have had experience with that, so, you know, teaching them how it happens, you know, the process that goes, the process that happens that can go wrong to cause cancer before we talk about it, helps them understand cancer more. And meiosis really doesn't have anything to do with cancer. (David, interview with teaching video)

David tried to help students make this causal connection between or among stories in order to get the picture of it. It was important to have students see this connection because it helped them remember the information better. Therefore, David cared less about appreciating observation, scientific models, and theories than sorting out connections among each piece/unit of 'content' for the purpose of making a coherent story. He liked hands-on activities because they helped students to see the story by visualizing it. Students' experiences through hands-on activity play a role of "cement" that connects stories (i.e., pieces of puzzles) tightly, so as to help students "remember the information better." In his DNA replication lesson, the hands-on activity in which used plastic DNA models gave students "something to link those definitions and steps that [he] talked about in the lecture."

c. Scientific community as authoritative source of scientific knowledge. David created a classroom community where students mainly reproduced the canonical scientific knowledge produced by the scientific community. Despite the fact that he liked students actively doing something and asking questions when anything was not clear to them, the roles taken by students or highlighted by David in this classroom community were different from the roles that scientists take in a scientific community, in the sense that students were not expected to develop their own explanatory model about the scientific phenomena, experiences, and observations. David's positioning about the roles of students in the classroom learning community was the major source of conflict with both his mentor and course instructor in their narratives on David's teaching practices. David understood the scientific community as an authoritative source of scientific knowledge that he had to cover in his classroom.

d. Making causal connections among topics in a unit to answer "why" questions. David described the topic of his lesson as focusing on its causal relationship at the topical level. For example, the topic of cell division was connected with the topic of DNA replication because cell division explains why DNA is replicated. Mitosis is connected with cancer because it is "the process that happens that can go wrong to cause cancer."

Monica and Adam's ways of understanding science for teaching: Three-dimensional model. Overall four characteristics were found in the ways that both Monica and Adam understood science as content for teaching: (a) appreciating the relationship between observation and scientific models or theories, (b) achieving scientific understanding by making connections between observation and theory through scientific practices, (d) considering the scientific community as the model for the classroom learning community, and (c) making connections among topics with consideration of its big ideas, key phenomena, or patterns.

a. Appreciating the relationship between observation and scientific models/theories. Whereas David described science as the story of or about something or the reason why it happens, both Monica and Adam appreciated the difference between observation and scientific theory in their lessons, and they emphasized 'pattern finding' as a key for making connections between the two. For instance, Monica explained the reason why she presented several real-world examples of the scientific model (i.e., incomplete and co-dominant inheritance): "For each inheritance pattern I included an animal, plant, and human example to make sure students could see that these types of inheritance patterns occur in many different organisms." It was problematic to Monica that students did not differentiate observation from inference. Monica said, "From what I observed, many of the students were making inferences rather than observations. For example, instead of stating that the flower contained both pink and white petals, students would say that both pink and white were dominant." Similar to Monica, Adam stated, "Being able to make an observation and draw conclusions, that's what the big part of 'The Lion King' pedigree is." Making observations and finding patterns were typical approaches that Adam used with his students in his classroom. He said, "I use these types of things a lot. Just the other day I put up a lesson on a phylogenetic tree. I put this on the projector and said, 'Let's name off all the observations that we can make about this, and what are some patterns that we can draw from this?' "

b. Achieving scientific understanding by making connections between observation and theory through scientific practices. Whereas David tried to help students to make causal connections to get 'the picture,' Monica and Adam tried to help students to make connections between observation and scientific models or theories. Monica and Adam understood how scientists learn about the world and that scientific knowledge is man-made, incomplete, changeable, and temporary. Monica said,

> Monica: I think some of the first couple of days, I made sure to impress upon them that like I make mistakes, they're going to make mistakes… but that that's okay, like that's how we learn, trying to relate it to science, like scientists make a bunch of mistakes before they get to the answer that they're hoping for or that they're looking for…Not everybody is—nobody is right all the time." (Monica, teaching video interview)

Scientific knowledge was integrated with its practice in a sense that scientists learn about the material world by asking questions, making observations, critically analyzing data, finding patterns, drawing conclusions, and applying knowledge to other real-world phenomena. Adam stated, "My students not only learn biology and the fundamentals of science. They develop the ability to question, observe and explain the world around them. The knowledge that they learn will be realistic and have a goal that can be applied to their lives." In Monica's incomplete/co-dominance lesson, she engaged students in scientific practices (i.e., observing various examples, formulating questions individually and discussing them with peers, collecting data, finding patterns from the observations) to help them develop "their own knowledge" (i.e., incomplete/co-dominance inheritance). To Monica and Adam, meaningful scientific understanding can be achieved by engaging students in scientific practices, such as inquiry or application, to make connections between observations and scientific models or theories.

c. Considering scientific communities as a model for classroom learning community. Both Monica and Adam tried to develop classroom communities where students play the role of scientists who develop their own knowledge by engaging in scientific practice, but their approaches to develop classroom-learning communities were quite different. Whereas Monica was sensitive about students' difficulties in engaging in this cultural practice of science and provided rich social and cognitive resources for students to be successful in her classroom, Adam tended to be less responsive to students' difficulties. He seemed to expect that students would be able to do without particular scaffolding, which led Adam to be less successful in developing classroom communities where students play the role of scientists.

d. Situating a topic in a unit with the consideration of big ideas, key phenomena, or patterns. While giving the context of the lesson to interviewers during the interviews, both Monica and Adam situated the topic of the lesson in a big picture of the unit through making explicit connections with big ideas, key phenomena, or patterns. For instance, Monica described that her topic of incomplete/co-dominance was in the category of complex inheritance, which was "different inheritance patterns" from Mendel's theory of dominant and recessive. Her account indicated that she understood the topic of this lesson (i.e., incomplete/co-dominance), key observations (i.e., complex inheritance), big ideas (i.e., Mendelian genetics), and how those are connected with one another.

> Monica: We were just *introducing* complex inheritance here, and it was kind of more of an inquiry, check out fine patterns and see what you see. Before this unit we did a unit with Mendel, and then the dominant recessive patterns. Following this – well, we finished up complex inheritance and then went in DNA afterward. *So this was the very beginning of those different inheritance patterns that didn't necessarily follow dominant recessive.* (Monica, interview with teaching video)

Adam also described that the topic of the lesson (i.e., family pedigree) would be the foundation for understanding the key phenomena concerning this unit (i.e., different types of inheritance). Adam said, "Later, I would show [students] different inheritance patterns and how they look on pedigrees."

> Adam: This lesson, I believe we had just finished polygenic inheritance. They had just had a quiz about incomplete dominance, co-dominance, sex-linked and normal inheritance. So *they're familiar with different types, we just hadn't got to a family type or shown any kind of pedigrees yet. Just today was the first time that they had thought of maybe a larger family, the larger effect and multiple generations.* [The goal of this lesson was] to establish the foundations for using a pedigree, to interpret later pedigrees. So *later I would show them different inheritance patterns and how they look on pedigrees*. (Adam, interview with teaching video)

It should also be noted that both Monica and Adam situated the lesson within a unit while pointing out its role in students' understanding of important genetic phenomena. In Monica's case, the lesson was "introducing complex inheritance" and "find patterns and see what you can see." To Adam, this lesson was "to establish the foundation for using a pedigree, to interpret later pedigree" for understanding different inheritance patterns.

Candidates' Designated Identities and Their Interpretation of Practices & Resources

David, Monica, and Adam's designated identities—the kinds of teacher they wanted to be and the kinds of practice they wanted to master—were examined from their stories about future self(s) in/and practices. Their vision statements collected at the three time points for two years—(a) at the very beginning of senior year, (b) at the beginning of the internship year, and (c) at the end of the internship year—were used as the major source of data. The interview with their teaching video conducted at the end of their internship was also used as supplementary source of data. Their stories of future self and practices were coded with respect to (a) goals of teaching science, (b) roles of activity, and (c) roles of students[25]. The results showed that each candidate held relatively consistent aspirations across two years, that was aligned with their ways of highlighting and coding practices and resources provided by professional communities. Their stories of future self(s) in/and practice became more specific and incorporated more technical languages as they got more experiences. Each candidate's goals of teaching science, in particular stated at the end of internship year, was directly connected to the ways that they understood science for teaching presented in the previous section. In the following, David, Monica, and Adam's designated identities are described with respect to the three aspects.

David: Guiding students to get the correct information in a fun and interesting manner by engaging students in various activities

David's designated identities manifested in the three stages of the program were analyzed with respect to his goals, classroom activities, the role of students, and the role of teachers (see Appendix 12 and Table 21).

Goals. David's perceived goals of teaching science were fairly consistent across two years. He continuously pointed out that good science teaching would "guide students toward the correct answer" and help them to "remember the information" by engaging students in some kinds of fun and interesting activities. For instance, at the very early stage of his senior year, David described how an activity would help students to remember information better, so to be useful in taking test.

> Since everyone was having so much fun with it we all learned it very well. Acting it out gave us all really good connections to remember the information too. I remember taking the test at the end of the unit and actually thinking about who was which part, so that I

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[25] See the results of coding in Appendix12

> could remember how some of the steps worked in the cycle of [mitosis and meiosis]. (David's vignette of good science teaching, at the beginning of senior year)

In his accounts of good science teaching written in next year, he again described how an ideal activity would help students to get the correct answer. Interestingly, the ways in which he described an ideal activity was fairly similar to his DNA replication lesson analyzed in this chapter. In his account of good science teaching, David stated that he would initially engage students in some hands-on activities to teach about human body, had them compare their models to the correct one constructed by the teacher, and had students correct their wrong models:

> After [students] are done [the hands-on activity] I would go through each system in modeling fashion. Each group would show me their posters, and I would tell them which parts are right and would construct my own poster to show exactly where things go for the whole class to see. The students could then compare their posters to mine and hopefully would learn from their mistakes as they take time to correct theirs. (David's personal account of good science teaching, at the beginning of internship year)

The interview conducted at the end of his internship year indicated that his goal of teaching science was delivering authoritative scientific knowledge but in a student-centered manner. He said, "Definitely I feed them information more than I would like to." His goal was "at least evening out the level of information that I'm giving them instead of them asking questions." David wanted his students to ask questions more actively, but the authoritative nature of knowledge that students ought to learn was consistent with the previous statement. In short, David seemed to carry his goal of delivering the "correct" information in a fun and interesting way by engaging students in a variety of hands-on activities throughout the two years.

The role of classroom activities. The kinds of classroom activity that David wanted to master were also fairly consistent in their nature across two years. For the most part, the activities were purposed to motivate students and get all of them to "do what they are supposed to do." The core concern for David was the boring part of learning the content. David stated, "I think that what I'm used to from teachers I've had is more of, like, the lecturing. Just spitting out information, so it's hard for me to break out of that." David wanted to teach science in a fun and interesting way by engaging students in various activities and relating science to students' everyday life. Initially at the very early of senior year, David pointed out, "relating lessons to [students] everyday lives", "always had some ways of making it interesting", 'not giving a long lecture' as the key characteristics of good activities. In his account in the beginning of internship year, he thought of "using a hand on strategy" and "having students to work together" as his classroom activities in an ideal situation for the motivational purpose. The data indicated that David expanded his activity ideas as he got more experiences. In his accounts at the end of the internship year, David included more specific strategies, such as group work, discussion, project, and student-centered notes as the kinds of activities that he would like to see in his future classroom.

The role of students. David wanted all his students to get engaged in activities, and do their work independently to learn science. The students in David's stories were consistently described as engaging in some activities and holding some responsibilities of getting things done, but students were not described as the ones who would develop their own knowledge. At the beginning of the senior year, David highlighted the role of students who paid attention to the teacher, engaged in fun and interesting activities, remembered the information, and learned the new vocabulary. At the beginning of the internship year, David described a few possible ways of engaging students in certain activities with the hope of "keep them engaged."

> The students in this situation would hopefully be engaged because they are working together and they are coloring in a giant picture with things that are actually in their own bodies. Students who may not know as much about the systems get clues from their partners that may remind them of things as they are working, which will hopefully keep them engaged as well. (David, the personal account of good science teaching, at the beginning of the internship year)

During the interview conducted at the end of the internship year, David said, "I'd say I'm a teacher who expects students to do what they're supposed to be doing. Like, they're supposed to meet me half way and, you know, do the things I want them to and - and if they do, then there's not really going to be too many problems or anything like that." David wanted his students to be more "independent" in their learning, so to ask questions about the procedures and activities that they were supposed to do to get the information. Overall, despite the repeated emphasis of actively engaging in some kinds of hands-on activities, the role of students in David's stories for two years were passive in nature in that students were not expected as someone who would develop their own knowledge.

Monica: Actively engaging students in inquiry and developing a community of learners

Monica's designated identities manifested at the three different stages of the program were analyzed with respect to goals, classroom activities, the role of students, and the role of teachers in her future classroom (see Appendix 12 and Table 21).

Goals. Monica emphasized that her goals of science teaching was actively participating students in scientific practices to help them learn the "big ideas" or "connect real world experiences to scientific concepts" as opposed to simply having students regurgitate facts or prepare for the test. At the beginning of the senior year, Monica stated that the exemplary teacher who she remembered made "the class see the Big Pictures in every lesson. We weren't there to take tests and regurgitate facts, but instead to participate in science and learn from it."

> The final, and I believe, most important teaching strategy that Mr. Erspamer exhibited was his ability to make the class see the "Big Picture" in every lesson. We weren't there to take tests and regurgitate facts, but instead to participate in science and learn from it. In my future science classes I revisited many of the subjects that had been covered in my seventh grade class. (Monica's vignette of good science teaching, at the beginning of the senior year)

At the beginning of her internship year, Monica again stated that her goal was "engaging students in inquiry-based learning." Monica particularly emphasized her another goal of creating learning environment specifically mentioning "a community of learners."

> One of the most important strategies I hope to incorporate in my classroom, is to create a community of learners. High school can be a tumultuous time in the lives of many students and the pressure to "fit in" on a daily basis can be seen in the interactions between students and their peers. This said, I believe it is important for my students to feel as though the classroom is a support system of both their peers and their teacher. If the students feel as though they are a part of a learning community rather than an individual responsible for their own success, I believe more meaningful learning opportunities will occur. (Monica's account of good science teaching, at the beginning of internship year)

At the end of her internship year, once again, Monica described her goal as teaching science "in an inquiry-based manner" while recognizing the demands of meeting the expectations such as standards. She stated, "The content, although obviously aligned with the standards, must be taught in an inquiry-based manner. The overall objective is to teach students, not chapters." Monica carried through her goals of participating students actively in scientific practices and developing a community of learners from the beginning to the end of her program.

The role of classroom activities. The consistent theme in Monica's stories about the role of activities across two years was helping students to connect science with real world examples or everyday experiences. At the beginning of her senior year, Monica described how scientific methods that she experienced with her 7^{th} grade teacher was meaningful in that it allowed students to be active in their learning process (e.g., develop a question pertaining the topic of inquiry), and to connect real world examples or experiences (e.g., insect dissection) with scientific model. It was something that Monica would like to do in her own classroom.

> As part of this unit, we also had to use the scientific method to develop a question pertaining to the internal anatomy of the squid. I had been introduced to scientific method before but only in worksheets that were basically fill in the blank. This time I actually had to come up with my own semi-formal lab report…Tying this lesson to every day, real world examples helped me to see why the scientific method was so important

Monica's idea of making connection between science and the real world appeared again in her account of good science teaching at the beginning of her internship year, but she described it in detail including specific strategy. Monica wanted to develop similar case studies that were introduced by the program "in order to demonstrate the connections between science and the 'real world'." At the end of her internship, Monica stated engaging students in the lesson using inquiry-based methods where "students are actively engaged in pattern finding." Interestingly, her description of "scientific methods" at the beginning of senior year was replaced into the stories about inquiry-based methods at her internship year.

The role of students. Students' active participation in activities was a consistent theme in Monica's stories across two years. At the beginning of senior year, Monica concluded her analysis of the vignette of good science teaching stating, "I remembered what I had learned in seventh grade because I had been an active participant rather than someone who could just repeat facts." At the beginning of the internship year, Monica highlighted the active role of students in the process of learning from data as the characteristics of good science teaching:

> Lab activities were the norm, and learning from your results rather than from what the teacher told you should happen was not unusual. Although scaffolding will be a major component of the learning process in my classroom, students will be expected to direct their own learning through hands on experiences. (Monica's account of good science teaching, at the beginning of internship year)

At the end of the internship year, Monica again highlighted students as "active learners" saying, "Students are working as active learners involved in their learning. The students will function as the teacher in many cases by leading discussions, and presenting their ideas to their classmates."

Adam: Teaching scientific knowledge that is applicable to students' lives and the fundamentals of science

Adam's designated identities with respect to goals of teaching, the role of classroom activities, and the role of students were analyzed (see Appendix 12 and Table 21).

Goals. Across the two years, Adam highlighted his goals in two folds. One was helping students to learn scientific content and/through scientific methods, and the other was developing a safe learning environment. Adam stressed the applicability of the knowledge to students' lives. At the beginning of the senior year, Adam stated,

> Students will have to learn biological basics and the scientific method. Students need to have some level of biology specific content but they need to be able to think of what they are learning in the rest of their lives. The use of scientific method in the classroom will either give them the concept or continue to reinforce the idea. (Adam's account of good science teaching, at the beginning of the senior year)

Whereas the idea of scientific methods were replaced into inquiry-based method in the internship year in Monica's case, Adam seemed to hold his notion of scientific methods by the end of his internship year. In his last account, Adam stated, "Becoming scientifically literate will allow people to understand the world around them and apply their knowledge to new situations. The scientific method forms the backbone of my instruction." Adam also pointed out "develop a safe and beneficial classroom to help students " explain and understand natural phenomena as another important goals in both the beginning of the senior year and the end of his internship year.

The role of activities. Adam consistently pointed out the lab as key activity in his instruction throughout the two years but in a slightly different way. At the beginning of the senior year, Adam pointed out the two roles of lab activities. One is motivational ("i.e., having fun) and the other was helping students to get the big picture of the unit. For instance, Adam stated,

> The lecture portion of class will help the students get an idea of the "big picture" of what they are learning. The labs will be fun for the students and we will discuss what they should have gotten out of the experiments. In my experience, I know that labs can lose the point of the assignment if the students lose focus. The students can also become too

focused on each step of the experiment without knowing the background science theory. Both labs and lectures are necessary to keep the class from becoming too monotonous.

At the end of the internship year, Adam specifically described two scientific practices emphasized by the program (i.e., inquiry and application), and how each practice would provide opportunity for students to develop their explanation. Adam stated, "These are plans that give students experiences where they will have to make conclusions and develop the explanations themselves; inquiry is effective in developing the science literacy skills that students need."

The role of students. The roles of students in Adam's vision statements were also fairly consistent across two years. Above all, Adam emphasized the role of students as active science learners who "formulate their own hypothesis", "be able to ask both me or their peers questions" (Adam's account in the senior year), and "critically analyze data or theories and explain their knowledge fits into the world around them" (Adam's account at the end of the internship year). Adam also highlighted students' social interaction in their learning process in his accounts of good science teaching at both the beginning of the senior year and the end of the internship year. At the last vision statement, Adam described,

> Students can transition effectively from class discussions to lab work. Students work together on class goals. Students may have to take notes, conduct labs, critically analyze data or theories and explain how their knowledge fits into the world around them. Students are able to use technology to develop their content knowledge in my course. (Adam's account of good science teaching, at the end of the internship year)

Three candidates' designated identities

The analysis demonstrated that the three candidates held relatively consistent designated identities—the kind of teacher they wanted to be and the kind of practice they wanted to enact in their future classroom—throughout two years of their time in the program (see Table 21). David was different from both Monica and Adam in that he assumed the authoritative, correct answer, thus his goal was transferring that knowledge. On the contrary, Monica and Adam's goal was primarily focused on actively participating students in scientific activities. The comfortable learning environment was key for student participation, and both Monica and Adam considered developing comfortable learning environment as another important goal. All three candidates wanted to see students' active engagement in their future classroom in order to get students to have some kinds of ownership of their learning. For David, students were depicted to have ownership in the process of finding or receiving the correct information by being independently engaged in activities. For Monica and Adam, students got to have the ownership of knowledge by actively constructing their own explanation about natural phenomena or data.

Table 21. Three candidates' designated identities

	David	Monica	Adam
Goals	• Guiding students to get the correct information in a fun and interesting way	• Engaging students in scientific practices • Developing community of learners	• Teaching scientific theory and/through scientific methods • Developing comfortable learning environment
Roles of activities	• Making science fun and interesting by making connection with student experiences (i.e., making it relevant)	• Helping students to make connections between science and real world examples/experiences	• Making science fun • Engaging students in scientific practices
Roles of students	• Actively engaging in activities while holding responsibility of their learning	• Actively participating in scientific practices • Being a member of a community of learners • Learning from data • Developing their own knowledge	• Actively participating in scientific practices & peer interaction • Learning from data • Developing their own explanation

Discussion

This chapter examined the mechanism of beginning teachers' learning to teach focusing on classroom activity practices using three candidates' cases. Candidates were provided opportunities for learning from professional communities, including their mentor teachers and the program by engaging in classroom activity practices. I examined two types of learning outcomes (i.e., actual practice and interpretation of practice) produced through one teaching episode at the last stage of the program using multiple sources of data, including written reports, teaching video, teaching artifacts, and interviews with candidates, their mentors, and course instructors. Monica and Adam's episodes were selected by the candidates themselves after informed about the purpose of this study. David cared less about selecting particular episode for this investigation, and it was one of his lessons during his lead teaching period. Although the interviews was focused on the teaching video of one teaching episode, it was evident that candidates, their mentor teacher, and their course instructors' stories about candidates' self(s) in/and practices (i.e., actual identities) reflected their accumulative observations throughout one or two years of experiences with candidates. Both mentor teacher and course instructor constructed their stories constantly comparing with and contrasting to the examples of candidates' other lessons that they observed.

The analysis of three cases showed that despite the fact that David was in a good position to learn reform-oriented practices while getting consistent resources, ideas, and advice from both professional communities, David was less successful in demonstrating his learning of reform-oriented practice. On the contrary, Monica was successful in making use of resources and ideas from the program, and developed reform-oriented instruction even though she was in a difficult position where she had to respond to the contradictory resources, ideas, and advice provided by her mentor teacher and the course instructor. The close examination of the three cases indicates that both candidates' ways of understanding science for teaching and their identities played significant roles in the process of developing certain classroom activities practices and their learning from professionals. The following discusses how candidates' ways of understanding science for teaching and their professional identities affected in their process of learning to teach.

The Role of Candidates' Ways of Understanding Science for Teaching

The candidates produced two learning outcomes as their responses to locally created occasions for learning. One is their actual classroom practice and the other is their interpretation of practice. The findings of this chapter demonstrated that candidates' understanding of science teaching affected candidates' selection of classroom activities mediated by their highlighting and coding of the resources, ideas, and advice for classroom activities.

Candidates like Monica and Adam appreciated the relationship between observation and scientific theories or models, and they thought that scientific understanding was achieved by making the connections between them. Their highlighting and coding of their classroom activities and resources demonstrated that they projected their understanding of science for teaching in their stories about practices and students' understanding of science. Thus, they selected the classroom activity that allowed them to help students to make the connections between observation and scientific models. In Adam's case, both school professionals and the program provided him consistent resources and ideas for science teaching, and his Lion King activity was the one that he got from his school. In Monica's case, her mentor provided her resources and ideas that were contradictory from the program, and Monica selected the resources from the program over her mentor's. Monica's highlighting and coding of her classroom activity was fairly similar to her course instructor's, but significantly different from her mentor teacher.

Although Monica was always respectful to her mentor teacher and picked up a couple management skills from her, Monica actively sought out resources and ideas outside of her mentor and selected the ones from the program when it was possible, such as the occasions for learning requested by the program.

On the contrary, David saw science as authoritative knowledge to deliver. To David, science was the 'why' part of the stories, thus, he tried to help students make the causal connections between phenomena and the story of the reason why it happened. This 'narrative' way of understanding science for teaching was reflected in his highlighting and coding of classroom activities, which was significantly different from both his mentor's and his course instructor's. Despite the fact that David selected the classroom activity from his mentor who modeled reform-oriented practice, David's classroom activity practice, his highlighting, and coding of the practices were focused on how this practice addressed his goal of transferring the correct scientific knowledge while fixing up the wrong knowledge. The cases suggest that both candidates' actual classroom practices and their interpretation of practices were fundamentally constrained by his way of understanding science for teaching because they selected the resources and ideas for classroom activities based on their ways of understanding science for teaching.

The Role of Actual and Designated Identities

The three cases also indicated that the candidates' learning to teach was the process of closing the gap between actual and designated identities as discussed by Sfard and Prusak (2005). The candidates' actual identities were presented as collective stories about candidates' self(s) in/and practices told by multiple people at the last stage of the program or after graduation. Although there is no doubt that candidates' actual practices might have been unstable or evolved as their responses to day to day expectations, the data showed that the collective stories constructed through multiple people's narrativatization tended to capture the patterns of actual practices or reify aspects of practices while constantly comparing and contrasting their observation at one episode with others. Sfard and Prusak discussed that the reifying quality comes with the adverbs such as always, never, usually, and so forth, that stress repetitiveness of actions (p. 16).

The three candidates' stories collected several times for two years showed that all of them brought strong momentum toward their designated identities—the kind of teacher they wanted to be and the kind of teaching practice that they wanted to master, and their aspiration of being certain kind of teacher was relatively stable throughout the two years of time when they were in the program. David wanted to teach authoritative scientific knowledge in a fun and interesting way by telling many relevant stories and actively engaging students in hands-on activities. Monica wanted to be a teacher who would actively participate students in activities in a cognitively challenging but socially and emotionally comfortable learning community. Adam wanted his students to be capable of working on problems actively and independently while interacting with their peers with a least amount of teacher's help. The candidates' stories showed how each of them perceived the gap between their actual and designated identities. Depending on candidates' *perceived* gap between actual and designated identities, they positioned themselves as learners of science teaching with respect to each professional in certain ways. Their learning outcomes—classroom activity practices and their interpretation of practices—were affected by their positioning because their choices of resources and ideas for classroom activities shaped their practices.

Both David and Monica began with a fairly similar initial script of science teaching from traditional teaching. But their designated identities as well as their ways of understanding science for teaching were significantly different each other, and their perceived their gaps between actual and designated identities in a different way. In the case of David, David recognized that "What I'm used to, from teachers I've had, is more of, like, the lecturing. Just spitting out information, so it's hard for me to break out of that." What David wanted to do (i.e., his designated identities) was actively engaging students in some hands-on activities and getting students to be independent in finishing their work in order to guide students to get the correct answer. However, students' active engagement was focused mostly on procedural aspects in its nature, such as "asking questions what they're supposed to be doing" or "reading something off of a board." Although David recognized that he currently "feed [students] more information more than what [he] would like to," he was not lecturing the whole hour. He was also engaging most of students in some hands-on activities, which was fairly close to his designated identities. He made use of his mentor's resources and worksheets for the most part. His positioning as a "laid back", "relaxed", and "reform-minded" teacher seemed to be connected with his perceived gap between actual and designated identities, which was not that far each other from David's point of view. David highlighted similarities of his practices to his mentor's rather than differences, while misinterpreting Mentor's practices in a way of aligning with his designated identities. For instance, David said, "Both like to tell stories, like personal stories that relate to things and allow the students to do that too." At a few occasions, David highlighted some differences from his mentor (e.g., planning, re-teaching), but interpreted those differences mostly as the matter of personal style or experiences. David might think that he was doing pretty much what his mentor or his course instructor wanted him to do.

On the contrary, Monica's stories suggested that she saw big a gap between her actual identities and designated identities. Monica also expressed her dissatisfaction about her actual identities (e.g., “got tired of lecturing”) and wanted to teach science differently as described in her designated identities, which explained Monica’s positioning as a learner who actively sought out resources and ideas from all the accessible resources. It was evident that Monica’s designated identities affected her highlighting and coding of her mentor’s practices as well as other resources and ideas. The major difference between Monica and her mentor teacher, highlighted by Monica, was the nature of the classroom learning community created by Ms. S. Monica aligned herself closely with the program and mostly selected the resources and ideas from the program over the ones from her mentor’s, which led her to develop reform-oriented science teaching practices at the end of her internship year despite her difficult position.

Adam’s designated identities aligned well with his mentor and the program’s vision to begin with. Although Adam seemed to be less active in making use of resources from the program, he luckily had access to the resources and ideas at his school placement that were similar to the ones from the program in nature. There was a perceived gap between Adam’s actual and designated identities, such as making a connection with students as modeled by his mentor. Adam recognized the gap, and that was “the part that I wanted to develop further.” With his relatively strong understanding of science for teaching, his designated identities that align fairly well with the program’s vision, and the coherent support from both professional communities, Adam was in a good position to learn reform-oriented practices and he demonstrated it though his actual practices were less sophisticated than Monica’s.

In summary, the three cases showed that candidates’ understanding of science for teaching affected (a) what they highlighted about their experience and classroom activity practices, and (b) how they coded (i.e., interpreted) what they highlighted. Candidates selected resources, ideas, and advice based on their interpretation of them; thus candidates who had ways of understanding science for teaching that initially differed from the program were less likely to make use of resources and ideas from the program.

Candidates' perceived gap between actual and designated identities, affected their learning from their mentor teachers and their course instructors as they engaged in classroom activities practice. Their perceived gap and strong momentum toward their designated identities led them to position themselves as a learner of science teaching in certain ways with respect to professional communities. They put a certain amount of effort to close their *perceived* gap between their actual and designated identities while making their choices of selecting certain resources, ideas, and advices from the professional communities.

Chapter 5.

Findings II: Assessing and Responding to Students

Overview

This chapter illustrates the process that secondary science teacher candidates learn from students through formative assessment practices while responding to deliberately designed occasions for learning. Fourteen teacher candidates' assessment practices were analyzed using both candidates' written analysis of and narratives on students' work. Overall, six out of 14 candidates were successful in using information about students both to improve their instruction and to suggest productive responses to their students through their assessment practices (i.e., providing quality opportunities for students to give information about themselves, identifying, interpreting, and responding), but the other eight candidates were less successful in learning from their students in a way of productively informing their practices. To further examine the mechanism of learning, I selected the three candidates, Leslie, Susie, and Teresa, who worked at the same or similar urban high schools with fairly traditional mentor teachers[26] but who developed different kinds of assessment practices.

The analysis shows how both candidates' designated identities—the kinds of teacher they wanted to be and the kinds of science teaching they wanted to master—and their understanding of science for teaching influenced the process of their learning from students through assessment practices by having created for themselves occasions for learning that differed in nature. Specifically, candidates' designated identities affected their positioning with respect to two professional communities (a) by having them highlight certain aspect of practices and resources provided by professionals and (b) interpret them in a different way under the influence of their

[26] See the detailed description of the three mentor teachers in the section of focus cases selection in Chapter 3

designated identities. The candidates' different highlighting and interpretation influenced their choice of assessment tasks/items that in turn generated vastly different types of student responses. The candidates' learning from students was constrained by the nature of occasions for learning created by these different types of student responses. Similar to their designated identities, candidates' understanding of science for teaching also influenced the nature of occasions for learning by causing them to select different assessment tasks or questions. Their understanding also affected the candidates' highlighting (i.e., identifying) and coding (i.e., interpreting) of student responses. As a result, the three candidates who worked at similar urban high school contexts developed quite different assessment practices.

This chapter begins by presenting the 14 teacher candidates' patterns of assessment practices. It then follows the detailed description of the cases of three candidates—Leslie, Susie, and Teresa. The description of each case consists of (a) stories about the candidate, (b) the nature of occasions for learning, and (c) the candidates' responses to the occasions for learning. The mechanism of learning from students is discussed through the cross examination of three cases at the end.

Fourteen Candidates' Patterns of Assessment Practice

Again, two patterns were found in candidates' assessment practice as the result of data coding (see Table 22). One group of candidates, consisting of six out of 14 candidates, including Leslie, Susie, and Monica, were successful in using information from students to both improve their practices of science teaching and support students' learning, which indicates that they were successful in making a productive 'feedback loop' both for their learning of teaching science and students' learning of science. Leslie, Monica, and Susie were similar in that they were keen observers and identified student responses in detail. Whereas Leslie in her senior year tended to be focused more on students' scientific ideas than on the social aspect, Susie's responses often focused mostly on students' social and personal aspect with the exception of her one teaching episode.

Table 22. Fourteen candidates' assessment practices

	Responding to students with specific strategies that address students' difficulties as science learners	Responding to students with broad and general motivational strategies that are not directly related to students' difficulties
Candidates Interns Seniors	Monica, **Susie**, Alisa **Leslie**, Scott, Lisa	David, **Teresa**, Adam, Shannon Mary, Kevin, Stella, Lynn
Providing opportunities (Types of assessment tasks)	Assessment tasks reveal rich information about students as science learners • Applying knowledge to novel situations • Developing explanations about phenomena through reasoning	Assessment tasks reveal limited information about students as science learners • Reproducing factual information • Displaying some skills or procedural knowledge
Identifying	Students' ideas, difficulties, misconceptions, and/or partial understanding	Right/wrong Complete/incomplete Little or no information
Interpreting	Interpreting student responses in relation to teacher's instruction, students' personal/missing experiences, or social/cultural resources	Interpreting student responses in relation to students' attitudes, attentiveness, behaviors, personalities, and motivation
Responding	Suggesting specific ideas of instructional modification that addresses students' difficulties	Suggesting general/broad ideas, such as hands-on activities, that are not directly related to students' difficulties manifested in their responses

The other group, eight out of 14 candidates including Teresa and David, were less successful in responding to students productively in the sense that their responses did not address students' difficulties as manifested in their work. In particular, this group of candidates commonly described student responses using binary opposites such as right or wrong, correct or incorrect, did complete or did not complete (ID-c & d: Shannon-100%, Mary 20%, Kevin 50%, and David 82%) or highlighted few to no student ideas (ID-f: Keven-13% and David 9%). Their interpretations were mainly connected to student behaviors or motivational issues in classes (IN-g: Shannon 40%, and Mary 60%). At many times they did not make any further interpretation about their observation (IN-l: Shannon 20%, Kevin 100%, and David 64%). Candidates' ideas for improvement in this group were broad and general for the most part, and were not directly related to students' difficulties (R-e: Shannon 100%, Mary 40%, Kevin 38%, Teresa 33%). Examples of this type of response are "spending a little bit more time with it…because it is a difficult part and students need more practice" or "giving them the framework of notes like the teacher had." Sometimes candidates in this group provided few to no responses (R-f: David 36%, Teresa 8%)[27].

The Case of Leslie

Stories about Leslie

Leslie was a white female senior who was majoring in Biology. She was a fairly typical teacher candidate who came from a nearby southern suburban area, and got into the teacher preparation program in her junior year without any teaching experience. She was one of the two candidates who participated in this study for two consecutive years from her senior to internship year.

To begin with, Leslie held a vision of science teaching that was similar to the program. In her account of "good science teaching" that she wrote very early in her senior year, Leslie stated that she wanted to help her students "to see how science affects their everyday life", "to take what they are learning and use it to understand their own bodies, interests, and hobbies", "to use it to make good choices as they grow into adults," and her lesson to "include tie-ins to

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[27] See the results of coding 14 candidates' assessment practice in Appendix 13

current events such as global warming, eating disorders and obesity, and cancer research" to accomplish her goals.

While working at the diverse urban high school where classroom management was a big challenge for most candidates, Leslie was keen on her students' ideas and their understanding of science. She said, "I guess teachers always think about, like, 'Are their students getting it?'" Leslie liked asking questions to students or getting questions from students because questions allowed her to "pull information out of the students." She also tried to bring many real-world examples into her lesson to make learning science meaningful. She thought that the ways students have been taught in their previous science classes were responsible for students' perceptions of science, thus she wanted "to create an environment that would allow students with all types of learning type to succeed." Leslie enjoyed being with students in her classroom. Her classroom was dynamic and interactive because students worked with their partners or as a group, and asked her many questions. Leslie's intern year mentor teacher, Mr. J., even joked that he would mark down Leslie's practices .5 out of 10 because she was "answering too many questions for [students]."

Leslie was an active and conscientious participant in her methods courses. She took all the assignments and comments from the instructors seriously, and asked instructors many questions about the assignment templates as well as instructors' comments on her plan to modify her lessons. Her course instructor, Dr. G, described Leslie as "one of our top candidates." Dr. G said:

> Dr. G: Leslie was really attentive to our templates that we laid out, what we wanted for assignments. She is very attentive. If we made comments, [she was] coming and asking questions about comment, even revising her unit or lesson plans, even if

technically she didn't need to revise it. She followed the templates that we laid out very carefully.

While working with Mrs. F at this challenging urban high school in her senior year, Leslie always took an initiative in finding resources and activity ideas that supported students' understanding. Mrs. F. said, "[Leslie] would come to the discussions that she would have with some suggestions or ideas already prepared." Interestingly, Leslie asked her mentor teachers many questions focusing on students' thinking and their responses on the topic, such as "How do you think the students are going to respond to this?" "Do you think they are going to struggle with this?" when preparing her lesson. Mrs. F said:

Mrs. F: [Leslie] would have questions that she needed to have clarified or she would say, "I'm not sure about this part; how do you think the students are going to respond to this? Do you think they are going to struggle with this?" She would come with questions specifically related to the lesson.

Leslie did not hesitate to go out of her mentor teacher's 'teaching repertoires,' and to bring outside resources into the classroom even in her senior year. For instance, Leslie selected an inquiry lesson activity that she got from the program despite her mentor teacher's initial reservations about it. Mrs. F. described Leslie as a "strong" and "confident" candidate:

Mrs. F: I believe that Leslie was pretty strong in terms of being able to take an initial idea and find a useable lab activity in her lesson…Leslie was more confident in the activities she chose, in terms of whether or not they would work or if they were appropriate, whereas other candidates would like a little more feedback.

Leslie was very respectful to her mentors, but she did not think of herself as "being my mentor teacher ten years from now." To Leslie, "science is the subject of discovery" by definition. She wants to help students "to better understand themselves and the world around them," even though students do not always see science this way. It was "My responsibility as a teacher" to provide opportunities for students to find the science in their everyday activities and to make connections.

> Leslie: It is *my job as a teacher* to help students make the connections between science content and real life. It is also *my responsibility* to provide opportunities for students to find the science in their everyday activities, bringing a new awareness that allows them to find value in, as well as take ownership of their learning. (Leslie, Teaching philosophy statement at the end of internship year, italic is added)

Leslie held the strong vision of science teaching (i.e., designated identities) that was well matched with the program's vision to begin with, and carried them through her experiences in both the program and school placements over two years.

The Nature of Occasions for Learning for Leslie

Leslie's mentor, Mrs. F, had 10 years of teaching experience at the West high school. She herself graduated from the same teacher preparation program 11 years ago, and had worked as a mentor teacher with four interns and several seniors from the program. Mrs. F's science teaching was fundamentally didactic in a sense that she intended to deliver authoritative scientific information to students even though she liked to do hands-on activities. Mrs. F selected classroom activities that would be "doable with large classes", "relatively low in cost, but yet still going to portray the concepts in a way that the students are able to connect the ideas with what we are actually doing." Both Mrs. F and Leslie valued students' experiences and tried to bring them into their lessons in order to motivate students who often do not seem to care about learning science.

As a mentor teacher Mrs. F was open to new ideas, and allowed Leslie to investigate new resources and to try them out in her classroom. Even when Mrs. F had some reservations about candidates' approaches, she considered it as candidates' "learning experience," and she tried to "provide them with whatever type of experience they would like" with her support. Therefore, Leslie was in a position to try out her ideas and to develop her skills of science teaching in the Mrs. F's classroom while working with diverse students at this urban high school.

Leslie's Responses to Occasions for Learning

In order to illustrate the characteristics of Leslie's assessment practices, I first describe Leslie's assessment practices in one teaching episode in detail, then present the patterns of her assessment practices that emerged from multiple data sources. I purposefully selected one teaching episode produced at one common occasion deliberately designed by the program to set up the comparison among Leslie, Susie, and Teresa. In this occasion, all candidates were asked to plan and report one inquiry activity sequence along with embedded assessment activities. They were guided to plan an inquiry activity that had the seven components: (a) establish a problem, (b) questions, (c) data and evidence, (d) student explanations, (e) scientific theories and models, (f) communication, and (g) lessons learned. Candidates had to analyze students' responses with respect to each component using their embedded assessment tasks.

I first summarize Leslie's inquiry activity from her stories of what happened. The embedded assessment tasks or questions designed or identified by Leslie in her report were italicized in the summary. Then follows my analysis about the four elements of assessment practices: (a) providing opportunities for students to give information about them (i.e., assessment tasks/questions), (b) identifying (i.e., highlighting), (c) interpreting (i.e., coding) and (d) responding. The general patterns of Leslie's practices identified from multiple sources of data are presented at the end.

Leslie's inquiry activity and assessment tasks/questions. The unit of Leslie's inquiry sequence was evolution by natural selection. As the objective, Leslie stated, "Illustrate how genetic variation is preserved or eliminated from a population through natural selection." Following the guideline of inquiry activity sequences provided by the program, Leslie opened the lesson by asking questions that reveal students' general perceptions and prior knowledge on evolution. She asked, *"Do you believe in evolution?" "Give the definition of evolution in your own words."* She had students *formulate questions about evolution*. Leslie engaged students in two data collection activities. The first one was a toothpicks activity—students picking four colored toothpicks in the grass of the schoolyard for one minute—that generated the data that showed the survival of fittest and change in the population using different numbers of remaining toothpicks. The second data collection activity was the bird beak lab that Leslie got from the program. This bird beak lab produced data that showed differences in survival rate depending on the types of food and the shape of beak. After this data collection activity, Leslie got students to work in small groups to analyze their data and find patterns. She asked specific questions to guide students' data analysis and pattern findings, such as "*What color of toothpick survived the best? Why? What will the toothpick population look like in a few generations?" "How is the bird beak lab alike or different from the toothpick lab*?" Students had to explain their data by responding to the question in *their lab report*: "*How did the environments affect the shape of the beak that could survive on each of the islands?*" After students' data analysis and explanation, Leslie discussed Darwin's theory of natural selection, and then finally she had her students *explain evolution using the three key ideas of (a) natural selection, (b) over reproduction, and (c) random mutation, including examples that explain students ideas, on a blank paper*.

Analysis of assessment practices in the inquiry teaching episode. I analyzed Leslie's assessment practices manifested in this inquiry teaching episode with respect to the four elements of assessment practices: (a) providing opportunities for students to give information about themselves, (b) identifying (i.e., highlighting). (c) interpreting (i.e., coding), and (d) responding.

A. Assessment questions/tasks. Leslie designed several embedded assessments to get information about students throughout her inquiry activity as guided by the program. But the key assessment questions appeared on the lab worksheet toward the end of the activity. Leslie's questions asked students to explain the mechanism of certain phenomena (i.e., change in population) using scientific theories or models (i.e., evolution by natural selection). She provided opportunities for students to use scientific theories or models developed from their inquiry activities (i.e., toothpicks lab, bird beak lab) to explain data or observation that they collected. Leslie asked, "*How did the environments affect the shape of the beak that could survive on each of the islands?*"; "*Explain evolution using the three key ideas of (a) natural selection, (b) over reproduction, and (c) random mutation, including examples that explain your ideas, on a blank paper*."

B. Identifying & interpreting (i.e., highlighting & coding). Leslie's assessment questions produced rich information about students' ideas and their thinking. Leslie carefully compared student responses with the ideal responses that she expected, and identified what students knew, partially knew, and what was missing. For example, Leslie stated:

> The students all stated that evolution was a change in species over time. Many of them were also able to explain what natural selection was; however, very few of them stated that natural selection was the force behind evolution. Some students could not explain natural selection the way it was described in the book or in the notes but they could give great examples about how it works. [Leslie, Intern, Inquiry activity report]

In this account, Leslie interpreted students' responses that included appropriate examples about the mechanism of evolution positively although students did not describe "the way it was described in the book."

C. Responding & learning from students. Leslie suggested very specific ideas to address students' difficulties that they identified, stating that "I would give them a rubric that would help students identify the important concepts as well as give them a problem to solve." Leslie also thought that the lack of clarity in students' responses regarding the relation of a genetic change in the process of evolution had to do with her unclear assessment task. Accordingly, Leslie noted the importance of establishing a strong problem at the beginning of the inquiry activity sequence, so that she will have students "try to come up with their own explanations to the problem at this stage" to "dig deeper into students' thinking" next time. Leslie's narratives showed that she received productive feedback on her instructional practices from students by engaging in this assessment practice.

Patterns of Leslie's assessment practices from multiple data. A total of four teaching episodes collected throughout two years were analyzed to find the patterns of Leslie's assessment practice. Each teaching episode included at least one plan and one report. Two out of four teaching episodes also included candidates' interview about their teaching video. In addition to the data from her teaching episodes, Leslie's interview that was conducted using a clinical interview video in her senior year was also analyzed to triangulate the patterns of Leslie's assessment practices.

The results clearly showed that Leslie consistently provided quality opportunities for students to give rich information about their scientific ideas or thinking by engaging them in scientific practices (O-f: 67%) even from the beginning of her senior year. For instance, in her lesson about DNA fingerprinting, Leslie had her students respond to the question of "why might the non-coding regions of a person's DNA be more variable than their coding regions of DNA (think back to what you have learned about mutation)?" In another lesson about microscopes and cells from her senior year teaching episode, Leslie had students observe onion and cheek cells to find similarities and differences between plant and animal cells, and then use that information to solve a problem of identifying an unknown material on the table. Her assessment questions included types of questions that ask factual information, but those questions were asked in the contexts of some investigation or application activity.

As the responses to Leslie's assessment questions or tasks, students produced many interesting answers that showed their ideas, misconceptions, and thinking process. Leslie identified students' scientific ideas, including partial understandings or misconceptions from the responses (ID-a & ID-b: 67%), interpreted students' ideas in relation to the experiences provided through her instruction or students' prior experiences (IN-a & IN-c: 100%), and then suggested specific instructional modifications that were directly connected to the students' identified difficulties (R-a: 67%) (see Figure 8 and 9). For instance, in her lesson about microscopes and cells where students compared and contrasted plant and animal cells from the observation of onion and cheek cells, Leslie identified a low achieving student's difficulties in understanding cell structure, highlighting misconceptions about the nucleus. Leslie stated, "My low achieving student, Cathleen, was unable to correctly identify a cell and a nucleus. She even had the misconception that a nucleus was its own cell which she called a 'neluic cell.'" (ID-a) She thought that the misconceptions about nucleus might be associated with insufficient observations about cells and nucleus provided with her instruction. Leslie stated, "I think it would have been useful for me to point a cell and a nucleus on more than one kind of cell instead of just doing it once during the demonstration." (IN-a) She suggested providing more experiences for observing differently shaped cells to help students find patterns among them. She said, "I would spend more time looking at pictures of cells under the microscope…I think that for some students, it would have been useful to practice identifying all kinds of different shaped cells and point out that the nucleus is always inside a cell, never on its own and never its own cell." (R-a) Leslie's responses were specific and tied to the difficulties that she identified in students. The analysis suggests that Leslie was successful in learning from her students by engaging in this formative assessment practice as demonstrated in this one teaching episode. The results of data coding of all four teaching episodes showed the clear patterns of Leslie's formative assessment practices across two years (see Figure 8, 9, and 10).

The patterns of practices that emerged from her own teaching episodes were even consistent with her approaches toward assessing and responding to Jeremiah during the interview with a clinical interview video. In this controlled context where all candidates had to respond to the same student in the video, Leslie identified accurately what Jeremiah did know and did not know in great detail, including Jeremiah's misconceptions about leaves and soil. For instance, Leslie succinctly summarized, "He knows that you need air, water, and light; you need those things, which is what you need for photosynthesis. He does know that it is not from the soil; he just goes back to it. He knows the key ingredients and he knows that plants have something special that animals do not." (ID-a) Leslie focused on Jeremiah's misconception about leaves and soil, and interpreted Jeremiah's ideas as a sensible way of making sense about plants. Leslie said,

> I think it is just, because that is just the only thing that he could think about logically that, in his mind, before he got to class, it is probably what he thought. And even though he sat through X many days of listening about photosynthesis, he still is going back to what he already knew, or already thought he knew (IN-c & IN-j) (Leslie, senior, Interview using a clinical interview video).

As her response to the question of "What would you do as a teacher if you have a student like Jeremiah?" Leslie suggested doing an experiment with students to address their misconceptions: "I might do the soil experiment with them, just to kind of prove that [plants] do not use soil. And then talk about we know that they need air, water, and light to survive; what are they doing with the air, water, and light, too?" (R-a) Leslie's response was focused on clearing up students' misconceptions that she suspected would be common in students of that age. The following charts in figure 8 and 9 showed that which aspects were more or less highlighted in Leslie's assessment practices with respect to identifying (i.e., highlighting), interpreting, and responding (i.e., coding). These charts were developed from the coding results. The relative percentages of each aspect of interpretative codes (i.e., content understanding, social, and behavioral/procedural) were calculated from the total number of coded units.

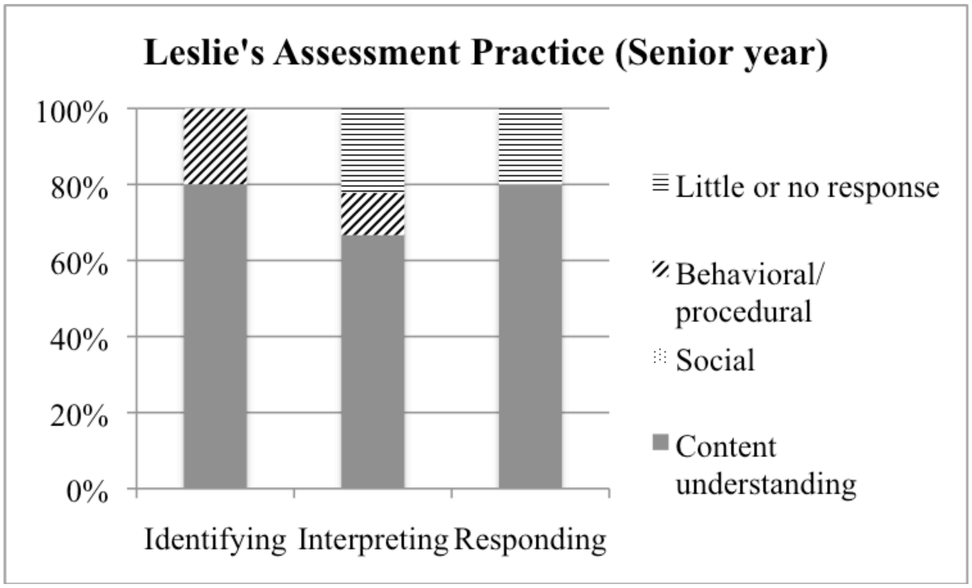

Figure 8. Leslie's assessment practice pattern in senior year (No response means the candidate did not provide any interpretation or did not make any suggestions in the unit of analysis)

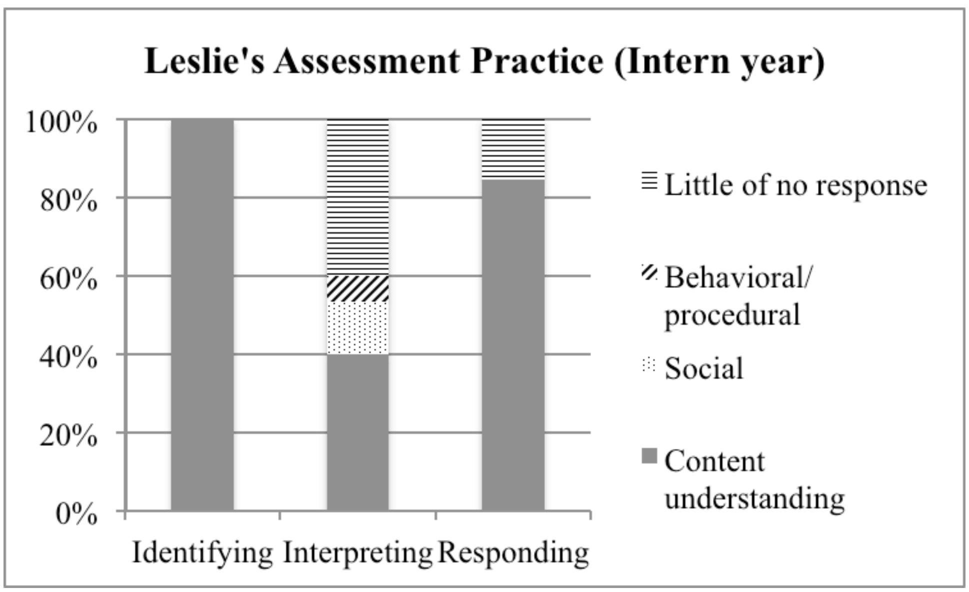

Figure 9. Leslie's assessment practice pattern in intern year

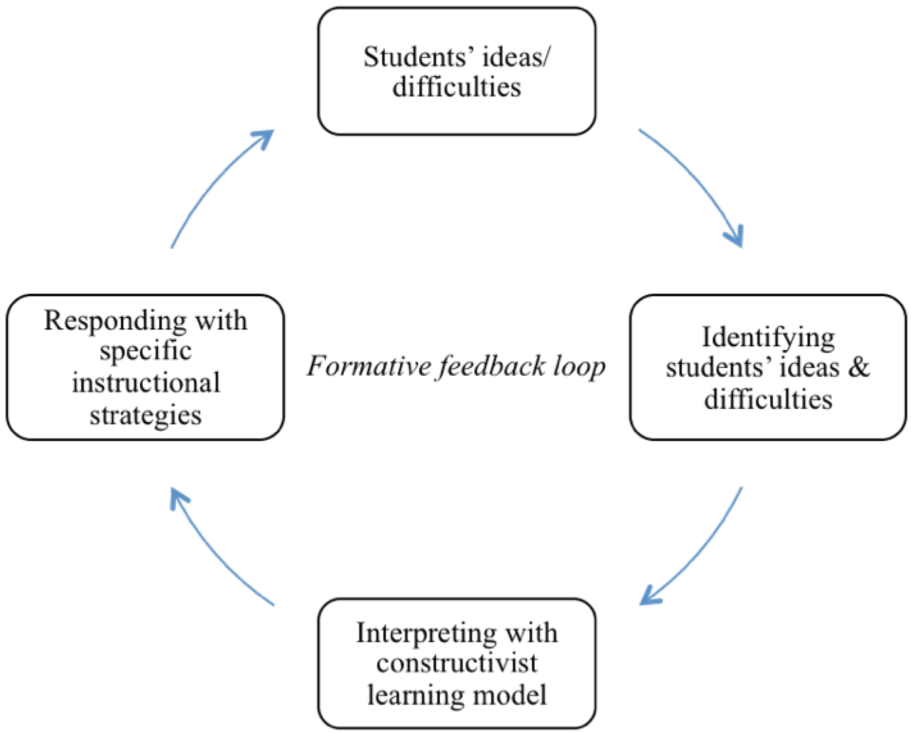

Figure 10 Leslie's approach of assessing and responding to students

The Case of Susie

Stories about Susie

Susie was a petite Asian female intern who majored in Chemistry and minored in English as a Second Language. Similar to Leslie, Susie came into the program in her junior year without any teaching experience. Susie worked at the same school as Leslie, West high, but with a different mentor. It should be noted that Susie worked with the same mentor teacher, Mrs. B, for two years from senior to internship year, which was very unusual. When she participated in this study, she was in her internship year, thus it was her second year of being in Mrs. B's classroom.

Susie had a fairly similar vision of science teaching as the program though she used different language. The kinds of science teaching that Susie wanted to do were engaging students in "the thought process" through students' collaborative activities in a classroom community while modeling scientists' work in the scientific community. She said, "I think in all aspects of the way I design the class, I try to emphasize that the process is much more important than the right or wrong answer." Susie likes to "have students work in groups, think-tank types of activities, and have them share their answers" because "I feel that's what people do in the scientific community." In her vision of good science teaching, Susie stated that her students would be "working like scientists by fielding ideas and revising them as a team."

Susie cared greatly about *all* students' engagement in her lessons to begin with. In the vignette of good science teaching that Susie developed at the beginning of her senior year, she highlighted the inclusiveness of everyone in activities such as demonstration as one of the key attributes of good science teaching. Susie was keen on students' personal and social characteristics, and frequently talked about how they played certain roles in their participation in her classroom. For instance, during the interview she pointed out, "A lot of the students are very competitive in this particular class, so I think that also plays a role in how the students behave in class and how they participate." While working with a diverse group of students at this urban high school who mostly came from low resourced families, Susie positioned herself as someone who provided care and nurtured her students as if she was their 'mom' at school. "[Students] fight for my attention"; "They're very needy"; "They are constantly asking questions and wanting me to take them step by step by step through everything." Susie said that a teacher ought to "feed students after breaking the information into chunks that they can digest."

As an intern at this diverse urban high school, Susie was not an exception in having difficulties in managing a classroom. Susie treated her students with respect though, and made an effort to reach all students, even when students challenged her. Susie's mentor, Mrs. B, described that Susie concentrated her efforts in "finding ways of reaching them instead of getting upset about it." Mrs. B proudly said that Susie had "developed a safe classroom that the students feel comfortable no matter who it is, and that there is a respect between student and teacher."

Although both Susie's mentor teacher and course instructor described Susie as a "thoughtful" and "reflective" intern, Susie interacted much more actively with her mentor teacher than the course instructor about her teaching practices. To the course instructor, Dr. R, Susie was a "quiet" intern, although Dr. R found her "to be very reflective, thoughtful, willing to think about her own practice and the kids." On the contrary, her mentor teacher, Mrs. B, said that Susie was "always curious as to the reasons behind the suggestions," and asked many reflective questions. Susie mostly relied on Mrs. B's resources, and imitated her teaching strategies in her daily practices throughout her internship. Interestingly, Susie was well aware of her 'imitation' of her mentor's practices as indicated in this comment: "Our personalities are not quite the same, and I've found that I've morphed a little bit into her personality, especially in terms of classroom management because I've seen her be so effective and I've recognized that." Susie used many techniques and strategies that Mrs. B modeled for her, and used language very similar to that of Mrs. B to explain her teaching practices. However, Susie also noted that there were some differences between her and Mrs. B in terms of their ways of teaching science. Whereas Susie likes to have students do group work and open-ended type activities (i.e., designated identities), her mentor teacher didn't like those activities because it made the class chaotic. Susie said,

> I'm still like fairly similar to what she's teaching, but I have felt more comfortable putting in my own spin on things…I think what I do, that's a little bit different from my mentor teacher, is I take time to – like she doesn't do a lot of the drawing pictures and having them work in groups, and I like to do a lot of like think-tank types of activities and have them share their answers, and she's very much more, I think, concrete and

> wants – doesn't like things that are very open ended. And at first I felt very like uncomfortable doing that, and as I was planning and things I would try to avoid things that like, because I thought maybe she would feel like that's really unnecessary or that's really foolish or that's you know whatever. But as the year went on I wanted to try different things and try new ideas and, yeah, do things like that. (Susie at internship year, teaching video interview)

Obviously, Mrs. B was not exactly the kind of teacher that Susie wanted to be. Susie was also aware that the kind of science teaching that she wanted to master did not exactly match Mrs. B's instructional model. As her responses, Susie primarily imitated her mentor's approaches early in the internship, but as the year went on she was able to "try different things and try new ideas."

The Nature of Occasions for Learning for Susie

Susie's mentor, Mrs. B, had approximately 20 years of teaching experience at the high school level, including 13 years at West high school. Mrs. B collaborated with the program for a long time as a mentor teacher, and Susie was her eighth intern. Her background was in medical technology and clinical laboratory science, and she received a teaching credential after she got her Masters degree in clinical laboratory science.

Mrs. B had a strong view about good science teaching that was easily characterized as structured and skill-oriented. She confidently stated that her goal as a science teacher is helping students to develop sets of 'content-free' life skills, such as organizational skills, communication skills, and thinking skills, without any hesitation. From her point of view, "most of [her] students are never going to use chemistry again," but they will use those life skills. If they develop those skills from her class, "they can learn the science at any time."

Mrs. B: Most of my students are never going to use chemistry again. Are they going to use some of the organizational skills? Keeping a notebook? Are they going to have to communicate with other people in a reasonable fashion? Are they going to have to read and follow directions? Yes! So things that may not necessarily seem like strictly science content that are more life skills are a lot of the things I want to see the kids walk out my door with. If they walk out with those, they can learn the science any time.

Mrs. B's approaches to both teaching science and mentoring candidates were highly structured and skill-oriented. Dr. R said, "It's like having somebody from the military be your teacher, not in a bad way, but in the sense of structure. [Mrs. B] was very clear about expectations, she scaffolded things, she helped students, and she was always there for them." Susie also added, "I don't know if this is even the right wording but this is the wording that [Mrs. B] uses. She is good at training her students. So it's very orderly and organized."

Mrs. B's approach to mentoring was highly structured and skill-oriented as well. Mrs. B always monitored Susie's practices in her classroom, and explicitly modeled all the small techniques in detail to help Susie develop certain 'skills' of science teaching that work for Susie. During the interview with Mrs. B, she proudly pointed out that the skills and techniques manifested in Susie's teaching video were those that Mrs. B and Susie had developed together, such as cues and signs between Susie and students indicating when to participate, to stop, and to proceed with whole class conversation. While working with Mrs. B for two years, Susie was constantly exposed to how Mrs. B skillfully got all students to do their work through drill and practice type problem solving activities under Mrs. B's structured modeling. The two professional communities (i.e., the teacher preparation program and the mentor teacher) that

Susie had to respond to provided her with different resources for and ideas of science teaching practice.

Susie's Response to Occasions for Learning

Similar to Leslie's case, I will illustrate the characteristics of Susie's assessment practice in inquiry teaching episode in detail, then present the general patterns of her assessment practices. I first summarize Susie's inquiry activity constructed from her stories of what happened. The embedded assessment tasks or questions designed or identified by Susie in her report are italicized in each summary. Then follows my analysis about the four elements of assessment practices. The general patterns of Susie's practices are presented at the end.

Susie's inquiry activity and assessment tasks/questions. The unit of Susie's inquiry sequence was solutions. She stated that the objective was to "Describe how various factors affect the rate of solution and solubility." Susie opened her inquiry sequence with students' discussion after splitting the whole group in half. One half of the class was asked to list as many factors that impact solubility *("What factors might affect how fast something dissolves?")* and the other half to list as many factors that impacted rate of solution ("*What factors might affect how much of something can dissolve?*"). Students had to come up with at least one factor through their discussion, write them down, and submit them to Susie. Susie complied all the factors that students came up with, and then assigned each student a factor (i.e., temperature, surface area of the solvent, stirring, crushing.). *Each student designed a lab that answered the question, "How does …. affect solubility or rate of solution" using a sugar cube and water*. After each student designed a lab individually, Susie asked students to discuss their designs together as a class, and addressed the issue of testing only one variable at a time and having control groups in students' lab designs. Next, she assigned students different labs to test different variables using students' lab designs. Students collected data (e.g., counting sugar cubes or timing) while performing one another's labs. Susie asked students to *write a lab report*. This report asked students to *"explain how their factor impacted or did not impact rate of solution/solubility based on the data they collected*." *Students were asked in a discussion scenario how their factor impacted the solution at a molecular level.* Finally, she engaged students in a roundtable discussion about the factor at a molecular level. During the roundtable discussion, Susie had each group *provide a mini presentation for the class that included: (a) what question their lab was attempting to answer, (b) whether they were testing for rate of solution or solubility, (c) what factor they were testing, (d) their data/lab results, and (e) conclusions that could be drawn from their data.* Susie wrapped up this inquiry sequence after having a whole-class discussion on the rate of solution and solubility at the molecular level.

A. Assessment questions/task. In this inquiry activity sequence, Susie provided an open-ended opportunity for students to give Susie rich information about themselves, including their understanding about designing experiments, engagement in scientific practices, and knowledge of rate and solubility, by having students design a lab by themselves. Similar to Leslie, Susie's key assessment questions asked students to explain the mechanism of certain phenomena (i.e., solubility) using scientific theories or models. She provided opportunities for students to use scientific models developed from their inquiry activities (i.e., solubility lab) to explain data that students collected through their lab. Susie asked them to, *"Explain how their factor impacted or did not impact rate of solution/solubility based on the data you collected*."

B. Identifying & Interpreting (i.e., highlighting & coding). Susie's assessment questions produced rich information about students' ideas and their thinking. Susie carefully compared student responses with the ideal responses that she expected, and identified what students knew, partially knew, and what was missing. Susie identified the characteristics of student responses while appreciating observation, patterns, and conclusions. She stated, “Some students did not draw a conclusion, only stating the patterns they found. Some simply stated that as their factor increased/decreased, the rate of solution/solubility went up/down.” Interestingly, Susie also noted that students did not understand the integrated nature of scientific knowledge and practices. She problematized students’ tendency of separating this scientific investigation from developing scientific knowledge. She stated, “The idea of the need for research was absent, therefore, students might have seen the process as simply validating a known fact.” Susie interpreted this problem as her failure to provide scaffolding for students effectively as shown in the following statement:

> I feel that I did not effectively scaffold the process of scientific research. It seemed that even while performing the lab, the students were convinced they knew the outcome and results. As a result, they may have forced conclusions that were not properly supported by their data. Also, I did not scaffold the process so that students were looking at the big picture. Rather, they saw it as completing separate, unrelated tasks. The resulting outcome was that the students were not able to critically analyze and piece together the parts of the lab (the question they were trying to answer, the data collected and the meaning and significance of their data). [Susie, intern, Inquiry activity report]

Both Leslie’s and Susie’s practices of identifying and interpreting indicate that the ‘science’ that they tried to teach with this inquiry activity was neither a description in the textbook nor a process separate from the content. It was an integrated body of knowledge and practice that allowed their students to make sense of the world that they experience.

C. Responding & Learning from students. Susie identified quality information about students, including their difficulties in engaging in scientific practices, from the student responses generated by her assessment tasks. Based on her interpretation of student responses, Susie suggested very specific ideas to address the students' difficulties that they identified. For instance, Susie suggested ideas to help students to distinguish between dissolving time and rate of solution as following:

> For students that were assigned rate of solution, I would have included a question that would require students to distinguish between dissolving time and rate of solution (ex. As temperature increased, what happened to the time it took for the sugar cube to dissolve. Followed by the question: What does this tell you about the rate?). [Susie, Intern, Inquiry activity report]

Susie's narratives showed that she received productive feedback on her instructional practices from students by engaging in assessment practice. The biggest lesson that Susie learned from this assessment practice was that "many students did not recognize the essence of science—experiments are about answering questions." She also highlighted that "students were uncomfortable with the idea that their data proved that variables were unrelated" despite the fact that "both conclusive and inconclusive results were equally valuable" in science. Therefore, Susie drew out the following lesson:

> I have learned that in order to scaffold students' learning in an inquiry lesson, that this idea must be discussed. It is important that students understand that we are forming hypotheses, designing and doing experiments for the purpose of answering our inquiry- a question we do not know the answer to. Data and results are not analyzed based on correctness; they only help us answer our question by proving or disproving a correlation.

If our results are inconclusive, it simply means we need to revise our design or hypothesis- it still provides us with information that we can learn from. [Susie, Intern, Inquiry activity report]

The analysis demonstrated that Susie was successful in both responding to students productively and learning from students.

Patterns of Susie's assessment practices. A total of two teaching episodes, including the inquiry one, were analyzed to examine Susie's assessment practice. The inquiry activity sequence was the outcome of candidates' responses to the occasions for learning deliberately designed by the program with the intention of engaging candidates in reform-oriented teaching during the last semester of their internship year. The other teaching episode was produced as the outcome of a general occasion for learning during the spring semester of the internship year. The data included Susie's plans and reports of these two teaching episodes, and one interview about Susie's teaching video. In addition, the interview using a clinical interview video was analyzed to triangulate the patterns that emerged from her own teaching episodes.

The results of coding of these two episodes indicated that overall Susie incorporated various types of assessment tasks ranging from ones that generated simple and short student responses to ones generating complex and long student responses. The kinds of opportunities provided for students included reproducing factual information (O-b: 33%), displaying some skills or procedural knowledge (O-c: 44%), applying models or principles to explain other examples (O-d: 11%), and developing explanations through reasoning about data (O-f: 44%)[28]. However, the opportunities that required students to reveal complicated scientific ideas with

[28] The total number of units of analysis was nine. Three of them were double coded because those units include students' multiple responses to several sub-questions. See the detail in the Appendix 12.

relatively long responses were mostly provided with her inquiry teaching episode. In the other episode about atomic structure and subatomic particles, she got students to practice calculating average atomic mass by following the equations (O-c), and asked, “In your OWN words, what is an isotope?” (O-b), and “What is the relationship between an element’s isotopes and the element’s atomic mass?” (O-b). In her inquiry lesson about solution and solubility, students were “asked to design a lab in which they could find out how their assigned factor impacted the rate of solution or solubility,” and then later they had “to explain how their factor impacted or did not impact rate of solution/solubility based on the data they collected.” (O-f)

Not surprisingly, the two different types of assessment questions from two different teaching episodes generated different types of student responses, which affected the other elements of assessment practices from identifying to responding. In the general teaching episode, Susie mostly *identified* whether students got right or wrong answers (ID-c) or completion of the tasks (ID-d) in her unit report. She then *interpreted* that students’ wrong answers or incompletion were associated with behavior issues (IN-g). For example, Susie reported about one low-achieving student, Alex, as following:

> Alex did not have his pre-lab completed and was asked several times in class to get started on it and finish it so he could get started on the lab. It appeared his lab partner was doing most of the work. He simply wrote down whatever she was writing. As I tried to ask him to explain the calculations he was doing, he was not able to explain it. In addition, he did not have time to finish the questions in class and chose to leave them blank. It appeared that he had absolutely no understanding of what was going on, beside the fact that we were counting and weighing beans. (ID-d, IN-g)

Susie's ideas for modification of her instruction included "assign independent activities or dividing the roles" for students to complete their work independently (R-d), and "find an alternative way of presenting and lecturing" to make "kill and drill type of activities" less boring (R-e). Her responses addressed some social dynamics in the classroom but were not directly related to students' difficulties. Things that Susie could learn from students through assessment practice were constrained by the kinds of opportunities that she provided with her assessment questions or activities.

In her inquiry teaching report as described above, however, she highlighted students' ideas and their difficulties in understanding the topic (ID-a & ID-b: 100%), and interpreted it by linking to her instructional approaches or students' prior experiences (IN-a & IN-c: 67%), and responded to them with some instructional strategies relevant to students' difficulties. For example, from students' lab reports about solution and solubility in the inquiry teaching episode, Susie identified that "some students did not draw a conclusion, only stating the patterns they found…. Also, students, who were assigned to investigate the rate of solution, did not distinguish between rate and time." (ID-a) Susie interpreted this in relation to her instructional approach saying "I did not scaffold the process…the resulting outcome was that students were not able to critically analyze the piece together the parts of the lab." (IN-a) Her response was very specific and tied with the students' difficulties that she identified. She stated, "For students that were assigned rate of solution, I would have included a question that would require students to distinguish between dissolving time and rate of solution (ex. As temperature increased, what happened to the time it took for the sugar cube to dissolve. Followed by the question: What does this tell you about the rate?)." (R-a) The analysis of the two teaching episodes showed that Susie's assessment practices were inconsistent and sensitive to the structure of assignment.

During the interview using a clinical interview video, Susie identified what Jeremiah did know and did not know accurately including his misconception about soil during the interview (ID-a). Susie said, “I think that’s evident that [Jeremiah] understands that staying alive means you need food and that’s how you obtain the food, from air, minerals, soil and light…[Jeremiah] might have a misconception on how the soil plays into the process of plant growth because he had said two different things.” Interestingly, she also highlighted that how the social environment created by the interviewer’s strategy might have influenced Jeremiah’s feeling as well as his responses.

> The interviewer at the very beginning, I think that was very important for the student, when [the interviewer] stated ‘don’t worry about being nervous’ and that kind of thing. It made the student felt that this was a safe place where he could express his thoughts and feelings and say I don’t know if he really didn’t know.

Susie interpreted Jeremiah’s dismissal of learning photosynthesis as the failure to make connections between abstract ideas (i.e., vocabulary) and students’ prior knowledge (IN-c). Accordingly, as her responses to Jeremiah, Susie emphasized the importance of helping students to see the value of learning in order to persist in learning the abstract ideas. She suggested that, “It’s important to go from bigger to smaller and not jump to an equation, or to vocabulary, or to specific parts of a process before explaining the application first.” Susie’s responses to Jeremiah were general and related to his difficulties to some degree, but may or may not address his specific difficulties in understanding the role of soil and leaves in plants making their food.

In short, Susie’s approaches toward assessing and responding to students were sensitive to the nature of occasions for learning, and specifically to the structure of the assignment. By asking different types of questions, she provided variable opportunities for her students to give information about what they knew. When she received quality student responses, she was able to use some of that information about students to provide productive feedback. Susie's responses were often grounded in general observations about students' social aspects and patterns of participation in the classroom (R-d: 44%) rather than interpretations of specific student ideas and their difficulties with the topic (R-a: 33%) (See the Figure 11 and 12).

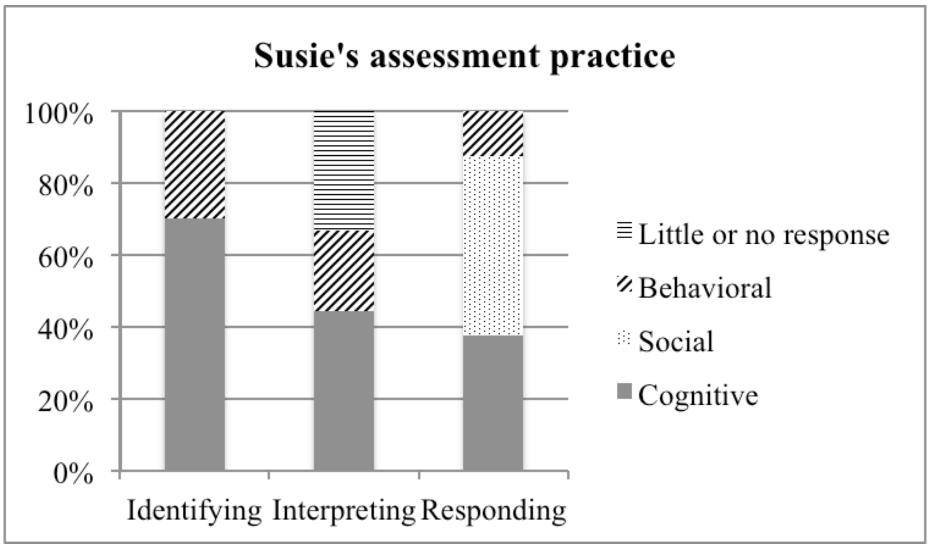

Figure 11. Susie's practice pattern

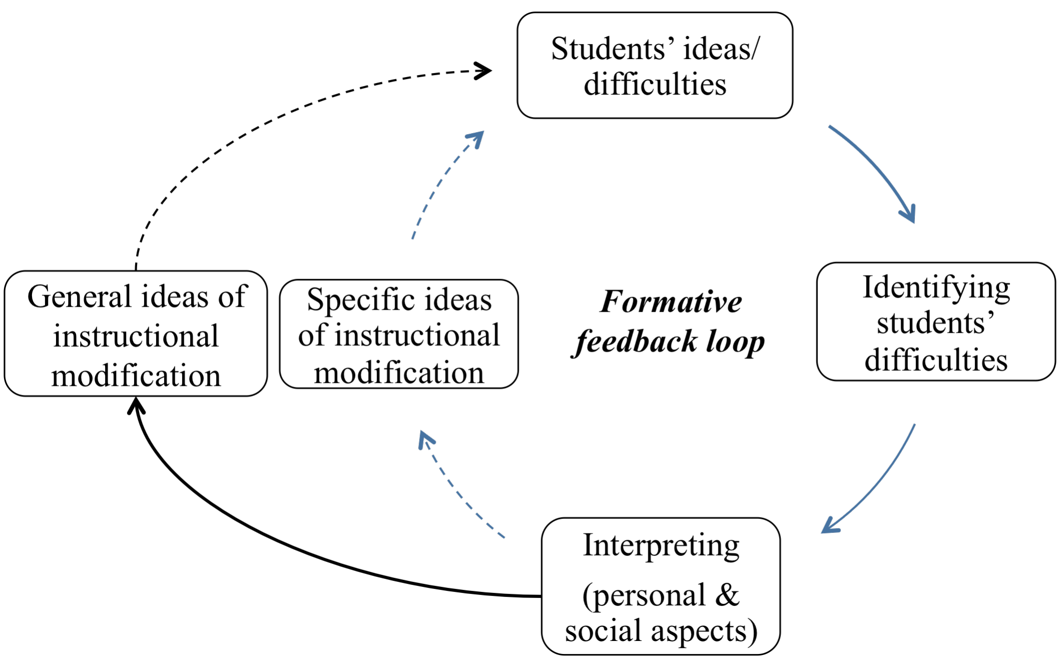

Figure 12. Susie's approach of assessing and responding to students

The Case of Teresa

Stories about Teresa

Teresa was a petite Asian female intern who majored in biology and minored in chemistry. She came from California, and had teaching experiences in an outdoor setting in the redwood forest in California, with students who mostly came from under-resourced families. Teresa had a strong desire to be an urban science teacher to begin with, and applied to be placed at an urban high school in her internship year.

Teresa thought that science should be fun and interesting to students as well as applicable to their lives. She liked using hands-on activities, doing activities with objects as opposed to with papers or worksheets, and "taking students off site and outside to do a cool activity" to get students excited about learning science. Her experiences at the redwood forest in California strongly resonated with her stories of teaching along with her challenges and frustration about managing a classroom at the Central high school. She said, "My teaching style evolved from being outside. So I think that being inside, it's a totally, I have to learn a new teaching style because the resources are different and how you teach is different."

A critical part of Teresa's ideas on science teaching involved getting students to have embodied or first-hand experiences, such as being a part of the story of science (e.g., DNA replication), seeing, touching, or feeling, just like she had done in California. However, to Teresa, large class sizes and limited resources and a small space inside an urban science classroom were big obstacles to teaching science in the way that she would like to teach. Teresa said, "I would like to do more hands on things. But it's really hard to do when you have so many kids and the classroom management just gets really crazy", "This year I think it's been the biggest thing that I've struggled with is classroom management…I feel like I have less resources, you're inside a classroom with twice as many students." Throughout her internship year, Teresa worked hard to find and try hands-on activities, including activities she brought from California. To Teresa, motivation was the biggest problem because there were many students who did not seem to care about learning science at this urban high school. Teresa simply thought that "once [students] start trying it, they will find it interesting," and then they would learn. Accordingly, she devoted herself to working with students one-on-one after school to get them to try it and motivate them. Teresa's mentor said that Teresa spent much of her time working with students individually. However, Teresa's classroom was not controlled, and there were, in her words, "Usually like multiple crazy things going on." During her instruction, most students did not pay attention to Teresa. They just kept talking, moving around, and texting. Teresa talked over students with a high pitch to make her soft voice audible because the class was so noisy and she did not project her presence as a teacher. The course instructor, Dr. R, expressed her concern about Teresa during the interview. Dr. R said, "I feel like [Teresa] had no control in the classroom. Until the spring, she was really struggling…she let the kids walk all over her. They did not respect her." Dr. R also pointed out that Teresa "blamed students a lot" in her journals while giving her "lip service" to the fact that the urban students needed to have more support, to be guided, and to develop these skills.

Despite the obvious challenges of managing classroom and frustrations, Teresa did not seek out any help or advice from either the course instructor or her mentor teacher. Teresa's mentor, Mrs. R. said, "I don't feel like Teresa ever really actively sought out anything [from me]", " I don't ever remember Teresa saying, "can you help me with this?" or, "Do you have anything for this?" She did a lot of work on her own." Mrs. R expressed her concern about Teresa with respect to the lack of communication. She said, "Honestly, my only concern with

Teresa was that I didn't know what she was thinking, as far as her emotions…just not knowing if she was happy or wanted more from me. I felt like I would offer, but she just always said, "No, I'm okay.""

It was obvious that Teresa did not want to be a teacher like her mentor and did not think of her mentor's instructional approaches as effective. In particular, Teresa highlighted Mrs. R's uses of worksheets or papers, saying Mrs. R "does a lot of worksheets." Teresa said, "[In California] we didn't have a whole lot of like paper things…my mentor does a lot of worksheets, and I don't think [students] were seeing it and visualizing it." It seemed to me that Teresa's strong vision of 'embodied instruction' made her strongly object to "paper/worksheet oriented instruction." The resources and ideas from Mrs. R clearly did not match with Teresa's designated identities.

It was also the case with Dr. R that Teresa was not "taking steps to seek out help." Dr. R said, "I did feel most uncomfortable because the reports [Teresa] was turning in were not very insightful. Her journals were really not very reflective. I worried about that because that kind of environment can eat you alive."

Throughout her internship, Teresa worked hard to enact her vision of science teaching that originated from her experiences at the outside setting in California, but despite the offered resources from both professional communities, she continuously came back to her previous experiences and looked for hands-on activities on the Internet instead of making use of resources and ideas from her mentor or the program.

The Nature of Occasions for Learning

Teresa's mentor, Mrs. R, had eight years of teaching experience at the Central high school ever since she graduated from the same teacher preparation program. She had been collaborating with the program as a mentor teacher for six years, and Teresa was her third full-time intern. Mrs. R had worked with several senior candidates as well and was therefore familiar with the structure and expectations of the program.

Mrs. R's classroom is usually packed with students. Her lesson always begins with journal questions to check students' prior knowledge. The questions vary from simple-recall type questions to thinking question. Mrs. R had a strong teaching voice and skillfully interacted with students both individually and as a whole class. During the students' work, Mrs. R walks around the classroom to check out their progress and understanding. Mrs. R's approaches to teaching science were focused on illustrating the science content in the textbook with activities. She used worksheets frequently, but she selected activities that allowed her to accomplish her lesson objectives whenever she could.

As a mentor teacher and graduate of the same program, Mrs. R understood the design of the program and its expectations of candidates. Mrs. R was very supportive and open to her interns' ideas. Mrs. R stated, "As with all of my interns, I always tell them that this is the time for them to try an activity, because there's always a fallback." Throughout the year, Mrs. R encouraged Teresa to try any lesson or activity while providing critical support, such as making sure to prepare the second activity or a back up plan. Mrs. R said, "[Teresa] did a lot of planning by herself." However, Teresa did not seem to take full advantage of being in Mrs. R's classroom despite "the free reign" given to her and Mrs. R's attempts to reach out to Teresa. Dr. R said, "[Mrs. R] was trying to be her mentor. I didn't know this until late fall, but her mentor said that Teresa never shared her concerns with her even when she asked. So [Teresa] wasn't communicating with her mentor in ways that might have been helpful to her because she might have gotten some helpful feedback and support from [Mrs. R]."

In summary, Teresa was provided opportunities for learning from students through assessment practices while working with diverse students at this urban high school with the support of both her mentor and the program. However, she did not interact with the two communities of practice as much as she actually could do even when she had difficulties and needed help.

Teresa's Responses to Occasions for Learning

Teresa's assessment practices in her inquiry teaching episode are described in detail. Then follows the patterns of Teresa's assessment practice.

Teresa's inquiry activity and assessment tasks/questions. Teresa's inquiry sequence was enacted as the start of the unit on bacteria. Teresa identified four state objectives before she stated her own objectives indicating that she formulated her objectives based on the following four state objectives:

> **B1.1C** Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).
>
> **B1.1D** Identify patterns in data and relate them to theoretical models.
>
> **B1.1E** Describe a reason for a given conclusion using evidence from an investigation.
>
> **B1.1h** Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.

Teresa's objectives were: "Students will learn about bacteria, and viral disease mechanisms and treatments, and use their knowledge to conduct a scientific investigation of antibacterial agents (disinfectants and antibiotics) using appropriate tools. They will then use their data to make a table and draw conclusions about the effectiveness of the disinfectants vs. the antibiotics."

Teresa opened her inquiry sequence showing an episode of a popular TV show, 'House.' This episode sparked students' interest. It also illustrated the difference between virus and bacteria with diagnostic medicine. After watching this episode, Teresa asked students when they have used antibiotics and disinfectants in their lives. Teresa went over the pre-lab, and began her inquiry lab. The lab was to compare the effectiveness between antibiotics and disinfectants using two types of bacteria. Students were asked to *develop a hypothesis as to what would happen if they placed six different antibiotic discs and six disinfectant discs onto agar plates inoculated with two different bacteria (i.e., E. Coli and B. Subtilis)*. Students performed the lab (i.e., plating disinfectants and antibiotics discs on two agar plates inoculated with two different bacteria). The following day, students measured the zones of inhibition, recorded the data in their own tables, and analyzed individual and class data. Students *wrote a lab report* responding to the questions: "*Why the antibiotic plates were affective in inhibiting specific types of bacterial growth only, and why almost all the disinfectants inhibited both types of bacteria pretty significantly*." *Students read the textbook, and found the answers of the questions of "how antibiotics inhibit growth and how disinfectants inhibit growth or kill bacteria*." Teresa went over the lab report with students, and had them turn in their worksheet.

A. Assessment tasks/questions. Teresa used several assessment questions in this teaching episode, but similar to Leslie and Susie, her key assessment questions appeared at the end of the episode, in her lab report. Teresa asked quite different questions from both Leslie and Susie. Whereas both Leslie and Susie asked students to explain the mechanism of certain phenomena using scientific theories or models with their 'how' questions, Teresa asked, "Why" questions, to see if students could explain the reason why it happens. Specifically, she asked*, "Why the antibiotic plates were affective in inhibiting specific types of bacterial growth only, and why* *almost all the disinfectants inhibited both types of bacteria pretty significantly."* She also asked 'how' questions, *"how antibiotics inhibit growth and how disinfectants inhibit growth or kill bacteria*," but she did not expect students to answer this question by themselves. She had students find the answers from the reading with her hope that her students "make connections from their reading." Whereas Leslie and Susie expected their students to come up with their own explanation using the scientific models and theories, Teresa had 'the answer' to the questions to begin with. In the report, Teresa clearly stated the right answer that she wanted to see from her students in the end:

> In the end, I [Teresa] wanted [students] to answer the questions the following way, but not until the end of the lab and the analysis:
>
> Antibiotics inhibit the cell wall to prevent reproduction. They are usually specific to one type of bacteria. *That is why they are used as medication*. They are specific, so they don't kill the other good bacteria that lives in our bodies…Disinfectants are chemical agents that either kill or inhibit the growth of a wide variety of bacteria. They interfere with cell processes like enzyme activities…Disinfectants use a combination of mechanisms to kill a wide variety of bacteria, so they are used as surface cleaners and for external use. They would harm the good bacteria inside of us and our cells if we ingested it. *That's why we don't drink cleaners*. (Teresa, Intern, Inquiry activity report)

This account suggested that Teresa held a two dimensional, narrative way of understanding science that conceived of science as stories or the 'why' part. She worked hard to help students make the connection between a phenomenon and the reason why it happens. Thus, she asked whether students knew the stories (i.e., What it is), or whether students could see the connections (i.e., why it happens). In both cases, it was less likely for Teresa to get rich information from students because for the most part students did not remember the facts or did not know 'the right answer' unless they had access to some authoritative sources, such as 'reading' in her inquiry activity.

B. Identifying & Interpreting (i.e., highlighting & coding). As expected, students struggled to respond to Teresa's questions in this inquiry episode. Furthermore, Teresa reported that students had trouble measuring the zone of inhibition accurately, and produced "fairly inconsistent data," which would make it much more difficult for students to respond to Teresa's questions. Teresa identified that students had trouble in making connections and answering her 'why' questions even though they know what an antibiotic is and what a disinfectant is. It was just puzzling to Teresa:

> I really wanted them to be able to make the connections themselves at this point, but it seemed to be really hard for them to do. They understood what an antibiotic was and what a disinfectant was, and saw the patterns in their data, but then couldn't put it all together. (Teresa, Intern, Inquiry activity report)

Teresa interpreted students' difficulties in "making connections" as the lack of critical thinking skills or "training." She stated, "I don't know how I really could have. I think that I need to just continue to try to push them to learn to think critically about things because they aren't trained to do that yet." It seemed to me that Teresa conceived of it as a separate skill that students need to develop to learn the content.

In addition, Teresa's highlighting was focused on seeing if students gave her the right answer or not. She positively interpreted the fact that students arrived at the "correct" and "same" conclusions in the end:

> Overall, students did well on this [assessment question]. They seemed to have many of the correct responses in the end. They struggled through the analysis of the experiment, but were able to arrive at the same end conclusions, and see the connection between the scientific models of antibiotics and disinfectants on bacteria. (Teresa, Intern, Inquiry activity report)

With respect to her mechanism questions (i.e., how antibiotics inhibit growth and how disinfectants inhibit growth or kill bacteria), Teresa noticed that most of students just copied the mechanism from the reading, so "It didn't really take a whole lot of thought." But she interpreted it as one success because students "learn the skill":

> The more important thing was that *they learned the skill of looking up answers in reading.* This is a skill that we have been working on all year. They used to freak out about having a page of reading in front of them and having to find the answers. They wanted to just be able to look it up in a glossary and be done with it. We read it out loud together though, and then they were supposed to find it on their own. Overall, they did pretty well. (Teresa, Intern, Inquiry activity report)

To Teresa, finding answers in reading was an important skill for students to develop in order to learn the content of science in readings such as textbooks.

C. Responding & learning from students. In contrast to Leslie or Susie, Teresa did not make any specific suggestions to address students' difficulties. The only response that Teresa came up with was "just continue to try to push them to learn to think critically about things" because she interpreted the problem as the matter of lack of 'skills' that students must have developed separately. After the analysis of student work, she stated:

> Students will get frustrated. It's really hard for ninth graders to try to critically analyze things, and I am kind of convinced that Central middle schools don't facilitate critical thinking, because my students hate it. They get frustrated so easily and just want a straightforward, "right" answer. It's really difficult to find that line between giving students too much information so they don't think for themselves, and not enough so they give up and start screwing around. [Teresa, Intern, Inquiry activity report]

The analysis suggested that Teresa was less successful in drawing out productive feedback on her own instructional practices as well through her assessment.

Patterns of Teresa's assessment practices. Other teaching episodes from the internship year were analyzed to find patterns of assessment practice. The interview with a clinical interview video was also analyzed to triangulate the patterns of assessment practice that emerged from her own teaching episodes.

The results of data analyses suggest that overall Teresa was less successful in learning from her students by engaging in the assessment practices. For instance, in her other teaching episode about cell structure and function, Teresa asked only simple recall type questions (i.e., 12 multiple-choice questions about factual information on cells), which generated very limited information about students and their ideas. In her report on her one student, Kathy, Teresa mainly highlighted the student's grades and her behavior issues, and concluded that Kathy "didn't learn anything."

> Kathy did awful on the test. She got the highest E in the class, but she told me she "threw out" her study guide. I think that she had given up by the time test came… She is one that I learned CAN NOT handle group work. She literally does not do anything academic during that time. Her and Jeny's grades just fell like crazy this unit because they were

> messing around with Jack and Tim the entire time they had to work on their projects, the labs and anything else. I was calling them back from their social worlds about 4-5 times a day and separating them and trying to get them to go back and work with their groups, but they were pretty defiant or just refused to work, so she didn't learn anything. (codes: ID-d, IN-g)

As shown in the example above, Teresa *identified* little information about students' ideas or nature of difficulties in learning the topic, and *interpreted* the result in relation to motivation or behavior issues. Teresa's *responses* to her students were straightforward, such as "not having them do group work", "go over everything with students" until students learn to complete assignments without teachers telling them the correct answer (R-e). Teresa's approach of assessing and responding to students showed a similar pattern in her inquiry lesson as described above. The opportunities she provided with her assessment items were mostly reproducing factual information or reproducing canonical knowledge in the textbook (O-b). There was little to be identified or interpreted from students' responses. When there was, it was mostly associated with students' behavior issues (IN-g), and her responses were either too general or not directly related to students' difficulties (R-d & R-e). Across two teaching episodes, Teresa mostly provided *opportunities* for students to explain the facts, laws, and theories that students know or remember (O-b & O-c: 75%). She *identified* student answers focusing on right vs. wrong or complete vs. incomplete (ID-c & ID-d: 33%), or in many cases identified little or no information about students (ID-f: 50%). She *interpreted* students' wrong responses mostly in relation to student attitudes, behaviors, and motivational issues (IN-g: 50%) or did not make any interpretation (IN-l: 33%). Teresa's responses were general and often not directly related to students' difficulties (R-d & R-e: 50%) (see Figure 13).

During the interview with Jeremiah's video, Teresa did not identify Jeremiah's ideas or difficulties in understanding photosynthesis, although she appreciated a little bit Jeremiah's knowledge about plants. Teresa highlighted 'what Jeremiah did not know' more than 'what he did know,' which was opposite to both Leslie and Susie's cases. In addition, Teresa did not notice Jeremiah's confusion about the soil as the source of food (ID-b). To Teresa, photosynthesis was school knowledge, and Jeremiah failed to understand it because "he didn't pay attention during photosynthesis [lesson]." (IN-g) Teresa suggested getting him interested using his garden as a hook, and using hands-on activities (R-e). She stated, "The fact that he has a garden is like super key. You can definitely use that as a means to like, well, first of all, interest him, and secondly, build on those experiences that he's had with the garden as far as like teaching him functions of the plant. You know?" (R-e)

In short, the data suggests that Teresa was less successful in learning from her students by engaging in the assessment practice that was deliberately structured by the program. Teresa mostly asked recall-type questions that generated kinds of student responses that had limited information about them. The other elements of assessment practices from identifying to responding were necessarily constrained by the types of student responses generated with the initial assessment questions. Teresa's patterns of assessment practices were consistent across her own teaching episodes as well as her interview with a clinical video. Despite the deliberately designed occasions for learning from students, Teresa was less successful in learning from her students (see Figure 13 and 14).

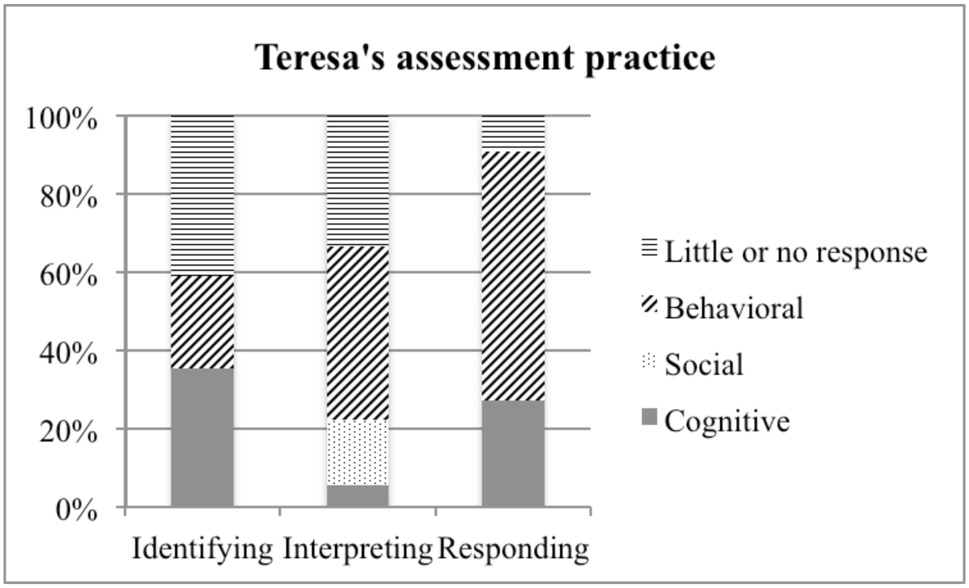

Figure 13. Teresa's assessment practice pattern

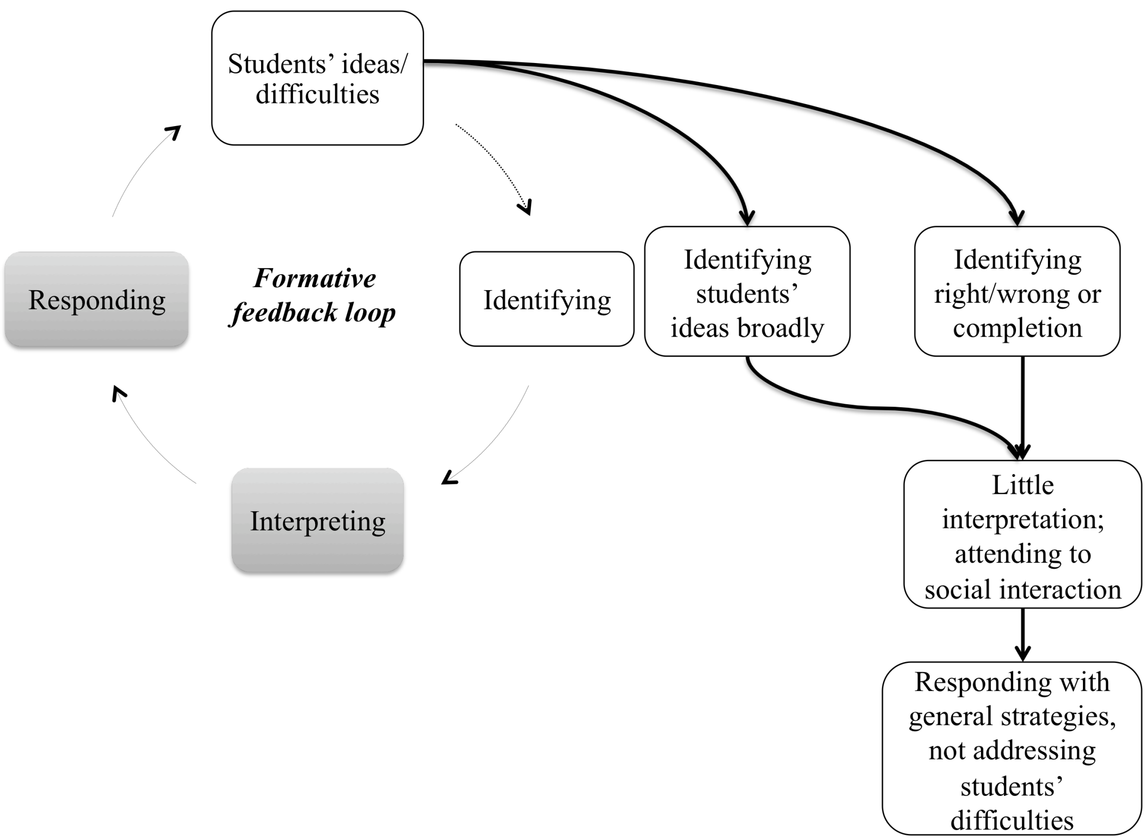

Figure 14. Teresa's approach of assessing and responding to students

Assessment Practices and Candidates' Understanding of Science for Teaching

The analyses of both classroom activities and assessment practices indicated that Teresa had a different way of understanding science for teaching from Leslie and Susie (see Table 23). Similar to David, Teresa thought that science consisted of content and process, and the content part of science was conceived as a story, the reason why, or the right answer produced by the scientific community. Leslie and Susie's understanding of science were similar to Monica's in that they saw science as the integrated set of knowledge and practices that enables students to make sense of the world. I found that their ways of understanding of science were deeply connected with candidates' assessment practices, which made a significant difference in their process of learning from students.

Table 23. Candidates' understanding of science for teaching

Narrative Ways of Understanding Science for Teaching (Two-dimensional Model): **Teresa**	In-depth Understanding of Science for Teaching (Three-dimensional Model): **Leslie and Susie**
• Considering science as stories of/about phenomena or scientific models; the answer, 'why' part, explanation • Achieving scientific understanding by making connections between or among stories ("seeing the connection") • Scientific community as authoritative source of scientific knowledge • Content vs. process (e.g., scientific method, problem solving skills) • Making connections among topics considering causal (logical) relationship	• Appreciating the relationship between observation and scientific models/theories • Achieving scientific understanding by making connections between observation and theory • Scientific community as a model for students' classroom community • Integrated understanding of scientific knowledge and practices • Situating a topic in a unit with the consideration of big ideas, key phenomena or patterns of a unit

Whereas Leslie and Susie, who understood science as an integrated body of knowledge and practice, tended to ask the kinds of questions that produced rich information about students, Teresa, who understood science as a story or the 'why' part about the phenomena, tended to ask questions that students were not able to answer. The differing nature of student responses generated from their assessment tasks/questions made a big difference in the following assessment practice, from identifying to responding, as well as their learning from students. Candidates' identifying and interpreting were also affected by their understanding of science for teaching. Whereas Leslie and Susie identified students' difficulties in both (a) making connections between observations and scientific theories or models, and (b) understanding the integrated nature of scientific knowledge and practice, Teresa tended to focus on correctness of the answer. Teresa was puzzled about students' difficulties in 'making connections' between phenomena and the reason why they happened, and interpreted that it was because students' lack of thinking skills. To Teresa, scientific content and skills were separated from one another though students should learn both of them. As the results, Leslie and Susie's narratives demonstrated that they were successful in making productive formative feedback work for both students and themselves, but Teresa was less successful in generating productive formative feedback loop for both.

Learning from Students and Candidates' Designated Identities

Leslie, Susie, and Teresa's designated identities were examined from their stories about future self(s) in/and practices. Their vision statements collected at the three time points for two years—(a) at the very beginning of senior year, (b) at the beginning of the internship year, and (c) at the end of the internship year—were used as the major source of data. The interview with their teaching video conducted at the end of their internship was also used as supplementary source of data. Their stories of future self and practices were coded with respect to (a) goals of teaching science, (b) roles of activity, and (c) roles of students[29]. Similarly to the three cases of classroom activities, the coding results of Leslie, Susie, and Teresa indicated that each candidate

[29] See the results of coding in Appendix12

held relatively consistent aspirations across two years, that was aligned with their ways of highlighting and coding practices and resources provided by professional communities (see Table 24). In the following, Leslie, Susie, and Teresa's designated identities are described with respect to the three aspects.

Leslie: Making connections between science and students' everyday experiences by engaging students in scientific practices

Goals. Leslie's vision statements collected from her senior year to internship year demonstrated that Leslie continuously looked for ways of helping students to make connection between science and student themselves. For example, in her senior year vision statement, Leslie stated, "I want my students to see how science affect their everyday life. I want to help them take what they are learning and use it to understand their own bodies, interests, and hobbies." At the end of her internship year, Leslie stated, "By teaching science, I am helping students to better understand themselves and the world around them." At the beginning of senior year, Leslie's goals were coded as both delivering content and skills (e.g., "remember some of the information") and engaging in scientific practice (e.g., "use it to make good choices as they grow into adults"). Leslie was not clear how she would help her students to make that connection through classroom activities besides bringing many real world examples, but in her last vision statement that she wrote at the end of internship year, she described her ideas in detail with specific examples. Leslie stated,

> One of the most basic techniques that I use to help students make connections is to start by drawing on my students' own interests and giving them a chance to experience science. For example, I discovered that many of my Biology students were interested in medicine so I built my diffusion and osmosis unit, a typically dry and confusing unit, on

discovering a treatment for patients with cholera. We modeled the intestine of a normal person and the intestine of a cholera patient using dialysis tubing, salt and water, and then recorded our results and made predictions about how to treat the patient. (Leslie at the end of internship year, teaching philosophy statement)

Roles of activities. Leslie consistently pointed out the role of activities in relation to content understanding in her three vision statements throughout two years. For example, Leslie stated that students would "take what they are learning and use it to understand their own bodies, interests and hobbies" (senior year), "connect big ideas to many examples" (at the beginning of internship year), and be assessed through activities (at the end of internship year).

Roles of students. Leslie emphasized students' group work and their active roles in developing their own knowledge as a key aspect of her instruction in all the three vision statements. It appeared that her ideas became specific as she got more experiences. She thought that students could learn better by interacting each other, they could develop their own understanding, and reveal their ideas and misconceptions. For example, at the beginning of her senior year, Leslie stated, "Group work helps students who are struggling to learn from their peers as well as allow students who are excelling to become even better by explaining what they know to others." In addition to students' social interaction, Leslie's vision statements in her internship year described students' development of their own knowledge through active engagement in scientific practices, such as "identify patterns, interpreting observations, discussing appropriate experimental methods, and evaluating the validity of conclusions."

> All students need multiple chances, and exposure to multiple learning styles, to use the scientific process and develop their own solutions to a common problem. This process includes learning to identify patterns, interpreting observations, discussing

appropriate experimental methods, and evaluating the validity of conclusions. All of these things allow students to take ownership of their learning as well as allow them to grow as a person.

The roles of students were consistently described in Leslie's vision statements focusing on both social aspect and content understanding throughout the two years.

Susie: Engaging students in problem solving just like what scientists do

Goals. One consistent theme of Susie's goals in her three vision statements was 'problem-solving' or 'inquiring the world.' Susie described her goals as helping students to understand various real world phenomena just like what scientists do in her three vision statements. At the beginning of senior year, Susie wrote a vignette of her high school physics class where the teacher presented various phenomena about sounds by having orchestra students demonstrate different pitches and engaged students in a problem. Students discussed what they observed, and "how the demonstration showed that the shorter the length of the vibrating string, the higher the pitch, thus the string vibrated faster than lower pitches." Similarly, her vision statement of the internship year described how she would teach 'gas laws' in a successful lesson. This lesson would start by a series of demo, including "egg demonstrations and balloon demonstrations." Students would discuss their observation and formulate a problem for them to solve. Students would come up with their own explanations about the patterns that they identified. The teacher assessed students' ideas before and after through various activities. And finally students solved another problems by applying their understanding to other examples. Susie wanted her students to see science as a 'process' or 'tool' for making sense of the world, rather than the information to remember.

In her last vision statement that she wrote at the end of internship year, Susie described her goals focusing on developing skills. It was not surprising given Susie's close relationship with her mentor, Mrs. B and her appropriation of Mrs. B's languages in her accounts.

Roles of activities. As described in the vignettes, Susie tried to incorporate many demonstrations, engage students in observation and pattern findings to help students to make connection between scientific concepts and real world examples. Susie highlighted the role of activities that support students' content understanding by engaging in scientific practices in her vision statements throughout two years.

Roles of students. Students' engagement in scientific practices (e.g., making observation, finding patterns, explaining other examples applying the concepts) was consistently highlighted in her three vision statements. In addition, students' social interaction by engaging in group work or whole class discussion was another key aspect emphasized by Susie in her vision statements at her internship year.

Teresa: Motivating students to learn science by engaging in firsthand, hands-on experiences

Goals. Teresa's goals were mostly focused on motivating students to learn science by engaging them in firsthand, hands-on experiences. While describing a vignette of good science teaching at the beginning of senior year, Teresa described how she was into the class because she "got to do a cool and practical experiments." She also liked that the lecturer was interesting, so the combination of lecture and lab could flow well. In addition, Teresa emphasized students' involvement in community, and development of "critical thinking in regards to scientific problems in the community" in her vision statement at the beginning of internship year. Teresa's goals were stated mostly focusing on motivational and social aspects in her three vision statements.

Roles of activities. Engaging students in firsthand, hands-on activities consistently appeared in the three vision statements throughout two years. Teresa highlighted the roles of those activities in two ways. One is motivating students to have them to "want to learn science," and the other is having students work together or work in group. In her last vision statement, Teresa stated that engaging, hands-on lessons would "make students think critically about the world around them" and make students do "scientific thought" without elaborating the meanings taken by her.

Roles of students. In the Teresa's three vision statements, students consistently described as someone who would be motivated to learn science and actively engaged in activities. For instance, in Teresa's vignette of good science teaching that she wrote at the beginning of senior year, students were described as the ones who led the experiments from design to data collection with teacher's help, and worked as a team to develop their own hypothesis. During the interview conducted at the end of her internship, Teresa expressed her aspiration of engaging students in various activities by taking them outside of the classroom, although that was not something that she could do due to the large class size and limited resources.

Table 24. Leslie, Susie, and Teresa's designated identity

	Leslie	Susie	Teresa
Goals	• Helping students to make connections between science and themselves (everyday experiences) • Engaging students in scientific practice	• Engaging students in problem solving just like what scientists do	• Motivating students to learn science by engaging them in firsthand, hands-on activities
Roles of activities	• Helping students to make connections between science and real world phenomena • Assessing student ideas	• Helping students to make connections between science and real world phenomena	• Motivating students • Providing opportunities of group work
Roles of students	• Actively interacting with both science and peers • Developing own knowledge, using knowledge to explain relevant experiences	• Actively participating in scientific practices • Engaging in group work; actively interacting with peers • Developing their own knowledge	• Actively engaging in hands-on activity • Working with peers

Discussion

Fourteen candidates in this study were commonly provided opportunities for learning from students while developing assessment practice with the support of the same reform-oriented teacher preparation program. The data showed that only six out of 14 candidates were successful in learning from their students by engaging in reform-oriented assessment practice. The other eight candidates were less successful in making use of information from their students to either improve their instruction or to provide productive responses to their students. I selected the cases of three candidates to further examine the mechanism of learning. These three candidates worked at similar urban high school contexts with fairly traditional mentor teachers with the support of the same program, but developed different types of assessment practices. Whereas Leslie and

Susie were successful in learning from their students to some degree, Teresa was less successful in using information about students productively.

One important difference in the three candidates' assessment practices was the nature of opportunities that candidates created with their assessment questions. Whereas Leslie consistently provided quality opportunities that generated interesting and long student responses that showed students' ideas and thinking, Teresa mostly asked factual, recall type questions that asked to reproduce canonical scientific knowledge. Susie's questions were distinctively different in two teaching episodes. In one teaching episode, she only asked skills and practice type questions, but in her inquiry teaching episode, she asked thought-provoking questions in the context of investigating certain phenomena. Not surprisingly, candidates' process of learning from students was constrained by the nature and quality of student responses produced from the assessment tasks or questions in the first place. The case of Susie was a good example that showed how the differing nature of student responses affected candidates' learning from students. In her general teaching episode where she only asked skills and practicing type questions, Susie mostly identified whether students got right or wrong answer, and interpreted it in relation to their motivation or attentiveness. Therefore, her responses were also mostly focused on addressing those motivational issues. On the contrary, in her inquiry teaching episode where she got students to design a lab about the influence of certain factor on rate of solution or solubility and to explain the results based on the data, she insightfully identified students' ideas and difficulties in detail, interpreted them in relation to the experiences and scaffolding provided through her instruction, and then suggested very specific ideas to address students' difficulties.

Given that the process of learning from students was greatly affected by assessment tasks/questions, it becomes critically important to understand what made candidates design or select certain assessment tasks/questions among available resources provided by professional communities. The close examination of the three cases suggests that candidates' designated identities and their understanding of science for teaching play important roles in their process of learning by having candidates select different kinds of resources through their highlighting and coding (i.e., interpretation). Similar to the cases for classroom activities, all three candidates brought some strong momentum toward their designated identities—the kind of teacher they wanted to be and the kind of practice they wanted to master. Leslie wanted to teach science meaningfully by engaging students in scientific practices. Susie wanted her students to experience science just like how scientists do in the scientific community through group work, social interaction, and open-investigation. Teresa wanted to give students first-hand, embodied experiences just like the ways that she did at the outside setting in California. Leslie and Susie's designated identities were well aligned with program's vision of reform-oriented practices, but Teresa's did not match with the program's vision. All three candidates' designated identities did not exactly match the models provided by their mentors on a daily basis whose instructional approaches were fairly traditional. Interestingly, however, the three candidates highlighted different aspects of their mentor's practice of science teaching using their designated identities as the reference, and interpreted what they highlighted in a different way while taking their position. They made different choices in designing or selecting assessment tasks or questions among available resources and advice provided by their mentor teacher and the program.

In Leslie's case, her designated identities matched well with the program's vision of reform-oriented teaching. She aligned herself closely with the program, and consistently selected resources and ideas from the program to design her classroom activities as well as assessment questions. These resources that were not normally available to Leslie herself, enabled her to learn from her students effectively by designing quality assessment tasks. For instance, Leslie selected an assessment activity from the program despite her mentor teacher's initial reservations about it during her senior year. Her inquiry activity during her internship year was one that she got from the program as well. Even though Leslie said, "I don't see myself as being [Mrs. F] ten years from now," she highlighted Mrs. F's relationship with students and her knowledge on students in her stories, and interpreted it as a useful resource for her to plan her lessons. Leslie said, "[Mrs. F] has a relationship with these students already and so, she kind of knows how the classroom works…so, it's nice to know what your mentor teacher does to work with this particular group of students." The data showed that Leslie took advantage of being with Mrs. F by asking many questions about students and their possible responses, and by picking up some practices that allowed her to enact the kinds of practices that she wanted to do. Leslie's assessment practices, especially the opportunities that she provided for her students through application type activities, was the outcome of her selection of resources. Leslie selected resources aligned with both her designated identity and the program's vision of good science teaching.

Similar to Leslie, Susie's designated identities did not exactly matched with the models provided by Mrs. B. But the nature of occasions for learning that Susie to which had to respond was quite different from Leslie. Whereas Leslie was a senior who visited Mrs. F's classroom twice a week, Susie was an intern who spent all day with Mrs. B. It was her second year of being in Mrs. B's classroom at that time. Furthermore, whereas Leslie's mentor was open to candidates' any attempt in her classroom, Susie's mentor, Mrs. B had very clear expectations for her intern and tried to provide structured experiences to develop her teaching 'skills.' While comparing her teaching with her mentor's, Susie said, "I think at the beginning of the year I was pretty close to eight [out of 10 in terms of similarity with the mentor]. I was like pretty similar to my mentor teacher." However, she was also aware of the difference between her designated identities and Mrs. B's practices. In particular, Susie highlighted the following aspects of practices as key differences: having students work in group vs. everyone should be on task, open-ended activities (e.g., think-tank, sharing answers) vs. structured and concrete. Susie interpreted her mentor's "management focused" practices as a reasonable choice given the characteristics of students in her classroom.

> I think for my mentor teacher, it's as long as things are very structured it's okay. I think it's very hard for her to watch me teach a class when everything is very chaotic and people are talking and then not everyone is on task. And so in terms of designing a lesson, I think she's very much focused on the management aspect, which I completely understand because for this particular group of kids that's something that you do need to focus on or the lesson kind of breaks apart. (Susie in the internship year, teaching video interview)

As the responses to her occasions for learning, Susie primarily selected resources and ideas provided by her mentor in her daily practice, which became the basis of Susie's actual identities—stories about current self(s) in/and practices. It allowed her to be successful in working with challenging students in the urban high school with her mentor's support. But Susie slowly found the space where she could try the kinds of practices as time went by where she "felt more comfortable putting in my own spin on things." It seemed to me Susie's two very different patterns of practices between two teaching episodes captured well how she responded to the different nature of occasions for learning while trying to close her perceived gap between actual and designated identities. When she had opportunities of doing the kinds of practice that she wanted to do, such as the inquiry teaching episode required by the program, she took advantage of it. It was a good opportunity for her to "put her own spin on it." Susie asked different types of questions during inquiry teaching episodes and successfully learned from her students.

In the case of Teresa, she had very strong momentum toward her designated identities originating from her experiences in California. She repeatedly talked about first-hand, embodied instruction in an outside setting, such as having students touch, feel, and being a part of it. Teresa also noticed that the instructional models and resources provided by both her mentor and the program did not match with her designated identities, but the ways that she highlighted and coded the differences from her mentor teachers were different from both Leslie's and Susie's. Teresa highlighted her mentor's paper/worksheet driven instruction, and interpreted it negatively because students could not see and visualize the content.

> [In California] We didn't have a whole lot of like paper things, we used cans to represent everything. You know, like they were the different parts. So when I'm teaching, a lot of things I'll set up kids like, they're the membrane or something they transport across the membrane to give the visual for them. So this way is*, my mentor does a lot of worksheets, and I don't think they were seeing it and visualizing it*. So I was like, you know I really want to do something that has the kids like put themselves into the idea of being part of the pedigree, so that they can think of themselves as like, I'm this part of the pedigree and this is how I would organize it. (Teresa, intern, teaching video interview)

Teresa highlighted her mentor's paper or worksheet approach that was contradictory to her aspiration of hands-on, embodied instruction (i.e., designated identities), and interpreted it negatively because she did not think students can "see it and visualize it." What Teresa highlighted was clearly affected by her designated identities that were grounded in her previous experiences, but the ways that she interpreted what she highlighted was connected to her understanding of science for teaching. From Teresa's point of view, her mentor's 'paper driven instruction' was problematic because it failed to visualize 'the content' of science to students. The content was the stories (i.e., stories about cell) that consisted of many pieces of information. The content of science was something out there that students should remember and visualize. Developing a new story was not a part of her 'content' of science. Teresa's understanding of 'the content' of science also accounted for the reason that she asked mostly recall-type questions in her assessment practices. Given her understanding of science, the recall type questions were the right questions to ask in order to see if students remembered the content through her assessment items. The process of learning from students was constrained by the types of student responses generated from assessment tasks or questions. Given Teresa's understanding of science for teaching, Teresa was not capable of asking quality questions that generated interesting responses from students without reaching out to extra resources. Despite the fact that both her mentor and the program made resources and ideas available, those resources were not selected by Teresa through her highlighting and interpretation on the resources and practices provided by both her mentor teacher and the program. She continuously went back to her limited personal resources from California aligning herself closely to them, or looked up new resources on the Internet that allowed her to enact her embodied instruction.

In short, the three candidates' cases demonstrated that candidates' designated identities affected the process of learning from students by: (a) having candidates highlight certain aspects of practices and resources provided by their mentors and the program, and (b) having them interpret what they highlighted in certain way. The candidates positioned themselves with respect to the professional communities based on their highlighting and coding, and selected certain resources and advice to develop assessment questions or tasks. Accordingly, their designated identities led the candidates to start the process of learning from students at the different places to begin with. Candidates' understanding of science also played important roles in the process of (a) designing or selecting assessment tasks and (b) interpreting student responses and responding to them. Candidates asked students about the important 'content' of science from their point of view. Thus the types of questions that candidates asked reflected how they understand the 'content' of science.

Chapter 6.

Discussion

The previous two chapters illustrate in detail the six candidates' responses to the occasions for learning along with the 14 teacher candidates' patterns with the two focus practices. The overall examination of the findings suggests that the two sub-groups of candidates were either successful or less successful in making use of resources and ideas from the program to develop both focus practices (see Table 25). Whereas Monica, Leslie, and Susie were successful in learning from both professional communities and students in their development of reform-oriented practices, both David and Teresa were less successful in learning from their professional communities and students. The case of Adam was interesting because he showed difficulties in learning from his students despite his enactment and interpretation of reform-oriented classroom activities. This chapter discusses *how* and *why* teacher candidates develop certain kinds of science teaching practices, based on my examination of the six focus candidates' responses to occasions for learning. I argue that candidates' learning of reform-oriented practices is profoundly affected by their ways of understanding science for teaching and their designated identities through their highlighting and coding (i.e., interpretation) of their experiences and resources. In the following, I first discuss candidates' understanding of science for teaching as reflected in their practices and interpretation. Then I describe how candidates' learning to teach was connected to the process of authoring identities. Finally, I discuss how local contexts created the different nature of occasions for learning for each candidate.

Table 25. Fourteen candidates' patterns of the two focus practices

	Reform-oriented practices	Traditional practices
Classroom activities (Learning from participation in communities of practice)	**Monica**, **Susie**, **Leslie**, ***Adam*** Scott	**David**, **Teresa**, Shannon, Alisa, Lori, Mary, Kevin, Stella, and Lynn
Assessing and responding to students (Learning from students)	**Monica**, **Susie**, **Leslie**, Alisa, Scott, Lori	**David**, **Teresa**, Shannon, ***Adam***, Mary, Kevin, Stella, Lynn

Candidates' Understanding of Science for Teaching Reflected in Their Practices and Interpretation of Practices

The findings demonstrate that candidates' ways of understanding science for teaching play a significant role in their ways of responding to the occasions for learning deliberately designed by the teacher preparation program. Two groups of candidates produced different kinds of practices by selecting different resources, ideas, and advice from professional communities based on their interpretation, which was profoundly constrained by their understanding of science for teaching (see Figure 15).

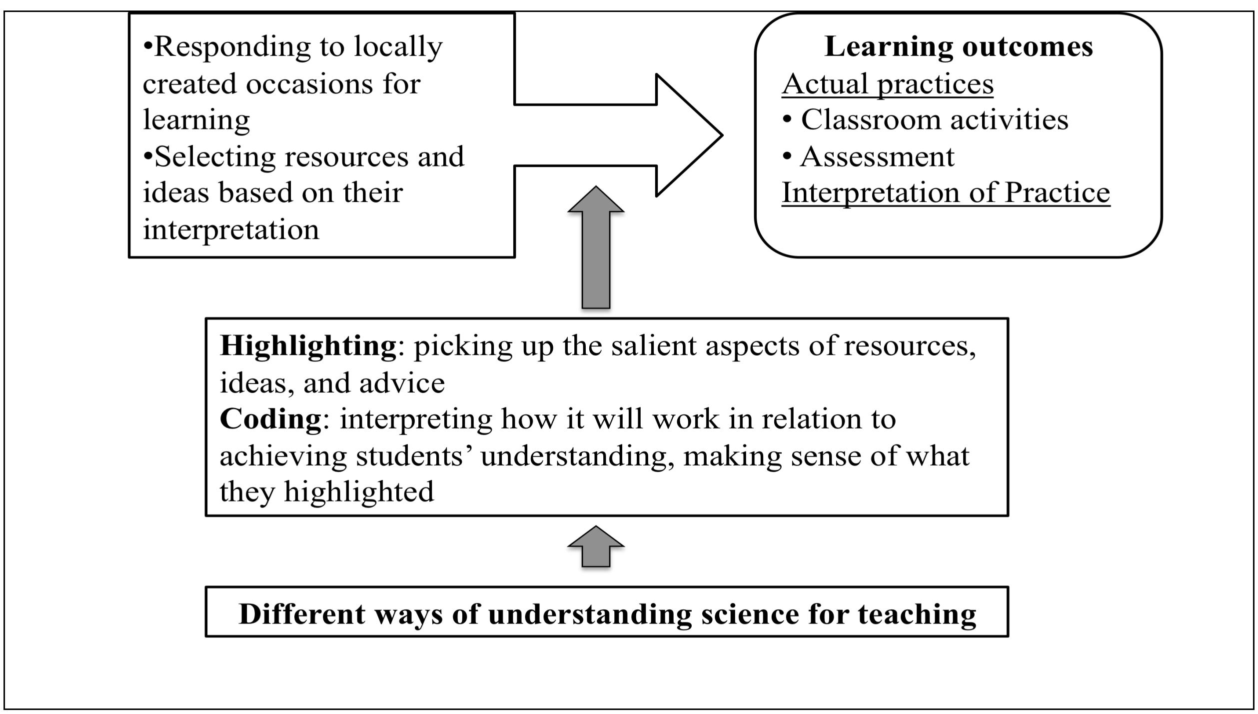

Figure 15. The role of knowledge in the process of learning to teach

Candidates' understanding of science for teaching reflected in classroom activities. The candidates who were successful in learning reform-oriented classroom activity practices, such as Monica or Leslie, shared the program's understanding of the nature of scientific knowledge and practice. They thought that scientific understanding is achieved by making connections between observations or experiences and scientific models or theories. They tried to develop classroom communities where students actively interact with one another as well as with the teacher in order to develop their knowledge in a social environment. While telling stories about practices of teaching through their written reports, vision statements, and during the interview, they highlighted the roles of students who "work together" and engaged in scientific practices, such as "making observations", "formulating questions", "finding patterns" from different examples, and "applying the knowledge" to real world examples. Their interpretation of the roles of both students and activities was associated with their sense about success or failure in engaging students in those practices to help students make connections between observation and scientific theory.

The other group of candidates who were less successful in making use of resources and ideas for reform-oriented practices, including David and Teresa, thought of science as authoritative knowledge that consists of stories, the answer, the 'why' part or explanation. Therefore, they conceived that scientific understanding is achieved by making connections between or among pieces of information (i.e., story) to get the complete story or explanation. Stories are 'content,' and there are sets of skills that students also need to learn from their science class, such as "problem-solving skills", "critical thinking skills", "measuring skills", or "scientific methods." In their stories about their teaching from multiple sources of data, these candidates particularly highlighted the 'visualizing' role of activity—how the activity helps visualize the story that they want their students to "see" and "remember." Their greatest concern was the "boring" parts of lecture (i.e., telling the story, giving the explanation); accordingly their interpretation of the roles of students and activities was mostly associated with the success or failure of motivating students.

One noticeable difference between the two groups of candidates in their stories of classroom activity practices was the substantial presence of the socioscientific interactions[30] in their highlighting and interpretation of the goals of lessons, the roles of students and the roles of activities[31]. The group of candidates who were successful in making use of resources from the program highlighted students' social interaction and even considered it as one of their goals of a lesson besides other cognitive goals. For instance, in the case of Monica, her main goal was engaging students in inquiry, having them find patterns from the data as described in both her written report and interview. In addition, she stressed her other goal of this lesson, "developing a safe learning community," pointing out how it is important for her to engage her students in activities to achieve her cognitive goal. In the cases of the candidates who were less successful in making use of resources from the program, there was little or no highlighting of the socio-scientific interactions in their stories about science teaching. Multiple data sources showed that the candidates who attended to the socioscientific interaction in the classroom appreciated the nature of scientists' work in a scientific community and made their efforts to model it in their classrooms.

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[30] This term was coined from Cobb, McClain, and Gravemeijer's (2003) discussion of three distinct types of classroom social norm. By socioscientific interactions, I mean the types of social interaction that are specific to science. Examples of socioscientific interactions are discussing observations, working together to find patterns from the data, or sharing scientific ideas with one another.

[31] See the Appendix 7: The results of coding about classroom activities

The cases of Monica and David demonstrate the powerful influence of candidates' understanding of science on their practices and interpretation under different contexts. Monica, who was provided contradictory ideas of and resources for classroom activities from the program and from her mentor teacher, aligned herself closely to the program, and actively made use of resources from the program. Her highlighting and interpretation of practices of teaching demonstrated that she understood the nature of scientific knowledge and practices as provided by the program's language. On the contrary, David, who was provided coherent reform-oriented ideas and resources from both his mentor and the program, did not select these resources or advice while misinterpreting the program's language. David had fundamentally different ways of understanding science for teaching from Monica[32]. These three candidates' cases show that candidates' responses to the deliberately designed occasions for learning provided by their mentor teachers and course instructors were constrained by their understanding of science for teaching through their interpretation of resources and advice from the professional communities.

Candidates' understanding of science for teaching reflected in assessment practice. Candidates' in-depth understanding of science for teaching also greatly affected their learning from students through assessment practices. One key difference between the two groups of candidates in their patterns of assessment practice was that with their assessment items or tasks they provided different types of opportunities for students to give information about themselves. Whereas the candidates who failed to make their feedback loop work (e.g., Teresa, David) tended to ask recall questions about factual information or questions that ask to reproduce stories in the textbook, candidates who were successful (e.g., Leslie, Monica) tended to ask questions that reveal students' thinking or reasoning. Learning from students start by providing

[32] Whereas Monica had three-dimensional model, David had two-dimensional narrative model. See the detail in Chapter 4.

opportunities with assessment items or tasks. Therefore, their use of formative assessment practices for identifying, interpreting, and responding to students' learning is necessarily constrained by the nature of student responses produced with the assessment items or activities. The candidates who thought of science as the content (i.e., authoritative stories, the 'why' part) *plus* process/skills, ended up getting limited opportunities for learning from their students due to the nature of student responses generated from their assessment questions. Furthermore, candidates' understanding also affected what they identified from student responses and the ways that they interpreted them, which led them to draw out different lessons from their experiences with students[33]. For instance, whereas candidates like Leslie and Monica interpreted students' inaccurate responses in relation to their incomplete experiences provided through their instruction and so suggested providing complementary experiences with their instruction, candidates like Teresa and David interpreted students' 'wrong' answers in relation to their lack of motivation and behavior issues, and suggested general motivational strategies. Even when they got complicated responses from students, which rarely happened, they were puzzled by it and interpreted students' difficulties as the lack of 'skills' (e.g., critical thinking skills). In summary, the program deliberately designed assignments as occasions to assist candidates' learning from their students. However, candidates' responses to the occasions, including their design of assessment items, identifying and interpreting students' work, and responding, were profoundly constrained by their understanding of science for teaching.

The characteristics of understanding of science for reform-oriented teaching. The data analysis indicates that there exists a specialized knowledge for teaching that strongly affects candidates' learning of reform-oriented practices. This knowledge is characterized as (a) depth of

[33] See the detailed analysis of inquiry teaching episode in Chapter 5

understanding, (b) integration of knowledge and practice, and (c) attentive to socioscientific interaction. First of all, the teacher who has this knowledge understands the nature of scientific knowledge and practice—the relationships among observations, experiences, scientific phenomena, and scientific models and theories. I envision this in-depth understanding as a three-dimensional constructivist model in the comparison of two-dimensional narrative model. As demonstrated in David's, Monica's, and Adam's cases, candidates tried to make different kinds of 'connections' as evidence of students' understanding as reflecting their ways of understanding science. The different types of connections, either simple two-dimensional causal connections or testable and revisable three-dimensional connections, were strongly resonant in their interpretation of practices (see Figures 16 and 17).

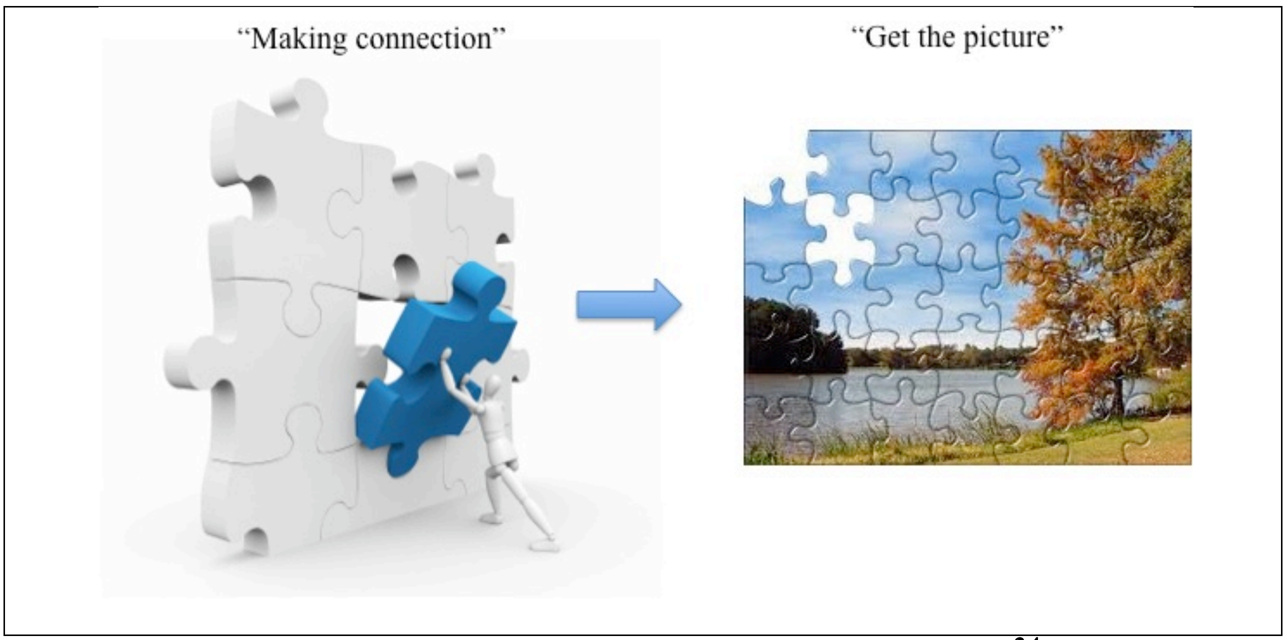


Figure 16. Two-dimensional narrative model: making causal connections[34]

[34] The images used in this picture are from Google images.

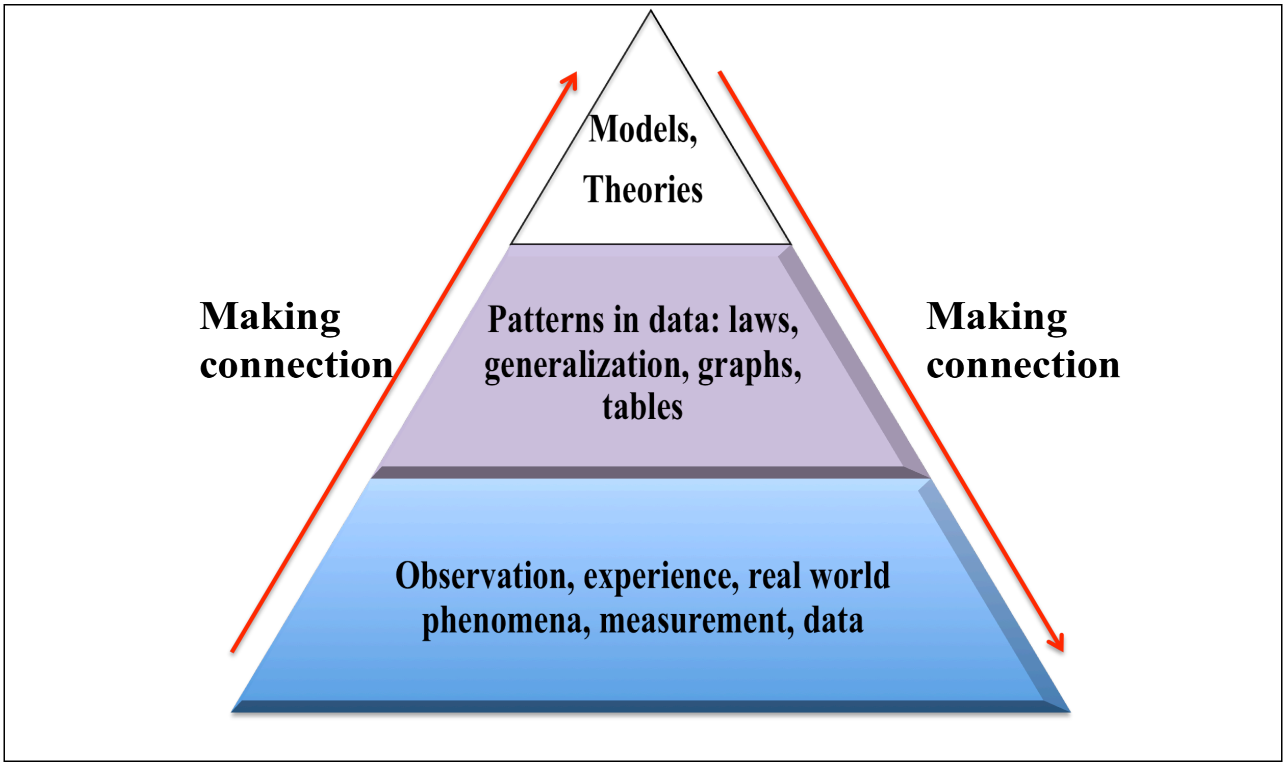


Figure 17. Three-dimensional constructivist model: making testable and revisable connections between observation/experiences and scientific models or theories[35]

Second, this knowledge is integrative in that candidates understand the integrated nature of scientific knowledge and practices, and its instructional representation through classroom activities, such as inquiry or model-based reasoning activities. As emphasized by many influential reform-oriented documents (NRC, 2000, 2007), understanding the integrated nature of scientific knowledge and practice is essential for teachers to engage students in scientific practice meaningfully. Candidates who were less successful in learning reform-oriented practices frequently talked about teaching some kinds of skills (i.e., scientific methods, process, critical thinking skills) separately from the content of science (i.e., stories, authoritative knowledge). Despite the fact that the science education community has been making efforts to move beyond

[35] This model is originated from Michigan High School Content Expectation, and modified by myself

this dichotomy, it appeared that this notion of teaching content, process, and, sometimes nature of science as separate entities, still strongly appealed to many teacher candidates. Lastly, the teacher candidates who have this knowledge see the parallel of developing scientific knowledge through the socioscientific interactions in a scientific community and in a classroom learning community. The candidates, like Monica, Leslie, and Susie, made their efforts to develop a classroom learning community where students played the role of scientists and developed their own knowledge through the socioscientific interaction while modeling scientists' work in the scientific community.

The six cases illustrated that candidates' practices and interpretation of practices were affected by their understanding of science for teaching mediated through their highlighting and coding (i.e., interpretation), and their selection of resources. It seems to me that the gap between the two groups of candidates in their ways of understanding science for teaching reflects the current challenges that the science education community faces. From a certain point of view, David was a pretty successful intern at his suburban high school, given that he was a fun and humorous teacher, and covered the state standards, for the most part, that consisted of content, process, and nature of science. Teresa worked hard to actively engaged students in a hands-on activity claiming that she covered the process part of the state standards in her 'inquiry' lesson even at this low resourced urban high school. Their practices '*only*' failed to engage students in the four strands of scientific proficiency, that is the goals of science education proposed by the most recent reform-oriented documents (NRC, 2007, 2011) developed from numerous research studies on science teaching and learning. As discussed in the literature review, the new goals are based on a fundamentally different view on science known as 'science-as-practice.' Many of the candidates of this study, including David and Teresa, had the traditional view on science that was aligned with the previous standards to some degree, but their practices of science teaching were less successful in providing their students opportunities of engaging in meaningful scientific practices.

Learning to Teach: Closing the Perceived Gap Between Actual And Designated Identities in the Field of Influence

Sfard and Prusak (2005) discussed that learning is "closing the gap between actual identity and designated identity" (p. 14). The six cases demonstrated that the candidates' learning to teach was the process of authoring professional identities while responding to the occasions for learning in a way of closing their *perceived* gap between actual and designated identities (see Figure 18). Depending on the perceived gap and their designated identities, they positioned themselves differently with respect to the professional communities that they involved, which affected their choice of resources and practices.

In this study, I posited that candidates' actual identities were collective stories about candidates' current self(s) in/and practices told by multiple people. Actual identities reflected the kinds of practice that candidates were currently capable of engaging in, but practices were not the same as actual identities. Whereas candidates' practices tended to be fluid and unstable depending on time, space, and interaction with people, this study showed that the collective stories about a candidate's current self(s) in/and practices were constructed in a way of capturing relative stable characteristics at certain point through the process of narrativatization. The stories about six candidates demonstrated that candidates, their mentor teachers, and course instructors narrativatized their current observations constantly comparing with and contrasting to their previous observations on candidates' self(s) in/and practices. In addition, candidates' actual identities reflected their understanding of science for teaching. Their understanding of science was one key personal resource that candidates drew on when they responded to their occasions for learning. Designated identities were stories about candidates' future self(s) in/and practices of science teaching, the kind of teacher who they wanted to be and the kind of practice they wanted to master. Candidates' vision statements collected multiple times at different stages of the program demonstrated that most of candidates held relatively stable aspiration of ideal teaching practices over two years. In general, their stories of future practices came to be elaborated with specific strategies and technical languages as they got more experiences. The candidates' highlighting and coding in their stories about self and practices showed their *perceived* gaps between actual and designated identities. Depending on their perceived gap and their interpretation of resources and practices provided by professional communities, the candidates positioned themselves as the learners of science teaching in certain way (see Figure 19).

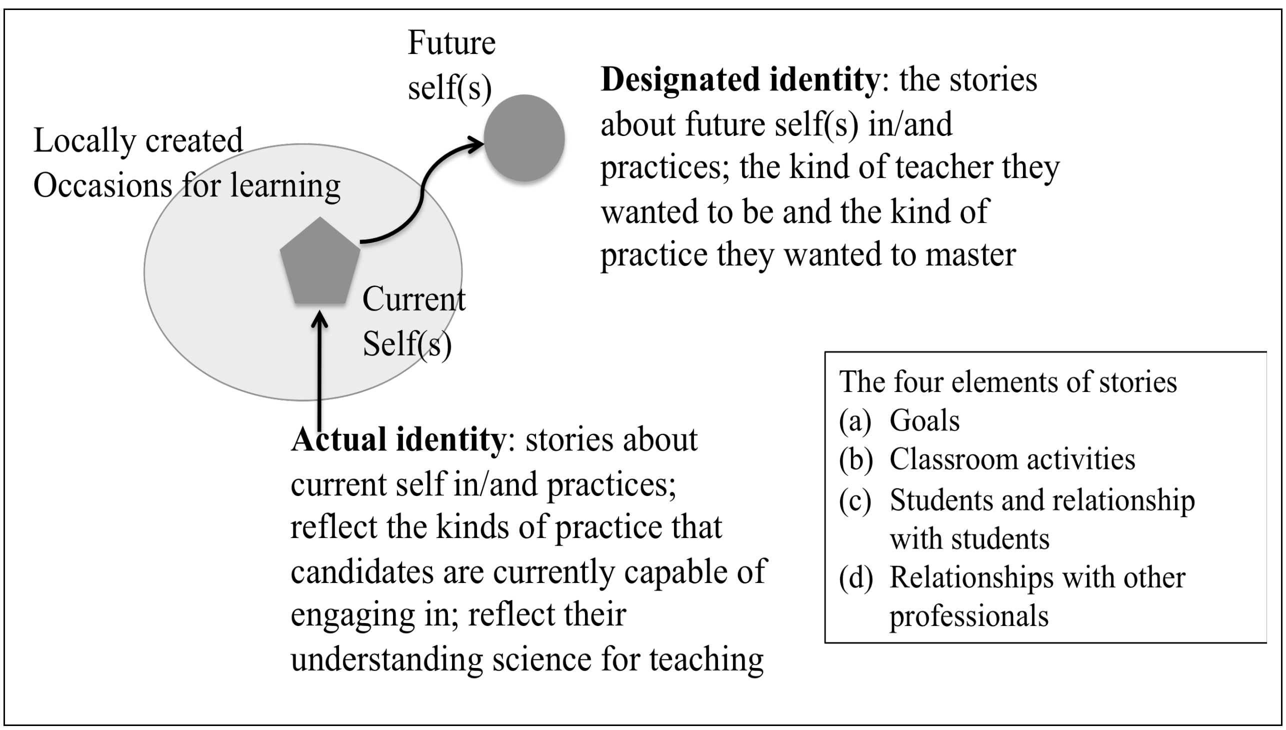


Figure 18 Learning to teach: closing the *perceived* gap between actual and designated identities

For instance, Monica was a candidate who mostly had experiences of traditional science teaching as a student, but who wanted to learn different ways of teaching science besides "lecturing." She said, "I don't feel like up until college, none of my classes really focused on inquiry or application as far as I can remember." "I get tired of lecturing and [students] don't like lecturing." As suggested in her accounts, Monica perceived significant gap between her actual and designated identities. She also recognized deficiencies in her current practice that she wished to correct. Monica actively sought out the resources to help her to close her perceived gap. Monica wanted her students to feel "accepted for who they are" through the support system in her classroom that she created. Her repeated highlighting of students' social interaction and positive interpretation of it reflected who she wanted to be as well as the way that she understood science for teaching. Her designated identities, especially her attention to cognitively challenging but socially and emotionally comfortable and safe classroom learning community, seemed to lead her to align herself closely with the program, and she mostly selected resources and ideas from the program to close the perceived gap between her actual and designated identities.

In the case of Teresa, who had teaching experiences in an out of school setting at the Redwood Forest in California, she carried strong momentum toward teaching science with first-hand, embodied experiences (i.e., designated identities), as demonstrated in numerous examples of her attempts to bring in outside, hands-on activities throughout her internship year as well as her vision statements. While struggling with students in a challenging urban high school (i.e., her actual identities), Teresa continuously looked for ideas and activities that matched with her vision of embodied instruction. Teresa clearly recognized the gap between her actual and designated identities. She said, "I think I need to refine my teaching style more. I mean I think I know, I have a lot of like ideas and concepts [about teaching]." While making her efforts to close the gap, Teresa also looked for resources and ideas. Her highlighting and interpretation of the resources were also affected by her designated identities. She mostly highlighted and negatively interpreted her mentor teacher's paper/worksheet instructional approaches that were contradictory with her designated identities. The resources and advice from both her mentor teacher and the program did not match her designated identities that had different prioritized values. Teresa continuously went back to her own resources from California, or resources on the Internet to close her perceived gap between actual and designated identities, instead of making use of resources and ideas from both professional communities.

In the case of David, he carried momentum toward delivering authoritative stories of science in a fun and interesting way, just as he was doing. In contrast to most of the other candidates, David did not seem to see big a gap between his actual and designated identities. Despite both his mentor's and his course instructor's concerns about his practice and the great differences in their highlighting and coding between them and David, David narrativatized his practice in ways that allowed him to depict his current practice as aligned with program goals or the instructional models provided by his mentor. David constantly appropriated the program's language to label his procedural practices in his stories. He interpreted that his teaching style was pretty "similar" to his mentor teacher because they "both like to tell stories, like personal stories that relate to things and allow the students to do that too." David's positioning as a "relaxed" and "laid back" teacher showed the ways in which David perceived a gap between his actual and designated identities.

Candidates who actively made use of resources and ideas from the program tended to share the program's vision of good science teaching and to build their designated identities based on that vision. They were those who took most advantage of resources and ideas from the program because of the alignment of their momentum toward their designated identities with the direction of support from the program. This alignment accelerated their process of learning by providing other tools and resources that are not normally available to candidates. For instance, Leslie had a vision of good science teaching similar to that of the program at the beginning of her senior year, including helping students apply science knowledge to students' everyday lives, and helping them to better understand their everyday experiences using science. Leslie actively sought out ideas and resources that allowed her to enact her vision, and she mostly selected resources and advice from the program over the ones available from the school professional community across the two years. In her senior year, Leslie respected her mentor teacher but she did "not see [herself] being a teacher like Mrs. F in 10 years from now." In her internship year, Leslie selected the resources and lesson ideas from a young science teacher in her school as well as from the program over the ones from her mentor teacher, Mr. J, who had 38 years of experience teaching in a traditional way. Candidates' learning to teach was the process of closing their perceived gap between actual identity and designated identity, being a certain kind of science teacher while closely interacting with the people and selecting the resources and ideas that aligned with their designated identities.

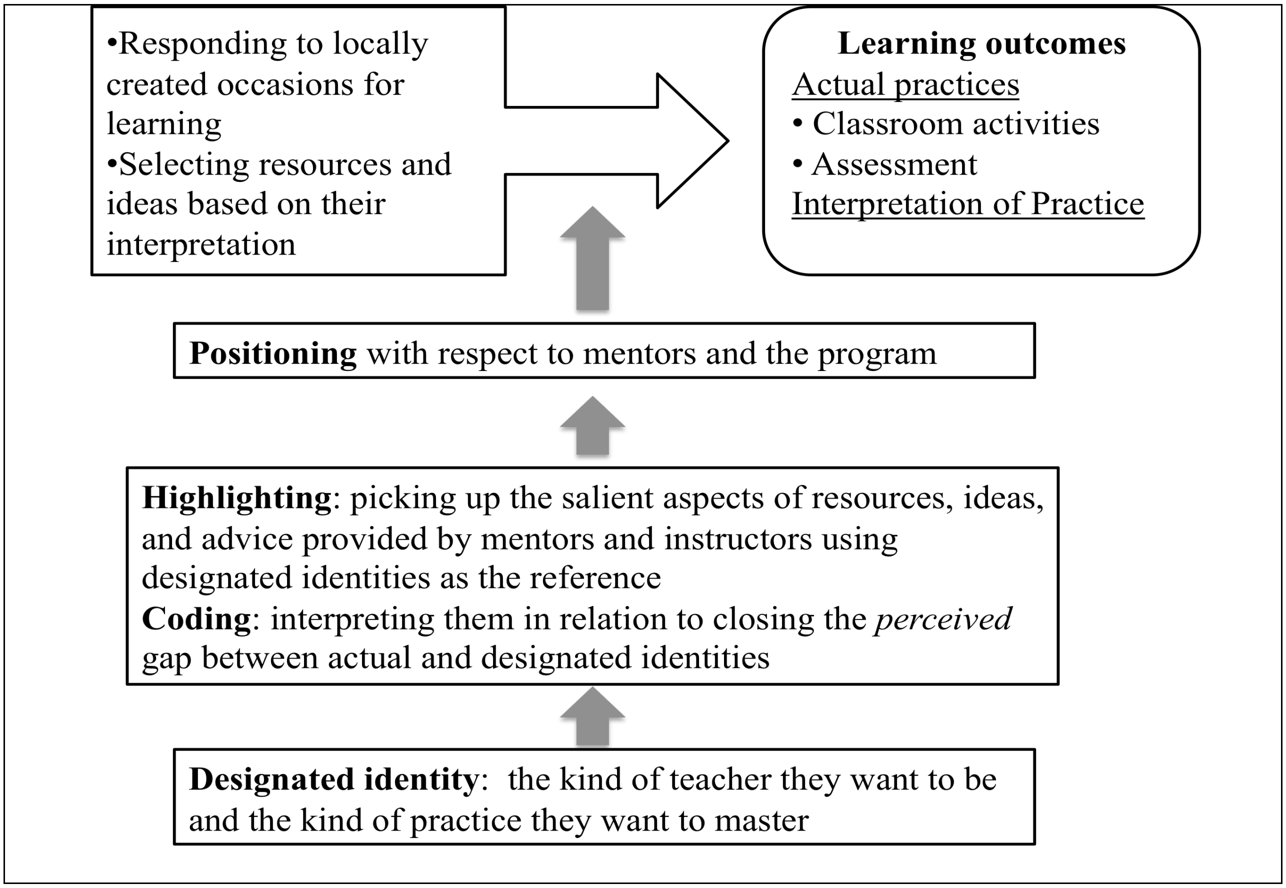


Figure 19. The role of designated identities in the process of learning to teach

Contexts: the Occasions for Learning that Locally Created for Each Candidate

It has been well recognized that contexts play significant roles in candidates' learning of reform-oriented practices (e.g., Bianchini & Cavazos, 2007; Crawford, 2007; Darling-Hammond & Richardson, 2009; Flores, 2006). It should be acknowledged that the role of contexts was not fully investigated in this study. Rather, my deliberate choice of six focus cases—three from similar suburban high schools, and three from similar urban high schools—made it possible for me to focus on the roles of knowledge and identities in beginning teachers' learning of practices as the outcome of responses to their occasions for learning. Nevertheless, this study gave me some insights on contexts—how the contexts for learning are generated for each candidate and what roles they may play in the process of beginning teachers' learning to teach.

In this study, I consider context as “a field of influences” that candidates have to interact with and respond to while traversing toward their designated identities. Candidates produce their practices and interpretations of practices as the outcome of their responses to the deliberately designed occasions for learning in a field of influences. Contexts made a big difference in the nature of the occasions locally created for each candidate. Although the program deliberately designed occasions for learning with the same structure of assignments for all candidates, not surprisingly the actual occasions for learning locally created for each candidate were not the same across candidates. The six cases showed that there were several factors that affected the nature of these occasions, including (a) contexts of the school placements, (b) types of advice from mentor and program, and (c) characteristics of mentoring.

First of all, the contexts of school placements make a difference in the nature of occasions for learning because of the available resources, equipment, characteristics of student communities, and the culture of school professional communities. For instance, the three candidates in urban high schools had to respond to the lack of equipment, and high demands of managing their classroom, which was not the case for the three candidates in suburban high schools. Leslie’s mentor, Mrs. F, captured well the lack of resources accessible to candidates:

> Mrs. F: We, as a department, are limited by the resources that we have available. We barely have enough funds to run dissection specimens, let alone fix broken microscopes. It’s frustrating when you have all these wonderful ideas and you're willing to put forth the effort in terms of lab setup and cleanup, and then just not have the equipment or the money available. (Mrs. F, Leslie’s mentor teacher at West high school)

Secondly, the types of advice from mentor and program also made a big difference in the occasions for learning, as was demonstrated in both David’s and Monica’s cases. Depending on the mentors' preferred instructional approaches, their understanding of science, and their understanding's alignments with the program's vision, candidates experience more or less tension in participating in both professional communities and selecting resources and ideas.

Finally, mentors' openness to candidates' trial and error also influenced the nature of occasions for learning. For instance, Susie's mentor, Mrs. B, had a very clear idea about her mentoring, and she structured Susie's experiences in her classroom systematically. Mrs. B modeled the detail of skills and helped Susie to develop sets of skills that were the core of learning how to teach science from Mrs. B's perspective. The occasions for learning created for Susie by Mrs. B were qualitatively different from many teacher candidates. Susie had to respond to Mrs. B's expectations as well as to her program's expectations.

Certainly, contexts played an important role in candidates' practices and interpretation of practices by creating certain types of occasions for learning. However, candidates' practices also depended on the ways that candidates respond to the local occasions, and their responses were profoundly affected by their knowledge and designated identities. This explains why "mentoring itself did not fully explain the differentially enacted inquiry" (Crawford, 2007, p. 635).

Conclusion and Implications

This study investigated 14 secondary science teacher candidates' mechanisms of learning in the context of a university-based teacher preparation program. The 14 teacher candidates were provided opportunities for learning from both professional communities and their students in order to develop practices of science teaching during their time in the program. This study focused on two key science teaching practices—(a) planning and enacting classroom activities, and (b) assessing and responding to students—that are closely connected to learning from professional communities and learning from students. As the conclusion, I present my model of secondary science teacher candidates' mechanisms of learning constructed from the evidence generated in this investigation. The implications on practice and research of teacher education are discussed.

The Mechanisms of Secondary Science Teacher Candidates' Learning to Teach

The teacher candidates' learning of science teaching practices was a dynamic and interactive process that involved candidates' understanding of science for teaching, their actual and designated identities, and the nature of the occasions for learning that were locally created for each candidate. The candidates were provided opportunities of learning reform-oriented practices at several deliberately designed occasions by the teacher preparation program. They produced certain kinds of science teaching practices and drew out lessons from their experiences as their responses to the occasions for learning.

The findings show that the candidates' understanding of science and designated identities led each of them to create different experiences for themselves. The candidates understanding of science and designated identities affected their highlighting—what seemed salient to them in the experience--and their coding—the ways in which they made sense of the aspects of experience that they highlighted. Based on their interpretation on practices, resources, and advice provided by the program, their mentor teacher, and their course instructor, the candidates made their choices of classroom activities and assessment. So even candidates in the same program, with similar mentors and contexts, created different experiences for themselves and had different interpretations. The program and mentors have far more control over external occasions for learning than they have over candidates' subjective experience—and it is the *subjective* experience that we learn from. All the candidates learned something about science teaching from their subjective experiences while generating certain kinds of "formative feedback loops" for themselves through their highlighting and coding. Their highlighting and coding were mediated by their understanding of science for teaching and their perceived gap between actual and designated identities (see Figure 20).

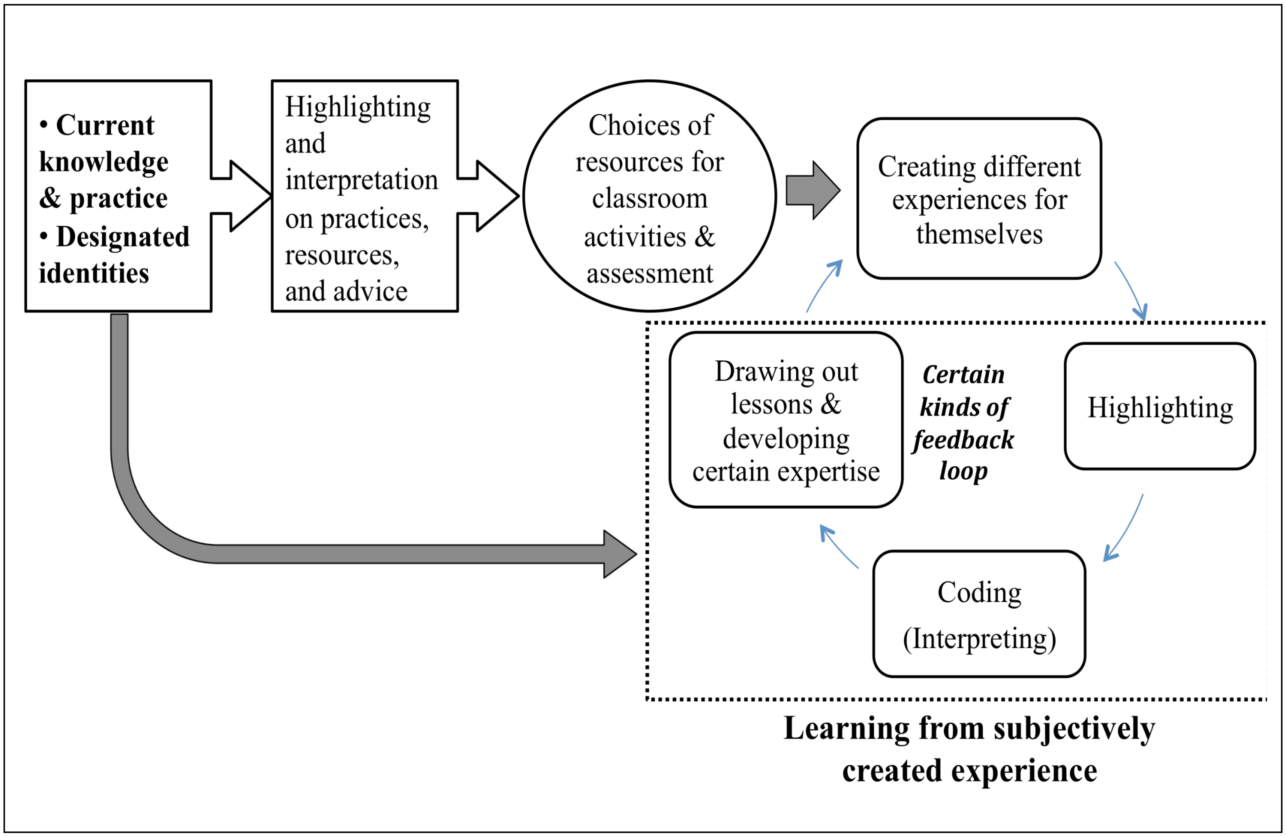


Figure 20. The mechanism of learning to teach

This study gives us some insights on candidates' success and failure in learning reform-oriented practices through a university-based teacher preparation program. The findings indicate that candidates who get the most benefit from the program are the ones who initially have a strong understanding of science, and a vision of good science teaching shared by the program. Because what candidates highlight in their experiences and resources, and how they interpret what they highlight, are shaped by their understanding of science and their designated identities, candidates who initially have a strong understanding of science as practice and designated identities that match with the vision of the program actively make use of the resources and ideas from the program. By doing so, they create quality opportunities of learning from their students, their mentors, and course instructors, and they are able to generate a 'formative feedback loop' productively in a way of engaging students in meaningful scientific practices. By contrast, candidates who have limited personal resources and a traditional understanding of science tend to be less successful in making use of resources and ideas from the program while failing to highlight and interpret the resources and ideas as they are meant to be. Teacher preparation programs deliberately designed occasions for learning for candidates with the hope of making their formative feedback loop work productively for both themselves and their students. However, as demonstrated in the data, many candidates actually were not capable of providing quality opportunities for students to give information about students themselves in the first place with their current ways of understanding science. They developed certain kinds of 'expertise' of science teaching while creating their own feedback loop with their subjective experiences, but this feedback loop was less productive for either responding to students' difficulties in learning science or adjusting their instruction in a way of better assisting students' learning.

Implications for Practice in Teacher Education

The findings of this study that highlight the critical roles of both candidates' current knowledge and practice of science teaching and their designated identities in their process of learning to teach provide us a couple of insights on curriculum and instruction of teacher education.

First, teacher preparation programs need to develop sets of 'practices' of teacher education to support candidates' development of in-depth understanding of science for teaching. Those practices should support candidates' engagement of productive feedback loops. This study showed that candidates who had a traditional view on science was less successful in creating a productive feedback loop for themselves given their current knowledge and practice of science teaching. Specifically, it is less likely for those candidates to select high quality classroom activity ideas or resources provided by the program or their mentor teachers as they are meant to be, given that candidates' interpretation are constrained by their current knowledge and practices. For the assessment practices, it was also less likely for those candidates to ask quality questions that generate interesting student responses that create 'information rich' occasions for learning. Candidates learned from the subjectively created experiences while creating certain feedback loop. Therefore, one key of assisting candidates' learning to teach is to provide careful scaffoldings at each step that involves in the process of creating feedback loops (see Figure 20 above), so to help candidates to engage in productive formative feedback loops. For example, collective highlighting and coding about curriculum materials or classroom activities through the activities of teacher education courses can be one way of expanding candidates' individual highlighting and coding to support their choice of classroom activities. With respect to assessment practice, providing high quality assessment questions for candidates' use can be one possibility in order to initiate and expand their formative feedback loop. By engaging candidates in the practices that help them to create a quality formative feedback look, we will be able to better support them to learn from their students and the professional communities, and to develop in-depth understanding of science for teaching.

The findings of this study also imply that we need to recognize and better support candidates' identity work. The six focus cases suggested that each candidate brought certain images of good science teaching practice and science teacher that consisted of goals of science teaching, activities, and students. According to the analysis of vision statements, their designated identities were relatively stable throughout two years, and candidates positioned themselves differently depending on their perceived gap between actual and designated identities. Candidates' strong momentum toward their future selves is understandable given their experiences through more than 12 years of schooling. In order to better respond and support their identity work, first, both teacher educator and teacher candidates ought to recognize candidates' designated identities (i.e., who they wanted to be), and how they perceived the gap between actual and designated identities by engaging candidates in various activities that reveal who they are, who they want to be as a science teacher, and what kinds of instructional practice they want to master. Some kinds of special event or activities that provide inspiring experiences for candidates to shift their momentums toward their future selves may need to be considered.

Implications on Research of Teacher Education

I close this dissertation by describing the implications for the future investigation of this study and research on teacher education in general.

First, research on teacher education ought to provide powerful explanations about the process of beginning teacher learning with empirically valid evidence in order to inform the curriculum and instruction of teacher preparation program as well as the policy of teacher education. However, the literature on teacher learning in the field of science education has been dominated by what I called, 'factor oriented research' over the last several decades, which have provided only limited explanation about the nature of difficulties in the complicated process of beginning teachers' learning to teach. The common popular notions of 'observation of apprenticeship' (Lortie, 1975), 'script of teaching' (Stigner & Hiebert, 1998), or 'previous experience' (e.g., Eick & Reed, 2002) accounted neither for all the facts that we observed in our teacher candidates nor for the ways in which the key factors influence on the process of learning to teach. I proposed one explanatory model to account for the complicated process of learning to teach using two analytical lenses—cognitive development and authoring identity. This explanatory model, by definition, needs to be tested, revised, and refined with further evidence with different cases in different contexts, in order to be used as a powerful tool for teacher education community.

Second, this study showed one approach of documenting beginning teachers' learning to teach focusing on the practice of science teaching. The current challenges for research on beginning teachers' learning reside in the fact that researchers should address both conceptual and technical issues for documenting teacher learning. Researchers should respond to the questions of "What we mean by a good science teaching?" "What should be counted as evidence of teacher learning and why?" Both issues are still subject to debate in the field of teacher education, which makes the research on teacher learning incredibly difficult. In addition to the conceptual issues, it is also challenging to parse out the practice of science teaching in a way of describe, analyze, and document. Kennedy (2010a) reminds, "We have faced serious technical problems in trying to translate our intuitive perceptions into precise terminology and reliable measurement scales" (p.245). This study proposed a conceptual framework for beginning teacher learning and learning outcomes focusing on the practice of science teaching. Various technical languages were defined to describe and analyze the practice of teaching, such as the unit of data collection, unit of data analysis, elements of practices, etc in order to document beginning teachers' learning outcomes in a empirically valid way. Both conceptual and technical aspects of the methodology will provide researchers one grounding point to further discuss and develop fine analytical tools for research on teacher learning.

Third, this study provides some insights on both potential issues and possibilities regarding the design of research on beginning teacher learning. Research focusing on the practice of science teaching is a highly demanding work that requires great amount of time and energy from both researchers and candidates in terms of data generation, collection, and analysis. The more teaching episodes (i.e., the unit of data collection) are analyzed, the more reliable the results would be. Multiple teaching episodes collected at different stages of program may also allow researchers to trace candidates' learning trajectories, including any shift of momentum in their learning trajectories. However, given our limited resources, we must consider the tradeoffs between the total number of teaching episodes and the quality of information of each teaching episode. For example, if we allow candidates to select teaching episodes as evidence of their learning with rationale, their choice and stories about their choice will give another layer of information on their interpretation of practices. The time points of data collection can be also considered as a way of enriching the information from one teaching episode. The teaching episode at the last stage of program provided informants with opportunities tell stories about candidates' self(s) in/and practices while drawing upon their observation throughout the whole period, which generated rich stories that captured reifying and significant aspects of candidates' self and practices.

Finally, this study demonstrated how the processes of learning from students, mentor teachers, and course instructors were significantly affected by candidates' actual and designated identities. Despite the fact that some researchers have attended to the issue of teacher identities, the notion of teacher identity has been a messy construct that was less successful in providing powerful insights on the process of learning to teach. In this study, teacher identities were operationalized as 'storied identities' that consist of stories about both current and future self(s) in/and practices. This operationalization was useful because it allowed me to capture the process of learning to teach in the unique contexts of beginning teacher learning as discussed in the introduction, including the involvement of multiple communities of practice, multiple authorities of good teaching practices, and degree of freedom for choice of resources. This study shows that candidates bring strong momentum toward their future selves with them, and their designated identities are relatively stable. What will be a better way of working with candidates who have a strong momentum toward traditional teaching? How can we better recognize their identities and identity work at the early of the program and during their time with us? How can we help them re-consider their future self(s) and its projected meaning in their practices and students' learning? How can we provide opportunities of making a shift of their momentum in a productive way? These are some of the questions that are critically important to respond to our candidates, and possibly put us in a better position to support our candidates' identity work.

This study shows the depth of challenges that the teacher education community faces. The time of candidates' work with us is relatively short in comparison to the time that they have developed their designated identities. We have a very ambitious goal of equipping candidates with reform-oriented pedagogy, but currently we do not have an ambitious pedagogy for teacher education that supports candidates' acquisition of this important knowledge for teaching and that can powerfully influence their momentum toward their designated identities. However, the field of research on teacher education is relatively young (Grossman & McDonald, 2008), and researchers have already begun to produce quality research studies that shed light on our understanding of beginning teacher learning. Despite the challenges that we face, I believe that our ambitious pedagogy will be developed as we better understand beginning teachers' mechanisms of learning.

APPENDICES

APPENDIX A

UNIT/LESSON PLAN TEMPLATE

TE 408: Lesson Plan and Report

Note: Titles and parts written in plain text are meant to be included in your final report. Notes in red italics (including this one) are advice on writing the report that you can erase from the final version.

- *Your **plans turned in before the lesson** should include Parts I-IV.*
- *Your **report turned in after the lesson** should include revisions in Parts I-IV and Part V.*

Name:	Partner:
Mentor Teacher:	School:
Date:	

Part I: Information about the Lesson or Unit

Describe the unit topic in which your lesson fits (e.g. genetics, forces), and the lesson topic (e.g. Punnett square, Newton's 3rd Law)

Unit:

Topic:

Type of Class

Choose the appropriate descriptors from the lists or substitute your own descriptions.

- Grade level(s): 6 7 8 9 10 11 12 High school basic elective/high track advanced (e.g., AP)
- Type of school: Urban Suburban Rural
- Tracking level: Untracked Lower track College bound Inclusion

Abstract

Write a short description (100 words or less) that provide a brief snapshot of the content and activities of your lesson. Include information about what your students will do as well as what you will do as a teacher. For example, in this lesson we will be doing a series of activities on the types of clouds. As a problem, we will ask what types of clouds are visible today and what do they mean for our weather. We will model with labeled pictures of different types of clouds and then have students identify new pictures taken from websites for coaching. The homework (fade) will be to answer the original question and include a drawing of the clouds.

Part II: Clarifying Your Goals for the Topic

This section lays out a general understanding of the topic at a level that is appropriate for your students. Note that Big Ideas, Objectives, and Observations/Patterns/Models are rarely covered completely in an individual lesson. If necessary, you should add material not included in your lesson in order to develop a more complete picture of the content that you are teaching.

It may be useful to use colors or italics to distinguish between content taught in the lesson and experiences or ideas that are not included in this lesson, but help to complete the topic.

In this section you should feel free to copy from the website or from resources such as state and national standards. Always include appropriate citations for any material you use. Modify the text so that it matches your lesson.

Knowledge: Big Ideas

Describe the most important patterns, models, and theories for this topic in 300 words or less. Use the language and ideas that you would like students in your class to be able to use. If appropriate, copy language from Benchmarks for Science Literacy or the National Science Education standards or other sources.

Big ideas are rarely confined to an individual lesson. If you are writing plans for a single lesson, you may need to include ideas from other lessons to write a coherent statement of the big ideas you want your students to understand.

<u>Checklist for Big Ideas</u>. Check to see if your big ideas meet the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Do you have a coherent summary of the most important patterns, models, and principles for your topic? Big ideas should express the key patterns and explanations in student language, not just name them.*
- *Have you used important ideas from Benchmarks for Science Literacy, the National Science Education Standards, or the Michigan Content Expectations?*
- *Is the language (e.g., vocabulary level) appropriate for students in your class? Big ideas don't include every vocabulary word in the unit (though they should include the most important ones), and they don't have many specific examples. The language you use in your summary of big ideas should be the language you would like your students to use.*
- *The word "students" does NOT belong in your statement of big ideas. Think of big ideas as what you would like your students to be able to tell you after the unit or lesson is over.*

Knowledge: Observations, Patterns, and Models/Principles

Use the table to explain how you will help students extend their experience and reduce it to order. Use the table to list:

- *Observations or data that you want your students to be aware of and work with. These could be personal experiences or data that are collected during this lesson or data that students get from demonstrations, websites, etc. They should be direct descriptions of objects, systems, or events in the material world. Observations include:*
  - *A list of examples that fit the patterns and models you identified in your Big Ideas.*
  - *A list of variables or specific characteristics that students need to notice about the examples. Some of the variables will be obvious characteristics of the examples; there may be other important "hidden variables" that students need to be aware of in order to see the patterns.*
- *Patterns that you want your students to see or be aware of in the data. Note that patterns usually describe relationships among variables—the variables that students observed in their examples.*
- *Models and principles that you want your students to use to explain or understand the observations and patterns.*
  - *Models explain patterns in terms of invisible mechanisms.*

- *Principles are general rules, such as conservation of matter and energy, that all models must obey.*

<u>Checklist for Observations, Patterns, and Models</u>. Check to see if your observations, patterns, and models meet the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Are your observations/experiences specific real-world objects, systems, or phenomena? Observations focus on specific real-world objects, systems, or phenomena, not the concepts we use to explain them. For example, "light-dependent reactions" and "light independent reactions" are not good real-world examples for photosynthesis. Similarly, "temperature," and "convection" are not good real world examples for heat transfer.*
- *Are the observations experientially real to your students. They should be either systems or phenomena that your students have already experienced or that you could help them experience, first hand or vicariously. (This does not imply that your list should consist only of examples actually included in your class activities.)*
- *Are the variables that your students will observe sufficient for them to see the patterns? If not, do you have plans for how to make your students aware of the hidden variables?*
- *Do your Patterns describe relationships among variables that students will observe or be aware of?*
- *Are your patterns explained by the models and principles—do the patterns serve as a "bridge" between observations and models?*
- *Are your observations, patterns, and explanations connected to your big ideas? The key models, laws, and theories in the big ideas statement should be listed in summary form in the Patterns or Explanations column of your table.*

	Observations or experiences	**Patterns**	**Models and Principles**
Goal OPM	Relevant examples: Variables:		
⇦ **Application: Model-based Reasoning**			
Inquiry: Finding and Explaining Patterns in Experience ⇨			

Practices: Objectives for Student Learning

Use the table below to list one or two Michigan Objectives and one or two specific lesson objectives that you will be addressing during this lesson. The Michigan Objectives should be copied from the Michigan HSCEs (http://www.michigan.gov/mde/0,1607,7-140-38924_41644_42814---,00.html) or GLCEs (http://www.michigan.gov/mde/0,1607,7-140-28753_33232---,00.html). For each objective, use the second column to say what type of objective it is.

You probably will not complete work on your objectives during a single lesson. Don't worry about that. We are more interested in longer term goals than in what students learn in an individual lesson.

<u>Checklist for Objectives for Student Learning</u>. Check to see if the objectives in your table meet the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Does each objective describe student learning—something that your students will be able to do after the class is over—not just a teaching activity to be completed in class? For example, "Conduct an experiment on plant growth under different environmental conditions" is a good learning activity, but not a good objective. It doesn't say what students will learn to do as a result of conducting the experiments.*
- *Does each objective relate to a set of examples, not just a single example? For example, "Explain how plants get their food" is a better objective than "Explain how an oak tree gets its food."*
- *Are your objectives connected with your Big Ideas and Observations/Patterns/Models? Does each objective describe ways that you would like your students to connect observations, patterns, and models or principles?*
- *Do you have a small number of objectives that describe significant learning? Do not write too many small objectives. Even a unit that is several weeks long should be organized around a small number of significant objectives.*

Objective	Type
Michigan Objective(s)	
1.	*Choose one:* Identifying SP Using SP Inquiry Reflection/Social Implications
2.	
Specific Lesson Objective(s)	
1.	
2.	
3.	

Part III: Classroom Activities

This section contains your plans for the activities that you will actually do in the classroom. They should be real plans for real activities, not made-up plans that you will not actually carry out.

Resources

Use the table below to describe and analyze at least three different resources (including lesson plans, laboratory investigations, data sets, simulations, websites, etc.) that you considered in developing your lesson. One resource can come from your mentor teacher; the other two should come from other sources. We will work together as a class to develop sources and criteria for judging the quality of resources.

Source and description of resource	***Possible uses for your lesson***	***Strengths and weaknesses***

Materials

List materials you will be using. Attach the files of materials that you have in electronic form.

Checklist for Materials. Check to see if your materials list meets the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Have you included everything you will need to teach?*
- *Do you have the materials ready before your lesson?*
- *Have you attached files for materials that you have in electronic form?*

Presentation materials (Overhead transparencies or PowerPoint presentations, etc): *(attach files)*

Copied materials (Handouts, worksheets, tests, lab directions, etc.): *(attach files)*

Pages in textbook: Book:______________________ Pages:_______

Laboratory materials: For the teacher or the class as a whole: *(attach files)*

For each laboratory station: *(attach files)*

Other materials: *(attach files)*

Activities

Describe the activities that you will be doing at three stages in the lesson: Introduction, one or more Main Activities, and Conclusion. These may be based on your mentor's lesson plans and materials or on ones that you developed yourself. They should reflect, though, your best understanding of what you will be doing. If you would have preferred to do something different, describe what you would have done in the "Improvements in Parts I-IV" section below.

- *Include important handouts or teaching materials, either as part of this file or separately.*
- *Share your plans with your mentor and course instructor in time to get comments before you teach.*

Checklist for Activities. Check to see if your activities meet the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Are your lesson plans ready in time for your mentor and course instructor to look at them and suggest improvements?*
- *Do the activities address the goals you listed above? (If not, you should change the activities or the goals.)*
- *Have you planned lesson introductions that will (a) connect this lesson conceptually with earlier lessons and (b) prepare students for the activities of the day?*
- *Do your whole class activities meet the criteria we have discussed in class for examples, explanations, opportunities for student participation, management, style/learning community, and opportunities for assessment?*
- *Have you planned lesson conclusions that will (a) review the main ideas for the lesson, (b) prepare materials and lab stations for the next group of students, and (c) connect this lesson to the next one.*

Introduction (-- minutes)

Describe introductory activities that will:

- *Get the class off to a well-managed start*

- *Make conceptual connections with previous lessons*
- *Help students anticipate problems and activities of the class*

Main Teaching Activities (--minutes)
Describe teaching activities, including:
- *Key examples, patterns, models or theories*
- *Key questions that you will use to start discussions*
- *What the students AND the teacher will be doing*
- *Embedded assessment activities that will indicate students' understanding at different points in the lesson*
- *References to materials you or the students are using during this activity*
- *Procedural details, including transitions, materials management, etc.*

Conclusion (--minutes)
Describe concluding activities that will:
- *Make sure students and materials are in order before students leave*
- *Help students review or summarize what they have learned*
- *Help students anticipate problems and activities of future classes*

APPENDIX B

ASSESSMENT ASSIGNMENT TEMPLATE

Part IV: Assessment of Focus Students

This section includes your plans for assessment of three focus students who have different levels of academic success in your class.

Focus Objective

Choose one objective to focus on for your assessment and copy it here.

Developing Assessment Tasks

Include an assessment task that will reveal your focus students' understanding of your strand: their knowledge, practice, and discourse. This task might be a single question or a series of questions. It might take many forms, including: (a) embedded assessment tasks such as worksheets, journal questions, or lab reports, (b) questions or tasks for clinical interviews, or (c) formal assessments such as test questions.

Include the actual task, don't just describe it. *If it requires special materials that cannot be copied into this section, attach them as Appendices or separate files.*

Checklist for Assessment Task. Check to see if your assessment task meets the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Have you included the actual questions that students will answer or prompts they will be able to respond to?*
- *Will you learn from incorrect answers? Can your students respond in ways that show ways of making sense of the topic even if they don't know the scientific answer?*
- *Is the task relevant to the focus objective? Does it engage students in the practice described in your focus objective?*
- *Would a scientist respond to the task with the concepts, patterns, or models that you are interested in?*
- *Is the task worded in a way that will be clear to the students? Will they understand what you are asking?*
- *Would a good answer to the task require students to relate some of the theories, patterns, and examples from Part II?*

Part V: After the Lesson Report

Complete this section after you have taught your lesson.

Story of What Happened

Choose 2 of the 6 focus aspects we have used for video and teaching lab analysis (examples, explanations, student participation, management, teaching style and classroom culture, student learning). Write a brief story of what happened when you taught the lesson (500 words or less) that provides evidence about those two aspects. (See the middle column of the video rubric for relevant types of evidence.)

Aspect	*Data and Patterns*	*Judgments about Quality*
1. How are the real world observations and examples used?	*List of observations and examples* *Sources of observations and examples: demonstrations, stories, student suggestions, etc.*	*Scientific appropriateness: Were the examples scientifically aligned with the key ideas of the lesson?* *Interest and relevance: Were the examples interesting and relevant to the students?*
2. How are the explanations constructed or given in this lesson?	*List of explanations* *List of representations: diagrams, equations, verbal models, etc.* *Source of explanations: Teacher, students, ?.*	*Scientific appropriateness: Were the explanations scientifically correct?* *Comprehensibility: Did the explanations make sense to everyone?* *Connection to examples: How well did the explanations connect examples with models and principles?*
3. What kinds of opportunities for engagement are provided for students? Who can be left out?	*Notes about who speaks and who does not.* *List of questions or other opportunities to participate*	*Inclusion: How many people participated? Were there patterns in who spoke the most?* *Meaningfulness: How meaningful was the participation to the students?*
4. How does the teacher manage class discussions?	*Turn taking: How the teacher chooses who will speak.* *Class organization: lecture, discussion, small group, individual work, etc.*	*Effectiveness of organization: Was it always clear what students were expected to do?* *Appropriateness of organization: Were the activities organized so that the purpose of the lesson was achieved?*
5. What is the teacher's style and the nature of the classroom learning community?	*Specific examples that exemplify the teacher's style or approach.* *Evidence about students' interest, engagement, cooperation.*	*Effectiveness of teacher's style: What aspects of the teacher's style or approach are most and least effective?* *Nature of classroom community: Does the classroom community have norms that favor student engagement and motivation to learn?*
6. What is the evidence of student learning?	*Purpose of lesson:* *Student responses: List of specific responses from students that showed something about their understanding*	*Appropriateness of purpose: Did the teacher have a goal that involved meaningful learning for the students?* *Usefulness of responses: Did the students say or do things that helped the teacher figure out how they understood the topic?* *Correctness of responses: What did the responses reveal about student understanding?*

Checklist for Story of What Happened. Check to see if your story of what happened meets the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Are the students (especially your focus students) actors in your story, not just an audience for what you did?*
- *Does your story provide evidence about your two focus aspects?*
- *Does your story include information about your students' activities and learning relevant to the objectives you identified for the lesson in Part I?*
- *Does your story include the events, issues, or problems that were most important to you personally and to your learning to teach?*

Two focus aspects:

Story with evidence about those aspects:

Making Sense of Focus Students' Responses

Descriptions of focus students

Choose three focus students who have different levels of academic success in your class. Assign them pseudonyms and describe them briefly in the table below.

Pseudonym	Academic Standing	Personal Description

Excellent Response or Rubric

Write an example of what you would consider to be an excellent response to your assessment task from a student in your class.

Finding and Explaining Patterns in Student Responses

Describe your focus students' understanding (i.e., their knowledge, practices, and discourse) with reference to the focus objective and the relevant examples, patterns, and models or theories. To do this, identify the key components of the "Ideal Response" you wrote in the previous section. Describe how each focus student did with each component.

Support your description with evidence from their work and your interactions with them, including your assessment task, written work they have done, informal conversations, their participation in class, their approach to laboratory or field activities, etc. ***If at all possible, include copies of the focus students' work.*** *You will not be graded on your students' achievement, but on how well you analyzed that achievement.*

Checklist for Analysis of Focus Students' Understanding. Check to see if your analysis meets the criteria below. Erase this section if you feel that you have met all the criteria. If you are having trouble meeting some of the criteria, use this section to explain your difficulties.

- *Have you provided evidence in the form of quotes or samples of your focus students' work? (If necessary, attach separate files or paper copies.)*

- *Have you described how your focus students understand the objective: their experiences and their ways of describing them, patterns that they see in their experience, their explanations of those patterns, their practices in doing the activities described in your objective?*
- *Have you related their knowledge and practices to the scientific knowledge and practices described in your big ideas and objective?*

Improvements Parts I-IV

Go back to your lesson plan and identify ***3 things you would change*** *to improve the lesson if you were to do it again. The changes can be in any part of the lesson plan. For example you might decide that your objective was unrealistic, that you didn't understand some of the big ideas or you would reword them, that you need different experiences that are more interesting to students, or that you would change the activities.* ***Explain both why you think each part was problematic in its original form and why you think your new idea is better****. Your explanations should include evidence from what happened. Also use whatever ideas from class you think are pertinent. For example, you think your students had trouble with a worksheet because you jumped from modeling to fading or you didn't motivate students because they couldn't see the value in the task because it didn't relate to their lives.*

Improvements in Your Understanding of Science Teaching

Write briefly about some important thing that you learned that will help you be a better science teacher in the future.

Attachments

If you have electronic files you are using with your lesson, either paste them here, or list them here and upload them as separate files to the course Angel site.

APPENDIX C

TEACHER CANDIDATES INTERVIEW PROTOCOL

The goals of this interview
The goal of this interview is to understand teacher candidates' ***knowledge and practices*** of science teaching, and their development of professional identity. In particular, we are interested in two key science teaching practices—a) classroom activities as ways of representing scientific knowledge and practices, and b) assessing and responding to students. This interview will be conducted at the last stage of their senior or internship year after involving in multiple communities of practice of science teaching. We will show a teacher candidates' self-made teaching video and ask questions of their practices and self as a science teacher. Interview questions will be focused on candidates' reflection on practices and their works. Questions directly relating to course instructors will be excluded.

Strategies
To effectively assess teacher candidates' knowledge and practice of science teaching while revealing their values and positioning, interviewers need to be strategic in asking questions.

1. Interview will be divided into four segments: a) before watching video, b) watching the first segment of video related to content, c) watching the second segment of video related to students' work, and d) wrapping-up questions.
2. Before watching video, the questions will be focused on a. candidates' general responses to the lesson and students in class.
3. While watching video segments, the interviewer will ask instructors to highlight and code candidates' practices with respect to the two focus practices.
4. Interviews will be focused on more candidates' practices than candidates themselves.

#1. Before watching video

Q1. [Broad opening question] Could you tell me about this class?

Q2. Tell me about this lesson.

Q2-1. Where did you get this lesson idea? Why did you choose it?

Q2-2. How did your mentor respond to this lesson? Did he/she like it or dislike it?

Q2-3. How was your relationship with your mentor in planning and teaching lesson in general?

Q3. Did you have any concerns?

Q3-1. How did it affect on this lesson?

Q4. How did this lesson go?

Q4-1. Would you do anything differently if you teach this lesson again?

Q5. What materials (PowerPoints, worksheets, etc.) did you use in this lesson. Can you show them to me?

Q5-1. Can you explain to me how you used these materials?

Q5-2. What do you think were their strengths and weaknesses?

#2. Watching the first segment of video
The interviewer shows the segment that relates to ways of representing scientific knowledge and practice to students through classroom activities.

Q1. Could you help me put this lesson in a context? What is the unit you are teaching, and how does this lesson fit into it?

Q2. What are your more specific goals for this lesson? What were you trying to accomplish there? [the same question to course instructor interviews]

Q3. You stated that …. is your specific goals for this lesson. How did you identify those goals?

Q4. How were you trying to do it? What kinds of approach did you take? [the same question to course instructor interviews]

Q5. What do you like about your approach? Why? [the same one]

Q6. What do you dislike about your approach? Why? [the same one]

Q7. What are the best materials, strategies, or activities that you can think of to teach this topic to students? Why?

Q8. Would you like to use them again in the future? What are the strengths and weaknesses?

Q9. Do you have other kinds of goals having to do with reasoning or skills or understanding the nature of science that you are working on in this lesson even though they are not specific content goals?

Q10. To what extent do you think you are successful at achieving your goals for students?

Q11. [Planned probes] Did you think about [some different ideas or resources that are more likely tied to the reform-oriented instruction]?

#3. Watching another segment of video

The interviewer shows the segment that relates to candidates' assessment about students and their responses about it. Typically this segment may involve in interaction between candidates and students during small group discussion or whole group discussion, questioning, etc.

Q1. Do you have any comment about students that were in this classroom?

Q2. How well do you feel that your students were doing on this content? [common]

> Q2-1. Can you explain to me how students responded to [particular questions in class or on teaching materials]? What were the differences between more and less successful students?

Q3. [recognizing] Did you notice any difficulty that students were having in?

Q4. [interpreting] Where do you think those difficulties came from?

Q5. [responding] How did you address the difficulty that students were having?

Q6. How do you think the ways that you interact with your students during the lesson? Do you like the ways that you did? Why?

Q7. Is there anything that you dislike with respect to ways of interacting with students? Why?

Q8. How were you assessing about students or students' understanding? [common]

Q9. Are there particular students in this video who really stand out for you? Why?

Q10. What do you think it would like to be a student in your classroom? What makes you think so? [common]

#4. Wrap-up questions (Professional identity)

Q1. [positioning with respect to TE] Are there ways the video reflects things that you learned from TE courses or field instructors? [common]

Q2. [Positioning with respect to students & assessment] Are there ways the video reflects things that you learned from your students?

Q3. [Positioning with respect to school professionals] Are there ways the video reflects things that you learned from your mentor teacher? [common]

Q4. How would you characterize the teacher in the video? How did you look like as a teacher to you? [common]

Q5. [identity] Does the video reflect the teacher that you hope to be?

Q6. Let's say, we are using 10-point scale. 10 is the ideal teacher that you would like to be. How would you score yourself now?

Q7. What are the differences? How would you explain the difference between 10 and your score?

APPENDIX D

JEREMIAH INTERVIEW PROTOCOL

#1. Before watching video

[Introduction] This is a clinical interview video with a sixth grade student, Jeremiah. One of the faculty members in science education interviewed him about photosynthesis for about 10 minutes. The purpose is to understand this student's thinking about photosynthesis and plants. (give participants, in particular non-biology majors, to ask questions about content while conducting interviews)

[The announcement] From now on, we are going to show segments of this video and then ask a couple of questions about the student as well as the interviewer.

#1. Name the parts of the plant and their functions [00:00-2:26]

Q1. [After the interviewer's prompt question: Could you tell me what each of those parts does for the plant?] How would you answer this question?

After looking at the rest part of this segment

Q2. [The analysis of J's responses] What did you learn about this student?

Q2-1. How well do you think J understands the parts and the functions of plants?

Q3. [The goals of the interviewer] What do you think the interviewer is aiming for?

Q4. [After J's comments about light and leaves] So what question would you ask next?

#2. How do plants get their food? Comparing plants and human beings [2:27-5:00]

Q1. [After the interviewer's prompt question: Could you explain to me how a plant survives? What kinds of things it does? Like how does it get its food?] How would you answer to this question?

Q1. [After the interviewer's prompt question: Compare the two - How would you compare with the plant in the way you get and use food?] How would you answer to this question?

After looking at the rest part of this segment

Q2. [The analysis of Jeremiah's responses] What are you learning about this student?

Q3. [The analysis of Jeremiah's responses] What do you think this student knows about plants and photosynthesis?

Q3-1. Can you give us the evidence?

Q4. [The analysis of the interviewer's goals and strategies] What do you think the interviewer is aiming for?

Q5. [The strategies of the interview] How is he trying to accomplish this?

Q6. [Critique about the interviewer] Let's say that you had the opportunity to trade spots with the interviewer, what would you do at this point in order to better understand the student?

#3. Remembering class unit on plants, Additional questions (Jeremiah's garden), Planned probe about photosynthesis [5:01-end]

Q1. [The analysis of J's responses] What are you learning about this student?

Q2. [The analysis of Jeremiah's responses] What do you think this student knows about plants and photosynthesis?

Q2-1. Can you give us the evidence?

Q3. [The goals and strategies of the interviewer] Is there anything that you noticed with regard to the interviewer's goals or strategies?

Q4. [The analysis of Jeremiah's responses] What kinds of information that you got from Jeremiah are useful or problematic to you?

Q5-1. Why?

Q5. [Candidates' perspective] Let's say that you were the teacher in that situation, what would you do with students like Jeremiah?

Q5-1. Why?

Q6. [Understanding about formative assessment: Identifying the goals of student learning] Let's say that you are going to teach plants and photosynthesis to the middle school students. How do you identify your goals?

Q7. [Understanding about formative assessment: Evaluating students' learning] How do you evaluate students' understanding about a topic that you are teaching? And when?

> Q7-1. What are some other ways to evaluate student understanding except clinical interviews?

Q8. [Understanding about formative assessment: Responding students' learning] How would you use with the information from the evaluation? What would you see in this video help you think about it?

Q9. What are the best materials, strategies or activities that you can think of to teach that topic to the middle school students?

> Q9-1. Does anything that you saw in the video help you to think about those strategies or approaches?

Q9. What did you learn about using clinical interviews as a tool for teachers?

APPENDIX E

CODING SCHEME FOR CLASSROOM ACTIVITIES

Table 26. Coding scheme for classroom activities

Interpretive codes	Codes	Descriptive codes
Goals		
Cognitive Lower level	G-b1	Reproducing factual information/canonical knowledge
	G-b2	Getting some skills or procedural knowledge
Cognitive Higher level	G-c1	Using a model or principle to explain patterns or examples; using micro level models (invisible) to make connection with macro scale visible phenomena
	G-c2	Developing explanations about the phenomena or solving problems by reasoning through data
	G-c3	Scientific reflection and social implication
Social goal (*these codes are applicable only to interview transcript*)	G-s1	Developing a productive learning community where students can navigate various ideas, experiences, and cultural resources and take risks of being wrong
	G-s2	Providing opportunities for students to interact with peers with the intention of supporting students' learning
Highlighted role of students in activities		
Procedural/ behavioral	S-b1	Following the direction
	S-b2	Filling out the worksheet or taking notes
	S-b3	Paying attention
	S-b4	Giving answers to teachers' questions (passively)
	S-b5	Getting things done
	S-b6	Reproducing the process or mechanism
	S-b7	Practicing problem or skills
	S-b8	Remembering information
Content understanding	S-c1	Thinking critically and analyzing it critically
	S-c2	Going through the thought process/ developing thinking skills
	S-c3	Making connections among concept, prior knowledge and new knowledge
	S-c4	Observing and finding patterns by themselves
	S-c5	Reasoning through data
	S-c6	Asking questions that lead students to further investigate the topic actively
	S-c7	Coming up with explanations grounded in evidence
	S-c8	Developing their own knowledge/ building own ideas
	S-c9	Understanding the purpose of activity and making connections

Table 26 (cont'd)

Social	S-s1	Sharing ideas and communicating with others, for example, during whole-class discussion
	S-s2	Working together as a group/ helping each other
Highlighted role of activities (examples, observations, demonstrations, experiments, etc)		
Motivation	A-b1	Making content interesting or relevant
	A-b2	Getting students excited
	A-b3	Getting students to do something regardless of its role in understanding content
	A-b4	Getting students to remember new information
	A-b5	Simple visualization of concept *without* making connection across scales or phenomena
	A-b6	Solidifying concept by confirming canonical knowledge
Content understanding	A-c1	Getting students to think critically by solving problems (puzzles)
	A-c2	Representing phenomena or models to make connection among observation, patterns, and models
	A-c3	Getting students to find some patterns
	A-c4	Giving students experience that they can build knowledge on
	A-c5	Making connection with previous or next lessons
Social	A-s1	Getting students to work together and help one another
	A-s2	Getting students to see the value of learning the concept

APPENDIX F

CODING SCHEME FOR ASSESSMENT PRACTICE

Table 27. Coding scheme for assessment practice

Elements of practice		**Code**	**description**
Opportunities	Content understanding	O-a	a. Revealing prior experiences or knowledge
	Procedural	O-b	b. Reproducing factual information
	Procedural	O-c	c. Displaying some skills or procedural knowledge
	Content understanding	O-d	d. Applying what students know/learn to explain other examples
		O-e	e. Developing explanations (arguments) through reasoning about experiences without data analysis or pattern finding
		O-f	f. Developing explanations (arguments) through reasoning about data/observations
		O-g	g. reflecting on an/reveal their understanding (mostly for teaching video)
	NA	O-h	h. Little or no opportunity (though ask questions)
Identifying	Content understanding	ID-a	a. What students know and do not know *accurately* (i.e. including partial understanding and misconception)
		ID-b	b. What students know and do not know *broadly or inaccurately*
	Procedural	ID-c	c. Right or wrong answer
		ID-d	d. Completion or incompletion of work (following direction)
	Content understanding	ID-e	e. Patterns of responses from multiple students
	NA	ID-f	f. Little or not identified

Table 27 (cont'd)

Interpreting	Content understanding	IN-a	Explaining about student responses while a. Making connection with teacher's instruction or specific (missing) experiences
		IN-b	b. Making connection with missing experiences in general
		IN-c	c. Making connection with students' prior experience/background knowledge
		IN-d	d. Making connection with personalities or working patterns
	Social	IN-e	e. Making connection with home backgrounds, language, family, and cultural resources (e.g., foster care, recent immigrant family)
		IN-f	f. Making connection with social interaction in classroom (e.g., group dynamics)
	Behavioral	IN-g	e. Attributing to students' attitudes, attentiveness, and behaviors (e.g., learning disability)
	NA	IN-l	j. No interpretation
Responding	Content understanding	R-a	a. Specific ideas of instructional modification which is connected with identified issue (student difficulties) (e.g., suggesting additional experiences such as an experiment)
	Behavioral	R-b	b. Specific ideas of instructional modification that do *NOT* address student difficulties
	Content understanding	R-d	d. General ideas of instructional modifications which *are related to* students' difficulties (e.g., helping them to see the value of learning about it)
	Behavioral	R-e	e. General ideas of instructional modifications which *are not directly related to* students' difficulties (e.g., more hands-on activity, making it relevant, spend more time on it)
	NA	R-f	f. Little or no responses

APPENDIX G

THE RESULTS OF CODING ABOUT CLASSROOM ACTIVITIES

(INTERPRETATION OF PRACTICE)

Table 28 Monica's highlighting of classroom activity practice

	Goals	Role of students	Role of activity
Content understanding	2	9	5
Social	1	5	3
Procedural	0	2	0

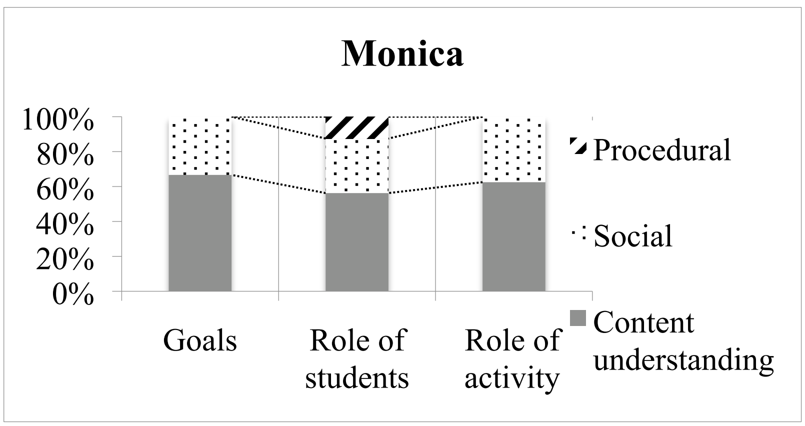


Figure 21. Monica's highlighting of classroom activity

Table 29. David's highlighting of classroom activity

	Goals	Role of students	Role of activity
Content understanding	0	2	3
Social	0	0	0
Procedural/behavioral	2	12	5

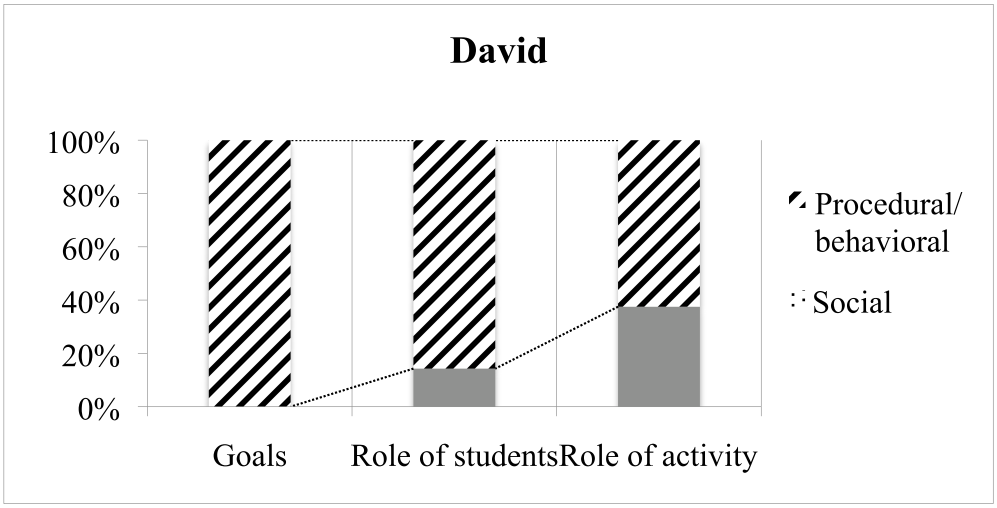


Figure 22. David's highlighting of classroom activity

Table 30. Susie's highlighting of classroom activity

	Goals	Role of students	Role of activity
Content understanding	1	5	0
Social	1	8	2
Behavior	0	2	4

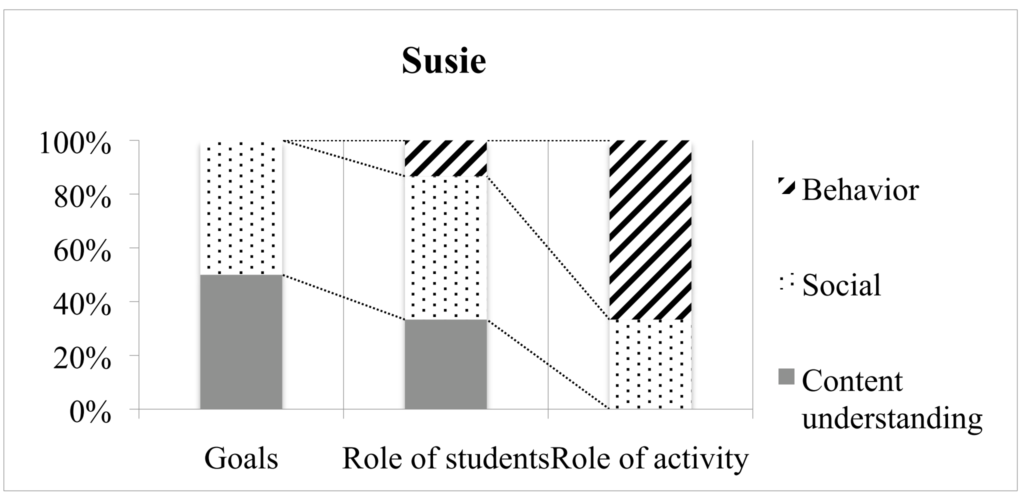


Figure 23. Susie's highlighting of classroom activity

Table 31. Teresa's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	1	1	2
Social	1	2	4
Behavior	2	5	1

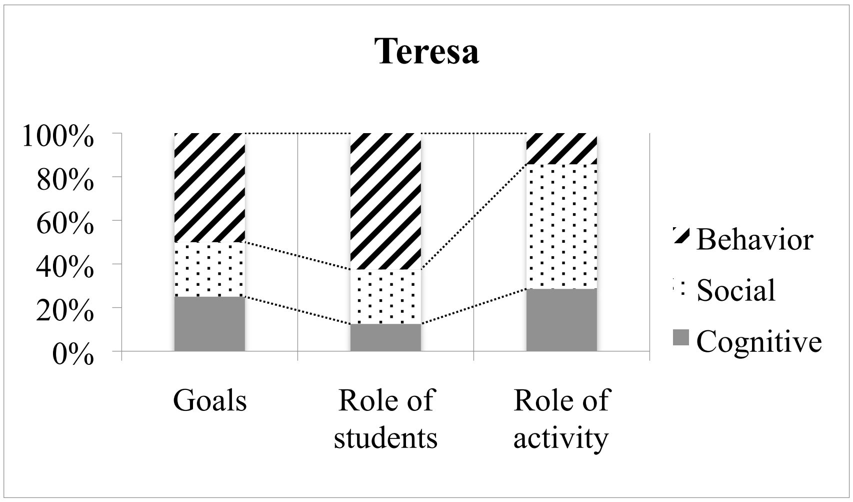


Figure 24. Teresa's highlighting of classroom activity

Table 32. Leslie's highlighting of classroom activity (senior year)

	Goals	Role of students	Role of activity
Cognitive	3	12	4
Social	0	0	0
Behavior	0	2	1

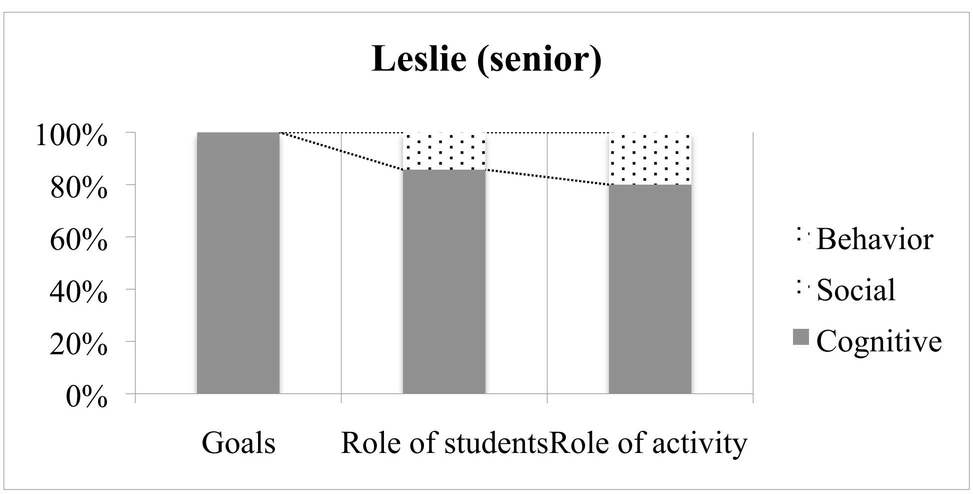


Figure 25. Leslie's highlighting of classroom activity (senior year)

Table 33. Leslie's highlighting of classroom activity (intern year)

	Goals	Role of students	Role of activity
Cognitive	1	3	3
Social	0	1	0
Behavior	0	0	2

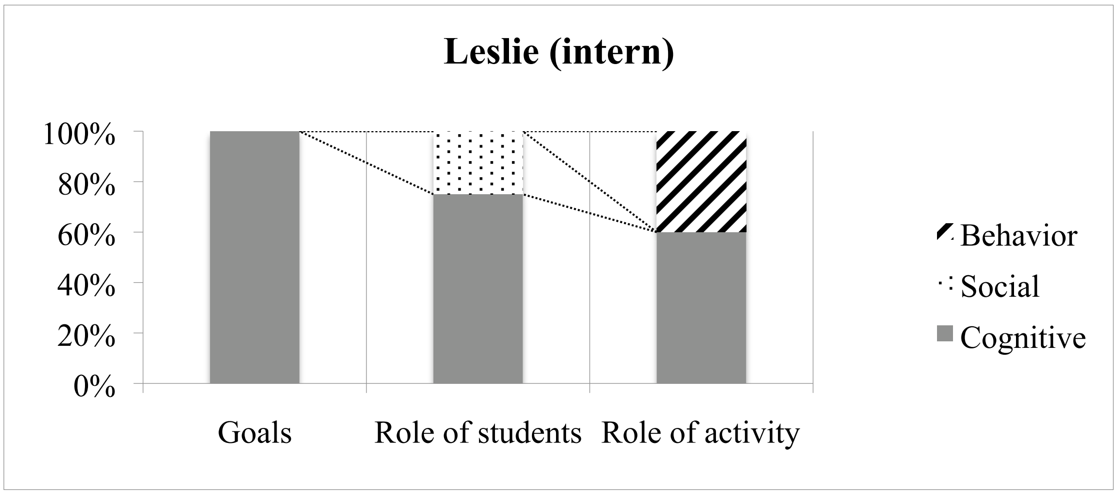


Figure 26. Leslie's highlighting of classroom activity (intern year)

Table 34. Adam's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	1	12	4
Social	0	5	1
Behavior	0	0	0

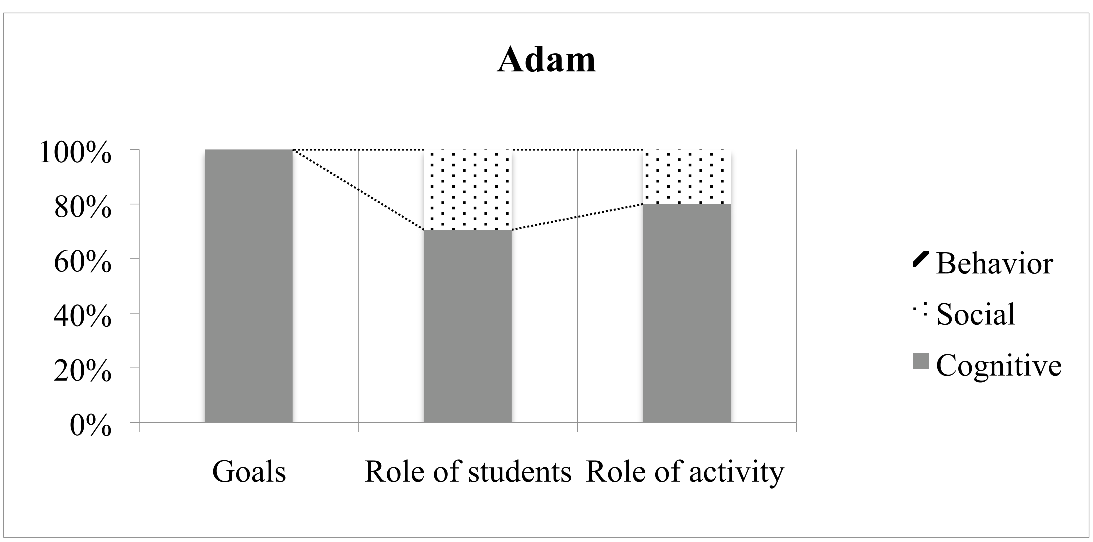


Figure 27. Adam's highlighting of classroom activity

Table 35. Scott's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	2	7	1
Social	0	0	0
Behavior	0	1	0

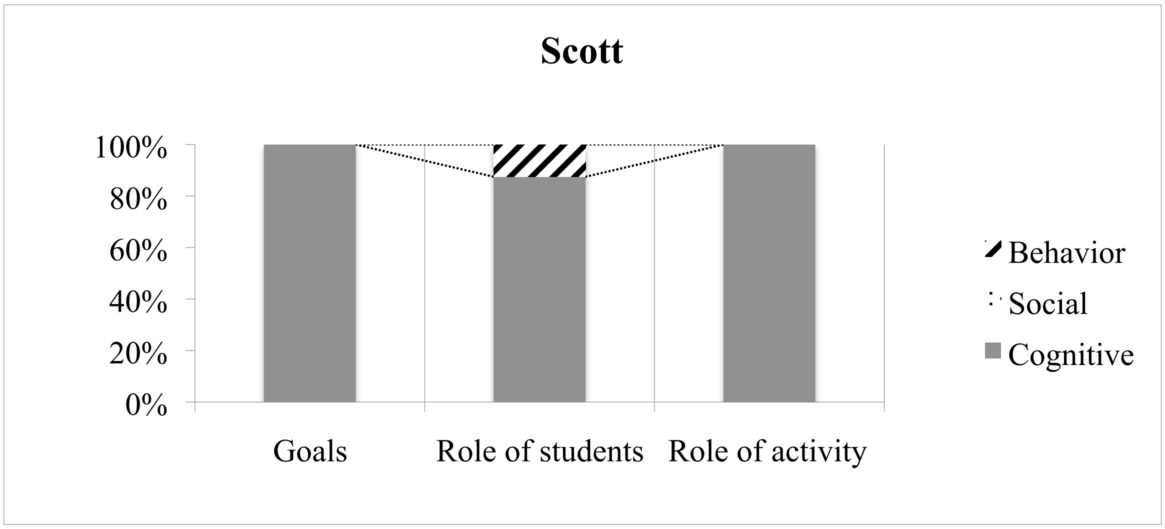


Figure 28. Scott's highlighting of classroom activity

Table 36. Shannon's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	0	1	1
Social	0	0	0
Behavior	1	2	2

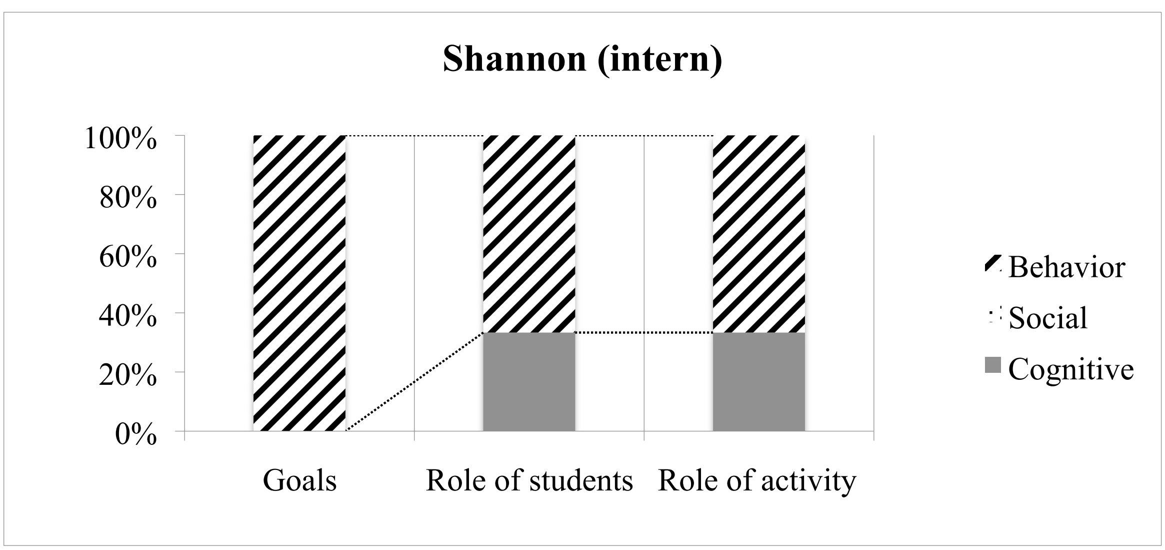


Figure 29. Shannon's highlighting of classroom activity

Table 37. Alisa's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	0	2	0
Social	0	2	0
Behavior	1	3	8

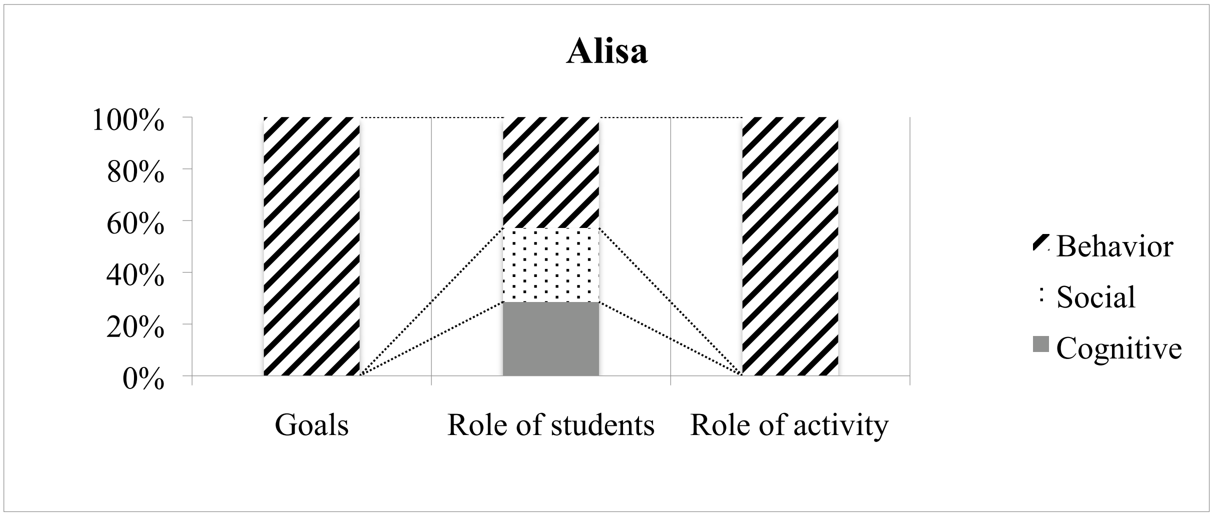


Figure 30. Alisa's highlighting of classroom activity

Table 38. Lori's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	2	2	1
Social	0	0	3
Behavior	0	1	4

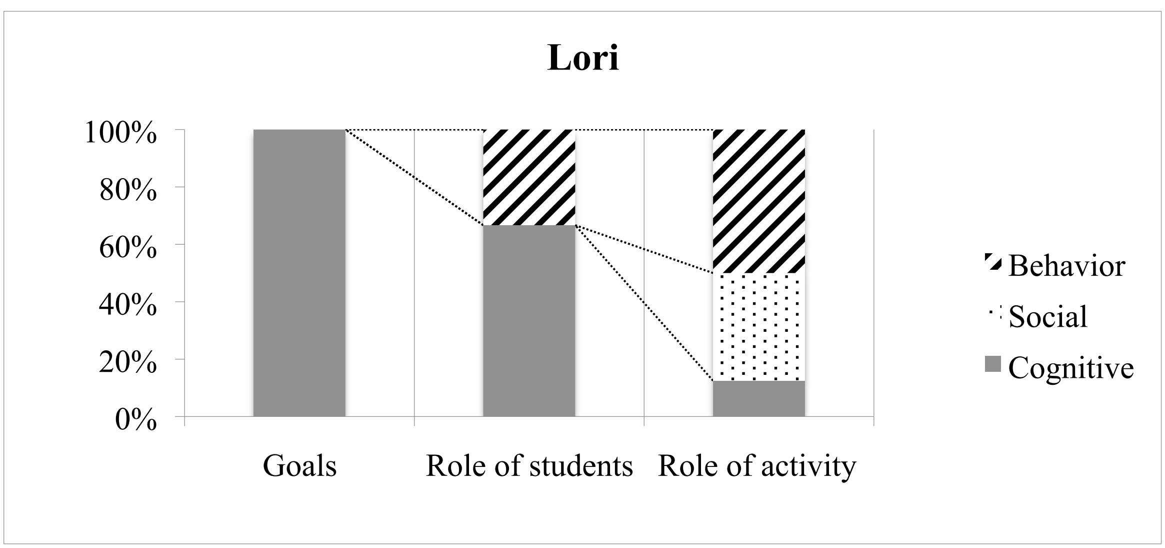


Figure 31. Lori's highlighting of classroom activity

Table 39. Lynn's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	0	1	0
Social	0	0	0
Behavior	1	1	3

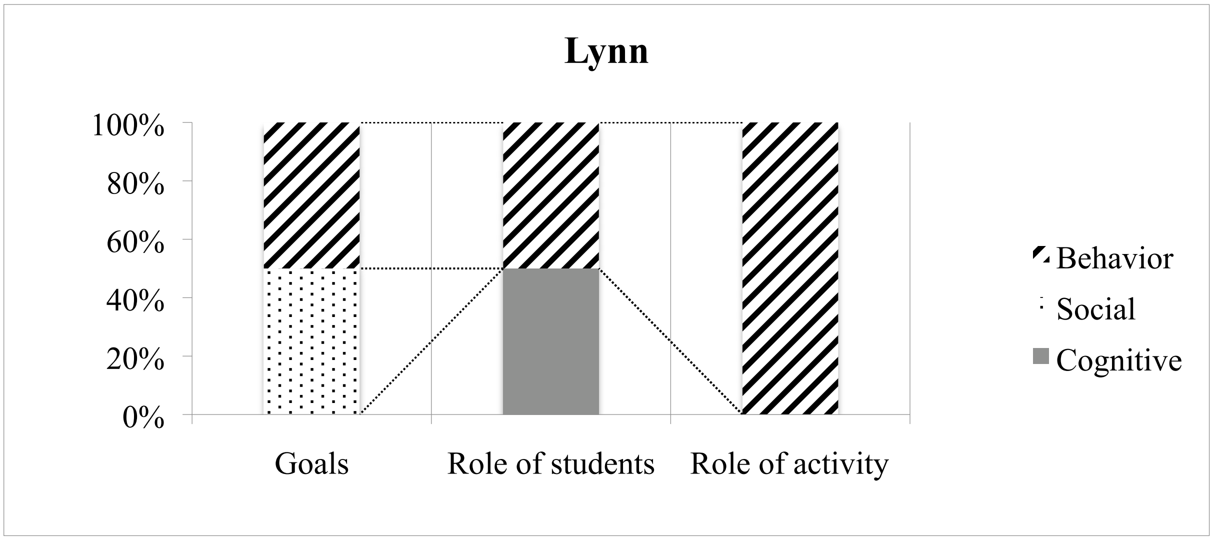


Figure 32. Lynn's highlighting of classroom activity

Table 40. Stella's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	0	1	2
Social	0	1	0
Behavior	2	5	4

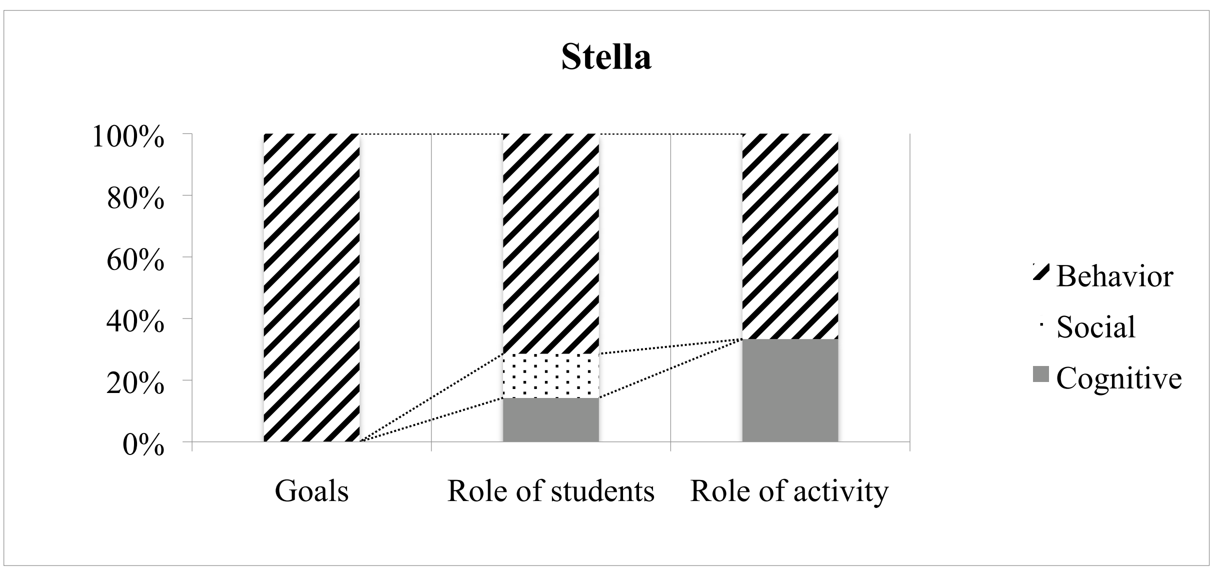


Figure 33. Stella's highlighting of classroom activity

Table 41. Kevin's highlighting of classroom activity

	Goals	Role of students	Role of activity
Cognitive	0	0	0
Social	0	0	0
Behavior	2	0	8

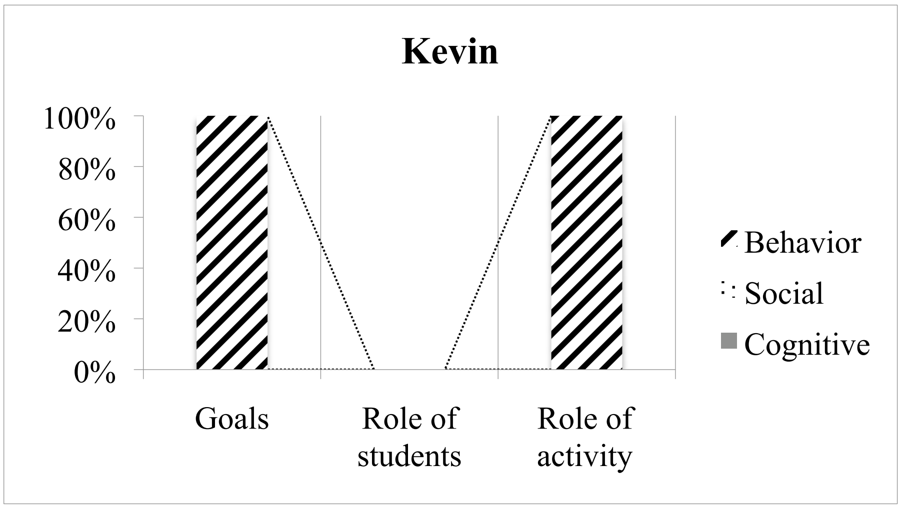


Figure 34. Kevin's highlighting of classroom activity

APPENDIX H

DAVID'S WORKSHEET: DNA REPLICATION ACTIVITY

Part II - Replicating a DNA molecule

4. Forming an original DNA molecule

A. Disassemble the DNA model formed in Part I. Construct a DNA model as shown in Figure 5.

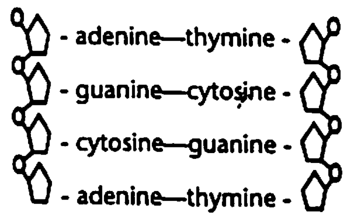


Figure 5 - DNA example for replication procedure

A. Remove the bottom half (three "steps") of the DNA ladder you made in Part I. (on Friday)

B. Rearrange the removed pieces into six nucleotides as follows:
   1. Remove the hydrogen bonds
   2. Separate each white phosphate tube from one black deoxyribose sugar.
   3. Each nucleotide is a trio of one colored base attached to one black deoxyriobose sugar which is attached to one white phosphate tube.

C. Connect each remaining individual nitrogen base to a sugar piece, and add one phosphate tube to that sugar as well. Remember that a phosphate-sugar-nitrogen base is called a nucleotide. You should have eight nucleotides when you are finished.

5. Starting the replication process - "unzipping"

A. A DNA molecule begins to replicate itself by breaking the hydrogen bonds between the nitrogen bases. Once several consecutive bases have been split, the DNA strand gives the appearance of being "unzipped."

B. Break the bottom three hydrogen bonds of the model you have just formed, leaving the first connection together.

APPENDIX I

MONICA'S WORKSHEET: INCOMPLETE/CO-DOMINANCE ACTIVITY

Easter Egg Genetics Lab

In this lab, the outside of the egg represents the organism's genotype and the jellybeans inside represent the organism's phenotype. Each half of the egg represents one allele (ex. if the egg has two red halves, the genotype is RR). Read through the scenarios below and complete the problems and questions.

Purple and Green Eggs (Purple = P ; green = p)

Bugs Bunny wants to be romantic so he brings his girlfriend Lulu Bunny two flowering plants. One of the plants is homozygous dominant for purple flowers and the other is homozygous dominant for green flowers. In the spring Bugs plants the flowers outside and by the end of the summer he realize that the plants have reproduced. Create a Punnett square and record the genotypes and phenotypes of each offspring.

Purple Plant – Genotype:_______ Phenotype:_______
Green Plant – Genotype:_______ Phenotype:_______
Offspring 1 - Genotype:_______ Phenotype:_______
Offspring 2 - Genotype:_______ Phenotype:_______
Offspring 3 - Genotype:_______ Phenotype:_______
Offspring 4 - Genotype:_______ Phenotype:_______

How does this type of inheritance relate to Mendel's Law of Dominance?

If Bugs allows the F1 generation (the offspring in the Punnett square above) to reproduce, what will be the genotype and phenotype ratios of their offspring?
Genotype: _______PP: ________Pp:________pp
Phenotype:

Red and White Eggs (Red = R ; White = r)

Roger Rabbit is homozygous dominant for red fur. His wife Lola Rabbit is homozygous recessive for white fur. They produce four offspring. Create a Punnett square and record the genotypes and phenotypes of each offspring.

Roger – Genotype:_______ Phenotype:_______
Lola – Genotype:_______ Phenotype:_______
Offspring 1 - Genotype:_______ Phenotype:_______
Offspring 2 - Genotype:_______ Phenotype:_______
Offspring 3 - Genotype:_______ Phenotype:_______
Offspring 4 - Genotype:_______ Phenotype:_______

What would the genotype and phenotype ratios be if two pink rabbits mated?

Genotype Ratio _______ RR: _______Rr: _________rr

Phenotype Ratio

What are some differences that you see between this type of inheritance and the dominant/recessive pattern you saw last week?

Can you think of any examples of this type of inheritance that you've seen before? If so, what have you seen?

Orange and Blue Eggs (Orange = O ; Blue = B

One day Rabbit and Pooh were combing the forest for honey pots when they saw a nest of baby birds up high in the tree. On the edge of the nest are the new hatchling's parents. One parent is homozygous for blue feathers and the other is homozygous for orange feathers. Create a Punnett square to discover what the offspring looked like.

Blue Parent – Genotype:_______ Phenotype:_______
Orange Parent – Genotype:_______ Phenotype:_______
Offspring 1 - Genotype:_______ Phenotype:_______
Offspring 2 - Genotype:_______ Phenotype:_______
Offspring 3 - Genotype:_______ Phenotype:_______
Offspring 4 - Genotype:_______ Phenotype:_______

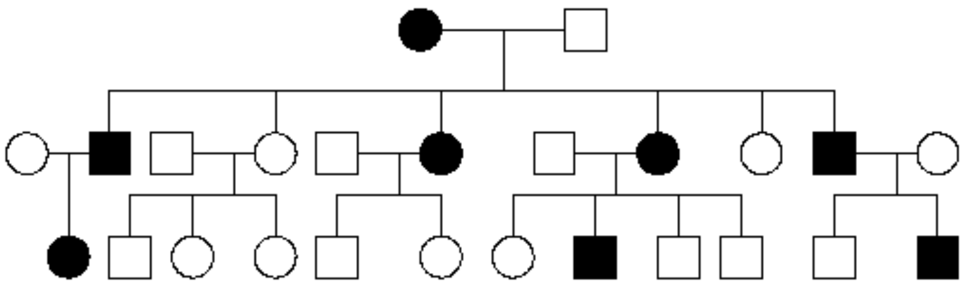
What are some differences that you notice between this type of inheritance and the dominant/recessive pattern you learned about last week?

Can you think of any examples of this type of inheritance that you've seen before? If so, what have you seen?

APPENDIX J

ADAM'S WORKSHEET: PEDIGREE NOTES

Pedigree Notes



Affected Males:

Affected Females:

Normal Males:

Normal Females:

Parents and children:

Siblings:

Twins:

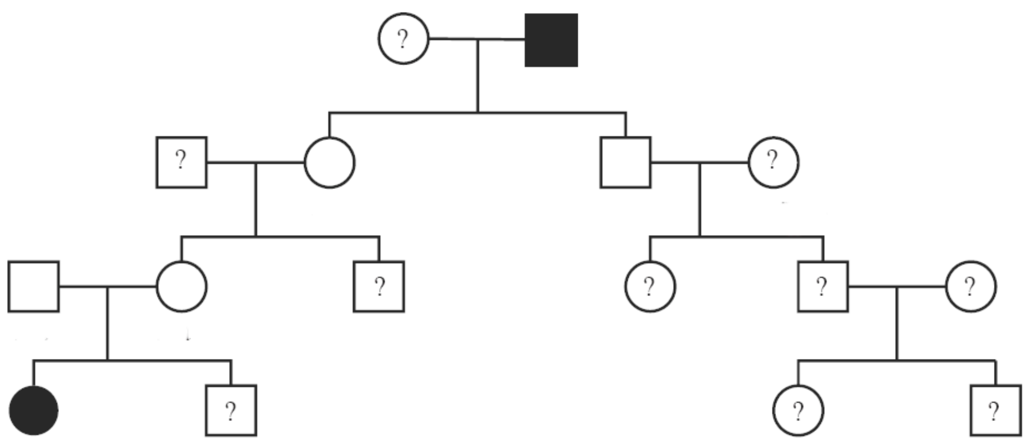
APPENDIX K

ADAM'S WORKSHEET: COMPLETE THE PEDIGREE

Name:

Complete the Pedigree

Write the genotypes next to the following pedigree to show how the filled individuals are affected by a phenotype that is controlled by a **homozygous recessive genotype** and the empty individuals are unaffected. Ignore the question marks.



APPENDIX L

THE RESULTS OF CODING OF DESIGNATED IDENTITIES THROUGHOUT TWO YEARS

Table 42. David's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills	2	3	1
	Engaging in scientific practices			
	Developing learning environment			
The role of students	Motivational	2		
	Content understanding			
	Social	1		3
The role of activities	Motivational	7	2	
	Content understanding	1	1	1
	Social			

Table 43. Monica's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills			
	Engaging in scientific practices	1	3	3
	Developing learning environment	1	4	
The role of students	Motivational			
	Content understanding	1	3	3
	Social	1	2	1
The role of activities	Motivational	1		
	Content understanding	2	1	NA
	Social			

Table 44. Adam's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills	2	3	1
	Engaging in scientific practices			
	Developing learning environment			
The role of students	Motivational	2		
	Content understanding			
	Social	1		3
The role of activities	Motivational	7	2	
	Content understanding	1	1	1
	Social			

Table 45. Leslie's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills			
	Engaging in scientific practices	3	3	2
	Developing learning environment	1		
The role of students	Motivational			
	Content understanding		1	4
	Social	1	1	1
The role of activities	Motivational	2		
	Content understanding	4	1	1
	Social			

Table 46. Susie's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills			1
	Engaging in scientific practices	1	1	
	Developing learning environment		1	
The role of students	Motivational			
	Content understanding	2	3	2
	Social		2	1
The role of activities	Motivational			
	Content understanding	1	2	
	Social			

Table 47. Teresa's designated identities from senior to intern year

		The beginning of senior year	The beginning of the internship year	The end of internship year
Goals	Delivering content and skills	2	1	2
	Engaging in scientific practices			
	Developing learning environment		1	
The role of students	Motivational		1	
	Content understanding	(2)		1
	Social	2	1	
The role of activities	Motivational		1	2
	Content understanding			
	Social	2	2	

APPENDIX M

THE RESULTS OF CODING ABOUT ASSESSMENT PRACTICES

Cohort I

Table 48. David's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
802 UP1	1	b	I	correct/simple	c	l	e
	2	b	I	correct/simple	c	l	
	3	b	I	incorrect/simple	c	g	
	4	b	I	correct/simple	c	c	
	5	b	I	mixed/simple	c	?	
	6	b	I	incomplete	d, f	l	
804 Inquiry Report	7	b	G	correct/simple	b	c	f
	8	d	G	inaccurate/complicated	c	l	d
	9	d	G	mixed/simple	c	l	f
	10	f	G	inaccurate/complicated	b	l	f
	11	d	G	correct/simple	c	l	f
Jeremiah's int.	12				a	g	e
Teaching video interview	13				d	g	b
	14				f	b	b

Table 49. Monica's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
802 UP1	1	b/d	I	incorrect/simple	b	f	R-d
	2	b/d	I	mixed/simple	b	d	
	3	b/d	I	correct/simple	b	e	
804 Inquiry Report	4	b	G	inaccurate/simple	a	a, f	a
	5	f	G	accurate/complicated	b	a, f	a
	6	b, f	G	correct/simple	b	a	a
	7	b, f	G	correct/simple	d	l	d
	8	d	G	inaccurate/complicated	b	l	f
	9	d	G	inaccurate/complicated	a	a	a
Jeremiah's Int	10				a	c	a
Teaching video	11		G		a	a	a
	12		G		a	a	a
	13		G		a		a
	14		G		a	a	d

Table 50. Susie's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
802 UP1	1	b, c, d	I	accurate/complicated	b	l	R-e
	2	b, c, d	I	inaccurate/complicated	c, d	g (?)	
	3	b, c, d	I	no response	d	g	d
804 Inquiry Report	4	f	G	generating ideas	b	a	a
	5	f	G	generating ideas	a	l	d
	6	c	G	inaccurate/simple	a	c	d
	7	f	G	inaccurate/complicated	a	a	a
	8	d	G	inaccurate/complicated	a	l	a
	9	f	G	inaccurate/complicated	a	a	d
Jeremiah	10				a	c	e
Teaching video	11		G		NA		
	12		G		b	a/d	d

Table 51. Teresa's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
802 UP1	1	b (?)	G	% (grading level)	c	d, g	
	2	b (?)	I	% (grading level)	b, d	d	
	3	b (?)	I	% (grading level)	c	g	
	4	b (?)	G	incorrect/simple	f	g	
	5	b (?)	I	No response	f	g	
	6	b (?)	I	% (grading level)	f	g	
804 Inquiry Report	7	i	G	No response	f	g	f
	8	i	G	No response	f	l	e
	9	c	G	inaccurate/simple	b	l	d
	10	f	G	inaccurate/complicated	a	b	d
	11	b	G	accurate/simple	f	l	e
	12	b	G	accurate/simple	c	l	e
Jeremiah	13				b	g	e
Teaching video	14		G		b	l	b
	15		G		b	d/g	e
	16		G		f	l	e

Cohort II
Table 52. Leslie's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
TE407 LP1	1	b, f	I	correct/simple	c	c, g	f
	2	b, f	I	inaccurate/simple	d	a	a
	3	b, f	I	inaccurate/simple	a	a	a
TE407 LP2	4	b	G	correct/simple	b	a	
	5	b	G	incorrect/simple	a	a	a
	6	f	G	inaccurate/complicated	b	a	a
804InquiryReport	7	a	G	inaccurate/simple	b	e	
	8	a	G	generating questions	b	a	a
	9	f, d	G	accurate/complicated	a	a, f	a
	10	b, d	G	accurate/simple	b	l	a
	11	b	G	inaccurate/simple	b	a	a
	12	b, d	G	inaccurate/complicated	b	l	d
804 ApplicationReport	13	b	G	inaccurate/simple	b	l	
	14	b, c	G	accurate/simple	b	l	a
	15	d	G	inaccurate/complicated	a	a	a
	16	d	G	inaccurate/simple	e	a	a
	17	d	G	inaccurate/complicated	a	l	a
804 teaching video interview	18		G	NA	a	g, a	a
	19		G	NA	a	NA	a

Table 53. Shannon's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
407 LP1	1	f	I	mixed/simple	b, d	g	e
	2	f	I	correct/simple	c, d	l	e
	3	f	I	mixed/simple	c, d	g	e
407 LP2	4	b	G	inaccurate/simple	b, d	a	e
	5	f	G	inaccurate/complicated	b, d	b	e
407 Jeremiah	6		I		b/c	i/k	d
	7		I		b	c/i	d
	8		I		c/d	g/i	d
407 Teaching Video	9		G		a	a	e
	10		G		a	a	a
804InquiryReport	11	b, f	G	inaccurate/complicated	b	l	
	12	b	G	accurate/complicated	f	l	d
	13	b, c	G	NA	d	l	d, e
804 ApplicationReport	14	f	G	inaccurate/complicated	a	l	d, e
	15	c	G	incorrect/simple	f	l	b
	16	c	G	incorrect/simple	NA	l	e
	17	b	G	incorrect/simple	c	l	b
804TeachingVideo interview	18		G		a	a	a

Table 54. Adam's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
804InquiryReport	1	b	G	correct/simple	f	l	d
	2	a	G	generating question	f	l	e
	3	b	G	correct/simple	d	l	f
	4	b	G	inaccurate/simple	c	l	e
	5	d	G	Not reported	c	l	e
	6	d	G	Not reported	c, f	g, l	f
804 ApplicationReport	7	c	G	correct/simple	c	c, f	e
	8	d	G	correct/simple	b	f	e
	9	d	G	inaccurate/complicated	f	l	e
	10	d	G	accurate/simple	d	l	e
Teaching video interview	11	e	G	inaccurate/complicated	b	b	e

Table 55. Alisa's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
804InquiryReport	1	b	G	accurate/simple	b	l	d
	2	e	G	accurate/complicated	b, d	a, g	d
	3	e	G	inaccurate/complicated	b	b	a
	4	c	G	correct/simple	c	a, f	a, b
	5	b	G	incorrect/simple	b, c	g	a, b
	6	f	G	inaccurate/complicated	b, c	g	d
	7	f	G	accurate/complicated	b	l	e
	8	f	G	inaccurate/complicated	b	g	e
804 Application Report	9	b	G	accurate/simple	b	l	d
	10	e	G	inaccurate/complicated	b	a, b, g	d
	11	e	G	inaccurate/complicated	b	b	a
	12	b	G	accurate/simple	a	a	a
	13	b	G	correct/simple	c	l	a
	14	b	G	Correct/simple	a	l	a, b
	15	d	G	Correct/complicated	b	l	a, d
Teaching video interview	16		G		d	g	b

Table 56. Mary's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
TE407 LP1	1	d	I	correct/simple	c	g	e, d
	2	d	I	incorrect/complicated	b	g	
	3	d	I	incorrect/complicated	b	g	
TE407 LP2	4	e	G	inaccurate/complicated	a	a	d, e
	5	d	G	mixed/complicated	a	a	a
Jeremiah Int.	1		I		b	h	d
	2		I		b	N/A	e
	3		I		b	k	b

Table 57. Kevin's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
TE407 LP1	1	d	I	inaccurate/complicated	a	l	E
	2	d	I	inaccurate/complicated	b	l	
	3	d	I	incorrect/complicated	c	l	
	4	d	G	mixed/complicated	a	l	
TE407 LP2	5	c	I	N/A	c	l	E
	6	c	I	N/A	c	l	
	7	c	I	N/A	f	l	E, b
	8	c	G	mixed/complicated	c	l	
Jeremiah	1				a		a
	2				a		a
	3				a	g	e

Cohort III

Table 58. Lori's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
408 LP1	1	c	I	Inaccurate/complicated	a	a, g	e
	2	c	I	accurate/complicated	a	l	
	3	c	I	Inaccurate/complicated	a	d	
408 3Days	4	g	I	Argument through reasoning/inaccurate & simple	a	l	
	5	f	I	developing a model; inaccurate/complicated	a	e	
	6	d	I	incorrect/complicated	a	a	
	7	g	G	inaccurate/simple	a	a, j	
	8	f	I	accurate/complicated	a	l	
	9	d	I	correct/complicated	a	a	
	10	g	I	accurate/complicated	a	a	a
	11	f	I	accurate/complicated	a	l	
	12	f	G	accurate	b	l	
	13	d	I	correct/complicated	a	l	
Teaching Video Interview	14		G		b	a	NA
	15		G		a	a	a

Table 59. Scott's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
408 LP1	1	d	I	inaccurate/complicated	a	l	D, a
	2	d	I	inaccurate/complicated	a	l	
	3	d	I	accurate/complicated	a	l	
408 3Days	4	O-d	I	incorrect/complicated	ID-a	IN-a	R-a
	5	O-d	I	Correct/simple	ID-d	IN-l	
	6	O-d	I	correct/complicated	ID-a	IN-l	a/c
	7	O-d	I	correct/simple	ID-d	IN-l	
	8	O-d	I	correct/complicated	ID-b	IN-l	
	9	O-d	I	Correct/simple	ID-a	IN-l	

Table 60. Stella's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
408 LP1	1	b	I	correct/simple	c, d	l	B
	2	b	I	incorrect/simple	c, d	g	E
	3	b	I	incorrect/simple	c, d	g, b	
408 3Days	4	a, b	I	inaccurate/complicated	d	l	e
	5	b	I	inaccurate/complicated	d	l	a
	6	b	I	inaccurate/simple	b	i	
	7	b	I	inaccurate/simple	d	l	b
	8	c	I	No response	d	g	
	9	a,b	I	inaccurate/simple	d	l	
	10	b	I	inaccurate/complicated	f	l	a
	11	b	I	inaccurate/simple	c	g	
	12	b	I	correct/simple	d	g	b
	13	c	I	inaccurate/simple	c	g	
	14	a,b	I	accurate/simple	d	l	
	15	b	I	accurate/complicated	d	l	a
	16	b	I	inaccurate/simple	c	l	b
	17	b	I	accurate/simple	d	l	b
	18	c	I	accurate/simple	d	g	
Teaching video interview	19				c	b	NA
	20				c	g	a

Table 61. Lynn's assessment practices

Data source	Unit #	Opportunity	Individual/group	Characteristics of student responses	Identifying	Interpreting	Responding
408 LP1	1	b, c, d	I	inaccurate/complicated	b, c	l	E, d
	2	b, c, d	I	inaccurate/complicated	b,c	l	
	3	b, c, d	I	inaccurate/complicated	c	l	
408 3Days	4	b, c	I	Correct/simple	c	g	E, d
	5	b, c	I	incorrect/simple	b	g	
	6	b, c	I	incorrect/simple	c	g	
Teaching video interview	7				a	l	?
	8				c	c	?

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