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Exploring the relationship between beginning science teachers' practices, institutional constraints, and adult development

Jesse Wilcox

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Exploring the relationship between beginning science teachers’ practices, institutional constraints, and adult development

by

Jesse Lee Wilcox

A dissertation submitted to the graduate faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY

Major: Education

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Iowa State University
Ames, Iowa

2017

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DEDICATION

For Kendra, James, Elizabeth, and Katherine.
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ABSTRACT

This year-long study explored how ten teachers—five first year, five second year—acclimated to their new school environment after leaving a master’s level university science teacher preparation program known for being highly effective. Furthermore, this study sought to explore if a relationship existed between teachers’ understanding and implementation of research-based science teaching practices, the barriers to enacting these practices—known as institutional constraints, and the constructive-developmental theory which explores meaning-making systems known as orders of consciousness. As a naturalistic inquiry mixed methods study, data were collected using both qualitative (e.g., semi-structured interviews, field notes) as well as quantitative methods (e.g., observation protocols, subject/object protocol). These data sources were used to construct participant summaries and a cross-case analysis. The findings from provide evidence that teachers’ orders of consciousness might help to explain why understanding research-based science teaching practices are maintained by some new teachers and not others. Additionally, this study found the orders of consciousness of teachers relates to the perceptions of institutional constraints as well as how a teacher chooses to navigate those constraints. Finally, the extent to which teachers implement research-based science teaching practices is related to orders of consciousness. While many studies have focused on what meaning teachers make, this study highlights the importance of considering how teachers make meaning.
CHAPTER 1: INTRODUCTION

Effective Teaching: Easy from the outside, complex from the inside

The general public, business leaders, and policy makers inaccurately perceive effective teaching to be easy (Berliner, 1992; Lortie, 1975). Perhaps a familiarity with the profession—developed from approximately 13,000 hours in close proximity to K–12 teachers—leads many to believe that effective teaching is not very difficult (Lortie, 1975). Munby, Russell, & Martin (2001) suggest that apparent ease of teaching is likely due to students’ limited vantage point,

As with any good performance, teaching looks easy. When we witness a near perfect performance in, say, the long program of a figure-skating competition, we recognize the many hours of intensive work that lie behind the apparent ease of execution under demanding circumstances. But we do not typically do this of teaching (p. 895).

Much like an audience of a figure-skating competition, students “do not receive invitations to watch the teachers’ performance from the wings; they are not privy to the teachers’ private intentions and personal reflections of classroom events” (Lortie, 1975, p. 62).

Students’ limited vantage point results in common false conceptions of effective teaching such as: 1) subject matter knowledge is sufficient, 2) following the textbook or curriculum guide is all that is required, 3) teachers learn how to teach on-the-job (Berliner, 2000; Clough, Berg, & Olson, 2009; Pushkin, 2001; Sykes, Bird, & Kennedy, 2010). When these misconceptions are held by policy makers, Clough et al. (2009) observe: “These [perceptions] manifest themselves in shallow traditional and alternative teacher licensure programs, back-to-basics fads, high-stakes testing that reflects trivial knowledge, and simplistic business model approaches to education” (p. 822).
Despite the deceptively simplistic appearance, effective teaching is a complicated endeavor with teachers making hundreds of non-trivial teaching decisions each day that greatly impact the learning of children (Berliner, 1987; Clough et al., 2009; Dewey, 1929). A considerable amount of content and pedagogical knowledge (Shulman, 1987) is required to accomplish instructional goals in the complex social environment of the classroom (Berliner, 1992). For example, effective teachers keep in mind the purposes of the lesson, identify and use what students know, and logically scaffold students through effective questioning strategies to bridge the gap between the current understanding and desired understanding—all while extensively monitoring student engagement and making necessary adjustments.

**Current State of Science Teaching**

The pervasiveness of simplistic notions of teaching have contributed to the perpetuation of traditional practices often used in schools—lecturing, emphasizing memorization of scientific facts, assigning worksheets and readings devoid of critical thinking (Clough et al., 2009; Goodlad, 1983, 2004; Herman, Clough, & Olson, 2013a; Tillotson & Young, 2013). Many researchers have noted a discrepancy between research-based science teaching practices and traditional practices often observed in schools (AAAS, 1990; Clough et al., 2009; Coble & Koballa, 1996; Goodlad, 1983, 2004; Herman et al., 2013a; NRC, 1996, 2012, 2013; Schweingruber, Duschl, & Shouse, 2007; Tillotson & Young, 2013). Research-based science teaching practices include asking thought-provoking questions, engaging students in meaningful activities that require student decision-making, eliciting and using student ideas to drive investigations, scaffolding students towards fundamental science ideas, etc. (AAAS, 1990; Clough et al., 2009; Coble & Koballa, 1996; Herman, et al., 2013a; NRC, 1996, 2012, 2013;
Schweingruber et al., 2007; Tillotson & Young, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). As a result of the proliferation of traditional practices, many problems regarding the current state of science teaching have been documented by the science education literature.

Many people have the same science misconceptions in elementary school as they do in college and adulthood despite being taught otherwise in school (Annenberg/CPB, 1997). Misconceptions develop when learners inaccurately use their prior knowledge to make sense of new information (Appleton, 1993; Ausubel, 1964; Driver & Easley, 1978). For example, many students wrongly believe the Earth’s seasons are caused by the Earth being closer to the Sun in the summer and further away in the winter (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Tsai and Chang 2005; Wilcox & Kruse, 2012). These ideas are likely derived from their own experiences with heat sources (e.g., fire, stove, heat vents) and distance. Because misconceptions, such as the seasons example, are often supported by students’ experiences in the natural world, they are very difficult to change (Annenberg/CPB, 1997; Posner, Strike, Hewson, & Gertzog, 1982).

Unfortunately, telling or showing students their ideas are wrong does little to change them (Appleton, 1993; Driver & Easley, 1978; Posner et al., 1982). Nonetheless, secondary teachers spend 75% of class time lecturing (Goodlad, 1983, 2004) and this heavy emphasis on lecture carries with it a dual-burden. If teachers do most of the talking, then they: 1) may not know students’ misconceptions (Goodlad, 1983) and 2) rarely have the opportunity to employ research-based teaching practices necessary to help students accurately make sense of science ideas (Annenberg/CPB, 1997; Goodlad, 1983, 2004).
As students in science classrooms spend a majority of time doing seatwork and passively listening to the teacher talk, science lessons are rarely characterized by intellectual rigor (Goodlad, 1983, 2004; Weiss, Pasley, Smith, Banilower, & Heck, 2003). When science teachers do ask questions, most elicit simplistic answers from students (e.g., yes/no, fill-in-the-blank) rather than thought-provoking responses that promote conceptual understanding (Weiss et al., 2003; Windschitl et al., 2012). With students devoting significant amounts of time to listening to a teacher or working alone, collaboration in the science classroom is almost non-existent, and students are rarely encouraged to explain their thinking (Goodlad, 1983, 2004; Weiss et al., 2003; Windschitl et al., 2012). Consequently, students have limited opportunities to wrestle with ideas by investigating their questions, distinguishing important concepts from supporting details, articulating current understanding, and connecting new information to existing knowledge. In traditional classrooms, students often learn about science, but rarely get to do science, which Yager (1988) refers to as learning the rules of the game but “never getting to play the game” (p.77).

Another reason students have limited experience with scientific investigations is that the science textbooks often govern teachers’ selection of content (Yager & Penick, 1983), despite being criticized for covering too many topics and thereby glossing over important concepts (Schmidt et al., 1999). For example, the average US eighth grade science textbook has between 50 to 65 topics, whereas Japan and Germany have just 15 and 7 topics respectively (Schmidt et al, 1999). The emphasis on discrete, disconnected topics in textbooks often results in teachers finding a host of topic-related activities rather
than logically sequencing meaningful classroom activities that scaffold students to deeply understand fundamental science ideas (Olson & Ihrig, 2011; Windschitl et al., 2012).

The decisions teachers make—whether they are effective or not—greatly impact the learning of their students (Good, Biddle, & Brophy, 1975; Goodlad, 1990). Tillotson & Young (2013) explain,

. . . the evidence is clear that science teachers who exhibit more [research]-based teaching practices can have a powerful effect on improving students’ attitudes toward science, their likelihood of considering a career in science, and how they envision science influencing their everyday life. This is in stark contrast to science classrooms where teachers rely on a dissemination model of teaching with emphasis placed on memorizing factual information that results in students seeing few connections between science and their everyday life (p 159).

Students deserve effective science teachers that understand and implement research-based teaching practices. For the current state of science education to change, effective teacher education is a critical component.

**The Need for Effective Teacher Education**

Shifting the culture of teaching from less complex traditional practices to the intricate practices of highly effective research-based science teaching requires deliberate and purposeful teacher education. Nonetheless, one proposed solution to address the current state of science education is to reduce the requirements of teacher education and increase the role of peer mentoring so new teachers can learn on the job (Paige, 2003). However, this sort of solution eschews the complexities of teaching and makes little sense. For example, Goodlad (1990) writes:

Had there been recognition and understanding [of the array of circumstances impinging on teachers’ performance], surely reformers would not have prescribed once again that old bromide: Have today's teachers mentor tomorrow's. Schools and teachers are not very effective, said report after report. Yet according to conventional wisdom, the best way to ensure a competent teaching force is to place neophytes in those same schools with those same teachers. Surely we can come up with better remedies than this (p. xiii).
While effective mentoring can provide support to new teachers (Bianchini, 2012; Luft, Dubois, Nixon, Campbell, & Bang, 2014), learning how to effectively navigate the complexities of teaching requires highly effective teacher education (Tillotson & Young, 2013).

Research on effective science teacher education reveals that the duration, coherence, effective modeling of the science educator, and emphasis on research-based practices greatly impact the extent to which graduates of the program can understand and implement research-based science teaching practices (Bergman, 2007; Clough et al., 2009; Thompson, Windschitl, & Braaten, 2013; Tillotson & Young, 2013).

Teachers need time to deeply understand and begin to implement effective science teaching (Bergman, 2007; Feiman-Nemser, 2001; Tillotson & Young, 2013). Just as students in the classroom have misconceptions about science concepts, pre-service science teachers have misconceptions about science teaching, misconceptions formed in large part by their experiences as students (Lortie, 1975). To understand and effectively implement research-based science teaching practices, pre-service teachers often have to confront their prior conceptions of teaching and then develop a new framework of teaching that is intelligible, plausible, and fruitful (Darling-Hammond, 2006a; Korthagen & Kessels, 1999; Posner et al., 1982). Pre-service teachers need at least a year of multiple methods courses with extensive field placements to foster reflective thinking necessary for conceptual change (Bergman, 2007; Tillotson & Young, 2013).

The quantity of science teacher education makes a difference, but only if the program is of high quality. Whereas many science teacher education programs are often criticized for being too theoretical (Kagan, 1992; Korthagen & Kessels, 1999) and for
promoting isolated research findings (Clough, 2003), highly effective science teacher education programs utilize a coherent framework to help teachers develop a research-base for making decisions (Bergman, 2007; Clough et al., 2009; Darling-Hammond, 2006a; Tillotson & Young, 2013; Windschitl et al., 2012). Specifically, Clough et al. (2009) argue that a decision-making framework for teaching can help teachers “make sense of education research, come to understand crucial teacher decisions, and how those decisions interact to affect student learning” (p.821). Windschitl et al. (2012) echo the need for program coherence and suggest science teacher education should promote numerous ambitious practices such as eliciting students’ ideas, helping students make sense of activities, and pressing for explanations to support student learning. While different programs may utilize different frameworks, Darling-Hammond (2006) makes clear that effective teacher education programs have a cohesive framework to provide a clear vision of research-based teaching practices throughout all coursework and field experiences.

A critical aspect of science teacher education program coherence is effective modeling from science teacher educators (Bergman, 2007; Tillotson & Young, 2013). For pre-service teachers to become effective, they have to conceptualize teaching differently than what they experienced as students (Darling-Hammond, 2006a; Goodlad, 1990). Therefore, science teacher educators must “practice what they preach” (Goodlad, 1990, p.75) by modeling the same research-based science teaching practices they expect from pre-service teachers. Moreover, science teacher educators also need to draw pre-service teachers’ attention to the pedagogical decisions made and have them consider the rationale for such decisions. As learning to effectively teach science often involves
conceptual change for pre-service teachers, the science teacher educator serves as an important source of support.

In addition to effective modeling from science teacher educators, further support systems are needed to assist the learning of pre-service teachers. Effective support systems include: 1) extensive field experiences where cooperating teachers model and promote research-based teaching practices, 2) learning cohorts that serve both as a peer support system and learning community, and 3) assignments such as writing theory-based rationales with an associated oral defense that press pre-service teachers to understand the impact of their decisions on how people learn and to promote the goals they have for their students (e.g., critical thinking, problem-solving, respectfulness) (Clough et al., 2009; Darling-Hammond, 2006a; Tillotson & Young, 2013). Each of these supports can help pre-service teachers to deeply understand the synergy and coherence of research-based teaching practices and thereby reduce the perceived theory-practice gap that is an obstacle to lasting science education reform.

**Eating Their Young- Socialization of Beginning Teachers into Traditional Practices**

Even when beginning teachers leave their program understanding, valuing, and attempting to implement research-based practices, these practices are often met with resistance and can be progressively eroded during their first years of teaching due to institutional constraints (Brickhouse & Bodner, 1992; Zeichner & Tabachnick, 1981). Institutional constraints refer to obstacles (e.g., physical structures, regulations, time, influence of stakeholders) that can significantly influence teachers’ decision-making (Brickhouse & Bodner, 1992). School stakeholders (e.g., policy makers, administrators, teachers, parents, students) often have different perspectives on the purposes of school
and the methods necessary to achieve those purposes than those promoted by research (Spector, Greely, & Kingsley, 2004). Stakeholders’ perspectives often represent oversimplified conceptions of teaching, such as teaching as transmission of knowledge (Tobin & McRobbie, 1996). As a result, research-based practices are often explicitly and tacitly subverted by the stakeholders. Due to these fierce constraints, teachers without extensive teacher preparation often conform to traditional practices within the first three years of teaching (Luft, Roehrig, & Patterson, 2003; Zeichner & Tabachnick, 1981). Even with highly effective teacher preparation as described above, teachers may end up teaching no differently than their traditional teacher education counterparts.

**Purpose of Study and Research Questions**

**Purpose of Study**

The institutional constraints beginning science teachers face are well documented (Berliner, 2000; Brickhouse & Bodner, 1992; Tobin & McRobbin, 1996; Zeichner & Tabachnick, 1981). In the face of these pressures, what is not well known is what accounts for the differences in beginning science teachers’ persistence with research-based teaching. Knowing more about how and why science teachers either persist, or don’t, with research-based teaching is vital to sustainable school reform. The purpose of this study is to understand the teaching practices and institutional constraints of the graduates from one secondary science teacher education program known for educating science teachers to value, understand, and implement research-based practices as well as understand and develop strategies for navigating institutional constraints. This study analyzes the impact of institutional constraints on beginning teachers’ teaching practices through the lens of adult development—the constructive-developmental theory developed by Robert Kegan (1982; 1994) —to analyze participants’ self-complexity or “order of
consciousness” (Berger, 2002). If teachers have a more complex meaning-making system, they may have a greater ability to reflect upon their circumstances, make more nuanced decisions, and ease constraints on implementing research-based science teaching practices.

**Research Questions**

**Teaching practices**

1. To what degree do participants understand research-based teacher decision-making?
2. To what extent do participants implement research-based science teacher decisions?

**Institutional constraints**

3. To what extent do participants perceive institutional constraints impact their teaching decisions?
4. How constraining and pervasive are participants’ perceived institutional constraints?
5. How do participants navigate perceived institutional constraints?

**Orders of Consciousness**

6. What are the participants’ orders of consciousness?
7. To what extent do teachers’ orders of consciousness relate to their perception and navigation of institutional constraints and teaching practices?

**Methodological Overview**

This study used mixed methods to study ten beginning secondary science teachers (five first-year and five second-year teachers) who were graduates of the same science teacher education program at a large Midwestern university. Participants in this study
included rural, urban, and suburban teachers from two Midwestern states. Nine of the ten participants were female and in their mid-twenties, and one male participant was in his early thirties. Each participant was observed at least three times during a six month period. Criterion-based sampling (Isaac & Michael, 1995) was used to select teacher participants for this study. Teacher participants in their first or second year of teaching were purposefully selected because the transition from pre-service to in-service tends to be an intense time for institutional constraints (Luft et al., 2003) and formative to the development of research-based teaching practices (Feiman-Nemser, 1983; Luft & Roehrig, 2005).

Classroom observations and semi-structured interviews were conducted with participants to determine their levels of understanding and implementation of research-based science teaching practices (research questions 1 and 2). To understand the extent to which teachers implement research-based teaching, classroom observations were scored using the Local Systemic Change Classroom Observation Protocol (LSC-COP) (Horizon Research, Inc., 2005) and the Schlitt/ Abraham Teaching Interaction Coefficient (SATIC) analysis (Abraham & Schlitt, 1973). The LSC-COP provides a guide to score the effectiveness of a lesson and the likelihood the lesson impacts student learning (Horizon Research, Inc., 2005). The SATIC analysis was used to provide a fine-grained analysis of the interactions (e.g., teacher questioning, responding to students, wait-time) the teacher had with students. Additionally, field notes were used to compare the extent to which participants’ teaching practices aligned to the Decision-Making Framework (Clough et al., 2009). Specifically, the researcher analyzed lessons to determine the degree to which participants’ teaching decisions (e.g., selection of content and activities,
structure of the lesson, teacher behaviors) were in line with the goal-directed nature of teaching (Olson, 2007) and the knowledge base of how people learn. Classroom observations, field notes, semi-structured interviews, and classroom artifacts were used to generate exemplar classifications (e.g., high, medium, and low) of teacher understanding and of teacher implementation of research-based teaching practices. The classifications were then used to categorize each participant’s understanding and implementation of research-based practices.

To evaluate participants’ perceived institutional constraints and their order of consciousness, the researcher conducted four semi-structured interviews (one interview after each observation and a final interview). Semi-structured interviews were also conducted with the participants’ mentors and administrators to help triangulate how constraining and pervasive institutional constraints were in the participants’ schools. Participant interviews were informed by teacher belief interview (Luft & Roehrig, 2007) and the subject-object interview protocol (Lahey, Souvaine, Kegan, Goodman, & Felix., 2011). Details on the teacher belief interview and the subject-object protocol will be discussed in chapter three.

The data described above were transcribed and coded using the constant comparative method (Glaser & Strauss, 1967; Harry, Sturges, & Klingner, 2005) to answer all parts of research questions. Transcripts from participants, mentors, and administrators were read and used to form initial codes (Strauss & Corbin, 1990). These codes were grouped by research question to analyze participants and to generate a cross-case analysis.
Study Limitations

This study was limited in scope to investigating orders of consciousness, institutional constraints, and research-based teaching. Data analysis of these aspects is influenced by the researcher’s conceptual framework. Therefore, chapter two explores how the researcher conceptualizes the science education literature related to this study. Conclusions from this study may apply to science teacher education programs and students with similar demographics to those indicated in this study, but may not be generalizable as students come from one program and are mostly female. This study also assumes participants’ teaching practices were not influenced by the presence of the researcher in the classroom and assumes participants were truthful in their interview responses. Additional study limitations are explored in chapter three.
CHAPTER 2: LITERATURE REVIEW

Effective Science Teaching is Perceived to be Straightforward, Intuitive, and Merely a Matter of Style

Despite the complexities of effective teaching, the general public often has simplistic views about teaching that were developed from their experiences as students (Berliner, 1987; Clough, Berg, & Olson, 2009; Feiman Nemser, 1983, 2001; Lortie, 1975). One commonly held view is that teaching is not very difficult, as if “someone can walk in off the street and deliver a curriculum to 30 or so children” (Berliner, 1987, p. 6). Munby, Russell, & Martin (2001) explain why effective teaching appears effortless to students when they write,

> As with any good performance, teaching looks easy. When we witness a near perfect performance in, say, the long program of a figure-skating competition, we recognize the many hours of intensive work that lie behind the apparent ease of execution under demanding circumstances. But we do not typically do this of teaching (p. 895).

Much like an audience of a figure-skating competition, students “are not privy to the teachers’ private intentions and personal reflections of classroom events” (Lortie, 1975, p. 62) and rarely acknowledge or even consider the extensive thinking and effort that is required for effective teaching. The pervasive perception of teaching, and science teaching more specifically, as straightforward and intuitive underpins other common beliefs such as: “(1) command of subject matter is sufficient for effective teaching; (2) effective pedagogical practices develop naturally through teaching experience; (3) teaching is simply a matter of personal style; and (4) teaching is essentially the passing of information from teacher to students” (Clough, Berg, and Olson, 2009, p. 822).

Just as the general public has inaccurate perspectives of teaching, science teachers, having observed their own teachers since first beginning school, develop
intuitive notions of science teaching that act as a lens through which new knowledge regarding teaching and learning is understood (Lortie, 1975; Zeichner & Gore, 1990). Therefore, notions of effective teaching are often “intuitive and imitative rather than explicit and analytical; it is based on individual personalities rather than pedagogical principles” (Lortie, 1975, p. 62). Clearly, learning how to teach begins before a teacher education program, and understanding those early experiences is important for promoting more effective practices (Goodlad, 1990).

How Teachers Form Perceptions

As noted above, teachers, even before they began formal teacher education, have almost a lifetime of informal experiences regarding teaching and learning (Feiman Nemser, 1983). Three different explanations are present in the literature regarding how these early experiences impact teacher thinking and decision-making.

Evolutionary Account. Stephans (1967) asserts that human beings have survived because of their deeply ingrained habits of telling each other what they know, correcting one another, and supplying the answer (Feiman Nemser, 1983; Stephans, 1967, Zeichner & Gore, 1990). These habits, often observed in classrooms, which Stephans (1967) calls “spontaneous pedagogical tendencies” (p. 94), have been used for generations and are resistant to change (Feiman Nemser, 1983).

Stephens (1967) argued that the consistency of teachers’ practices throughout history is evidence that these practices may be habitual rather than deliberate and rational (Stephans, 1967; Zeichner & Gore, 1990). For instance, young children playing school often instruct each other on what to do—even if they have not yet had experiences with formal schooling. Although Stephans’ evolutionary account has not been widely
accepted in teacher education, his work highlights the importance of predispositions that nearly all teachers to some extent bring to teacher education, and “he presents a convincing case that at least some [perceptions of] teaching cut across individuals and contexts” (Zeichner & Gore, 1990, p. 8).

**Psychoanalytic account.** Drawing from Freud and psychoanalytics, Wright and Tuska (1967, 1968) assert that the decision to teach is impacted by an individual’s personality, external factors (e.g., money, opportunity, custom), and inner motives. These inner motives are formed from relationships children develop with parents and teachers that have “residual influences” as the children grow into adulthood (Wright & Tuska, 1967; 1968). Wright & Tuska (1967) assert that: “early satisfactions and frustrations set the stage for subsequent attitudes towards teachers and teaching, and the kind of teachers young women [or men] enrolled in teacher training tend to become is governed by the effect this childhood heritage has on their personalities” (Wright & Tuska, p. 124). That is, adults remember the feelings they had as children when they think about teaching and their childhood relationships. The childhood feelings and memories serve as prototypes for subsequent teacher decision-making. This account of early influences on teachers is often referred to as the “childhood romance” theory, as Wright (1959) researched teachers’ anecdotes of why they chose education—many of which included “a conscious identification with a teacher during childhood…” (Feiman Nemsar, 1983).

**Apprenticeship of Observation.** Lortie (1975) emphasized the role that thousands of hours of being a student has on becoming a teacher. The extensive prior knowledge of teaching and learning that teachers developed when they were students influence the way teachers see classroom situations. Teachers’ knowledge of what they
learned in school seems to be entangled in how they learned it, as “many teachers’ ideas of how to teach particular topics can be traced back to their memories of how their own teachers approached these topics.” (Grossman, 1990, p.10).

According to Lortie, teachers internalized the teaching practices they observed as students, which he calls “apprenticeship of observation.” “Teachers end up imitating internalized models of past practice, e.g., doing what their second grade teacher did when children got restless” (Feiman Nemser, 1983). As pointed out above, these imitations are limited, as students only see aspects of teacher decision-making and are not aware of the complexities of highly effective teaching (Lortie, 1975).

Implications of these influences. These accounts of influences on teachers’ perceptions each indicate that the past has a role in the practices teachers use. Indeed, teaching practices have remained largely unchanged despite decades of reform efforts (Cuban, 1984; Simmons, et al., 1999). Perhaps one reason for the consistency of practices is that teachers are often not aware of how their prior experiences influence their thinking and decision-making. Russell & Martin (2007) write, “Just as children are unaware of their initial beliefs about [natural] phenomena and unaware of how personal experiences shape and constrain those beliefs, so those who are learning to teach science tend to be unaware of their initial beliefs about what and how they will learn in a program of science teacher education.” (p. 1151). The next section will address these common science teaching practices and how they differ from research-based practices.

Teacher Decision-Making

Effective teaching is a complicated endeavor (Berliner, 1987; Clough et al., 2009; Dewey, 1929; Good & Brophy, 1994; Leinhardt & Greeno, 1986) that requires accurately
interpreting complex classroom behavior and using those interpretations to make appropriate decisions in a “relatively ill-structured, dynamic environment” (Leinhardt & Greeno, 1986, p. 75). Science teachers make numerous non-trivial decisions about planning and implementing lessons, managing the learning environment, interacting with students, performing administrative tasks, and navigating social aspects of the school environment (Berliner, 1987). For example, teachers have 1000 different interpersonal exchanges a day that must be acted upon (Good & Brophy, 1994).

Sandra Mitchell (2009), writing about the complexities in science research, points out, “Complexity often carries with it a type of ineliminable or ‘deep’ uncertainty that is not adequately represented by methods better suited to more certain, predictable, and static parts of nature” (p.3). Similarly, traditional approaches to science teaching often eschew complexity in favor of prescriptive strategies (e.g., Marzano et al., 2000). Reductionist strategies, used to simplify complexities, often don’t accurately account for the difficulties of deep conceptual learning. Instead, these efforts have largely neglected the role of the teacher by attempting (unsuccessfully, one might add) to circumvent the complexity and synergy inherent in effective science teacher decision-making (Clough et al, 2009). Dewey (1929) warned against prescriptive approaches to education when he wrote,

[Teachers] want very largely to find out how to do things with the maximum prospect of success. Put baldly, they want recipes” (p. 15). “There is a pressure for immediate results [of strategies in the classroom], for demonstration of a quick, short-time span of usefulness in school. There is a tendency to convert the results of statistical inquiries and laboratory experiments into directions and rules for the conduct of school administration and instruction” (p. 17-18). “School administration and instruction is a much more complex operation than was the one factor contained in the scientific result. The significance of one factor for educational
practice can be determined only as it is balanced with many other factors (p.19).

Instead of promoting isolated research findings (Clough, 2003), teachers need a useful, systematic approach to help guide decision-making in the complex science classroom environment (Darling-Hammond, 2006a; Good & Brophy, 1994). Clough et al. (2009) put forth a Decision-making Framework (Figure 1.1) that “makes teacher decision-making a central feature, while explicitly addressing [science teacher] decisions and how they interact… to help educators understand synergistic relationships and aid in the making sense of the dizzying array of research findings” (p. 826).

The Decision-making Framework places student goals and knowledge of how people learn as pillars from which to draw upon when making decisions. Clough et al. (2009) explain the purpose of the Decision-Making Framework is to “illustrate that all teacher decisions regarding science content, tasks, activities, materials, models, strategies, and teacher behaviors should be made in light of desired goals for students and how students learn” (p. 829). While the Decision-Making Framework does not capture all aspects of teaching and learning (Clough et al., 2009), it provides an “advanced organizer” (Ausubel, 1964; West & Fensham, 1974) — a broad, general structure—to help teachers make sense of the complexities of science teaching and learning. The next section of the paper will explore student goals, their associated student actions, and how people learn.
**Science Education Goals**

Well-considered goals for students that reflect the “knowledge, abilities, and dispositions students should acquire or develop during their K-12 years” are crucial for
guiding teacher decision-making (Penick & Harris, 2005, p. 5). A clear vision of science education goals necessary for making effective science teaching decisions (Clough et al., 2009; Clough, 2015a) and are inherent in all science education reform documents (AAAS, 1990; NRC, 1996, 2012, 2013). Clough (2015a, p. 26) & Clough & Olson (In Press) provide a list of common goals in science education (Table 2.1).

Table 2.1. Goals for Science Education

- Demonstrate deep robust understanding of fundamental science concepts.
- Exhibit an accurate understanding of the nature of science.
- Exhibit an accurate understanding of the nature of technology and engineering.
- Identify and solve problems effectively.
- Be creative and curious.
- Use critical thinking skills.
- Use communication and cooperative skills effectively.
- Actively participate in working towards solutions to local, national, and global problems.
- Set goals, make decisions, and accurately self-evaluate.
- Access, retrieve, and use existing scientific knowledge in the process of investigating phenomena.
- Convey self-confidence and a positive self-image.
- Demonstrate an awareness of the importance of science in STEM and STEM-related careers.

While science teachers generally have a shared vision of their goals for students, teachers rarely teach or evaluate these goals (Clough, 2015a; Penick & Bonnstetter, 1993). Instead, many teachers often eschew these goals in favor of superficially covering content. Perhaps one reason teachers rarely consider goals when making decisions is due to the abstract nature of goals (Clough et al., 2009). Clough et al. (2009) emphasize the importance of identifying a plethora of student actions congruent with each desired goal. Creating an extensive list of such student actions makes apparent how all of the goals are interconnected and may help “persuade teachers that promoting deep
understanding of science content is linked to promoting other goals as well” (2009, p. 837).

**How People Learn**

Along with a clear vision of desired student goals, understanding how people learn and why they often struggle in learning establishes a foundation for research-based teacher decision making (Bransford, Brown, & Cocking, 2000; Clough et al., 2009; Olson, 2007; Penick & Harris, 2005; Watson & Konicek, 1990). However, knowledge about how people learn is rarely applied to science teachers’ practice (Madsen & Olson, 2005). Without thoughtfully considering how people learn, many teachers resort to trial and error strategies (Olson, 2007) or educational fads (e.g., learning styles, flipped classroom, process-oriented guided inquiry learning) (Madsen & Olson, 2005; Olson, 2007). Trial and error approaches and education fads often eschew the complexities of teaching by using partial truths and attempting to provide quick-fixes to complex issues (Clough et al., 2009; Dewey, 1929; Slavin, 1989).

Yet, Rousseau (1762/2007) noted over 250 years ago child development and knowing how children learn was an important consideration, particularly for those involved in education when he wrote,

> We know nothing of childhood; and with our mistaken notions the further we advance the further we go astray. The wisest writers devote themselves to what a man ought to know, without asking what a child is capable of learning. They are always looking for the man in the child, without considering what he is before he becomes a man (p. 7).

Since Rousseau, researchers in cognitive psychology, psychology, and science education have added a great deal to our understanding of how people learn (Table 2.2).
Table 2.2. *Important Concepts Regarding How People Learn in Science.*

- Behaviors can be modified either by changing the environmental influence before the behavior, as in classical conditioning, or changing the environmental influence that follows the behavior, as in operant conditioning (Skinner, 1987; Woolfolk, 2013).

- Learners’ external responses (e.g., facial expressions, answers to questions, how learners act) to a stimulus can be used to evaluate the degree to which someone has learned (Thorndike 1898/1998; Watson 1913/1994).

- Children are better able to abstract, reason logically, and handle complexity as they mature (Karplus, 1977; Lawson, 2002; Piaget, 1961) especially if concrete experiences precede abstractions (Karplus, 1977; Olson, 2008).

- Interactions with others facilitate learning as people within a culture share symbols (e.g. language, metaphors, images), called “semiotic mechanisms”, that act as a bridge between a shared cultural understanding and an individual’s inner speech and influence how an individual thinks about the world (Herman, 2013; Vygotsky, 1978).

- Interactions with “more knowledgeable others” wakens new levels of development a learner couldn’t achieve alone (Vygotsky, 1978, p. 57). As a result, “the child is able to copy a series of actions which surpass his or her own capacities, but only within limits. By means of coping, the child is able to perform much better when together with and guided by adults than when left alone, and can do so with understanding and independently. The difference between the level of solved tasks that can be performed with adult guidance and help and the level of independently solved tasks is the zone of proximal development (Vygotsky, 1978, p. 117).

- Learning is a constructive process where learners use their prior experiences and knowledge to actively interpret and make meaning from new information. (Scott, Asoko, & Leach, 2007). These meaning making and knowledge organization processes are known as assimilation and accommodation. Assimilation refers to the process of understanding something new by fitting it into what is already known (Collins, 2002; Piaget, 1961). Accommodation is when the learner changes how he or she thinks about the new information rather than changing the information to fit his or her thinking (Collins, 2002; Piaget, 1961).

- When the learner’s prior knowledge is inaccurate, it can act as a barrier to understanding new information and may be assimilated incorrectly. Inaccurate knowledge—often referred to as misconceptions—can be “remarkably resistant to change” because these ideas are “deeply embedded in students’ thinking and in some sense appear to work for students (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010, p. 24).

- Posner et al., (1982) assert that in order for students to undergo conception change— thereby accurately accommodating a science idea—the idea must be plausible, fruitful, and intelligible. More recently, scholars have noted the importance of additional cognitive and motivational factors that impact a learner’s ability to undergo conceptual change (Pintrich, Marx, & Boyle, 1993; Scott, Asoko, & Leach, 2007).
Implications of Learning Theories for Science Teaching. Students’ behaviors, cognitive development, social environment, and prior knowledge all greatly impact their readiness and ability to understand science. Therefore, effective science teaching is more likely to occur when teachers eschew vague, unsubstantiated, and problematic notions of learning styles (Pashler, McCaniel, Rohrer, & Bjork, 2009) and instead draw from well-established principles regarding how people learn (American Psychological Association, 1997). Loucks-Horsley, Hewson, Love, and Styles (1998) make clear the relationship between teaching and learning when they write,

... learning lies at the heart of any conception of teaching; the corollary is that a conception of teaching that does not include learning is a contradiction in terms. On the one hand, teachers need to match who the learners are and what they know with the intended curriculum in ways that make this a task that is reasonable for learners to be able to achieve. Assuming it is solely the learners’ responsibility to make the necessary connections between where they are and where the teacher intends them to go cannot be a part of what it means to teach. (p. 31)

While the learning theories and goals should guide teacher decision-making, they do not tell a teacher how to teach. Contextual factors in any complex decision-making process such as teaching or medicine impact particular decisions, even though those decisions are informed by well-established research in both respective disciplines. Teachers who seriously consider how people learn and consider the goals they have for students have a much firmer foundation for effective decision-making (Clough et al., 2009). Without a framework grounded in student goals and how people learn, many teachers may not overcome their preconceived notions of effective teaching and end up teaching in the same traditional ways in which they were taught (Feiman-Nemser, 1983; Goodlad, 1990).
Traditional Science Teaching Contrasted with Reforms-based Science Teaching

The teaching practices commonly observed in science classrooms are referred to as “traditional science teaching practices” because they have been the dominant form of instruction for over a century (Cuban, 1984; Simmons et al., 1999). Traditional teaching practices include, but are not limited to: lecture, limited student interaction, cookbook labs and other highly directed activities, reliance on textbooks and worksheets (Cuban, 1984; Simmons, et al., 1999). These practices differ markedly from effective science teaching practices directed at achieving goals like those appearing in Table 2.1 and science education reform documents (AAAS, 1990; Banilower, et al., 2013; Clough et al., 2009; Coble & Koballa, 1996; Cuban, 1984; Goodlad, 2004; Weiss et al. 2003, Simmons et al., 1999; NRC, 1996, 2012, 2013; Schweingruber et al., 2007; Tillotson & Young, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). The gap between traditional teaching practices and reforms-based practices is often attributed to differences in views of the nature of knowledge (Tobin & McRobbie, 1996) and the purposes of schooling (Postman, 1995) as Schön (1987) summarized,

Professional schools of contemporary research universities give privileged status to systematic, preferably scientific knowledge. Technical rationality, the schools’ prevailing epistemology of practice, treats professional competence as the application of privilege knowledge to instructional problems of practice. The schools’ normative curriculum and separation of research from practice leave no room for reflection-in-action, and thereby create— for educators, practitioners, and students—a dilemma of rigor or relevance. (p. 229).

Below, three categories of decisions that all science teachers make illustrate how traditional science teaching practices contrast with those appearing in science education reform documents.
Traditional Decisions: Science Teacher Behavior Patterns

Teacher behaviors include, but are not limited to, teacher questioning, non-verbal behaviors, and how teachers interact with students. Although teachers interact with students daily, many teachers are not cognizant of the kinds of questions they actually ask, the time they wait after having asked a question or after a student answers a question, or the non-verbal behaviors they exhibit (Olson, 2007), and often attribute what they do to their style (Clough, Olson, and Berg, 2009). As a result, teachers’ common interaction patterns are often habitual and ill-informed.

Lecture is the major form of instruction (Banilower et al., 2013; Goodlad, 2004; Weiss et al., 2003; Yager & Penick, 1983), taking up to 55-75% of class time (Banilower et al., 2013; Goodlad, 2004). Swift & Gooding (1983) found that even when teachers believe they are running discussions, they still talk the majority of the time. These “discussions” tended to be lectures with occasional questions interspersed. When science teachers do ask questions, most elicit simplistic answers (e.g. yes/no, fill-in-the-blank) rather than promoting conceptual understanding (Weiss et al., 2003). Repeated findings show that up to 80%-90% of questions asked by teachers require mere recall of knowledge (Banilower et al., 2013; Klingzing & Klinzing-Eurich, 1988; Weiss, et al., 2003).

When teachers ask questions, they typically wait less than one second after they ask a question (wait-time I) and even less time after a student has answered (wait-time II) before responding to students (Rowe, 1964; 1974; 1986, Swift, Gooding, & Swift, 1988; Tobin & Capie, 1983). When students respond, teachers “tend to move the discussion back to themselves by judging almost every student response, question, or comment...” (Klingzing & Klinzing-Eurich, 1988, p. 235). As a result, interactions that promote
student collaboration, wrestling with ideas, articulating their understanding, making connections, and synthesizing ideas don’t happen with much frequency (Weiss et al., 2003). Instead, science lessons often lack student participation required for intellectual rigor (Goodlad, 2004; Walsh & Sattes, 2005; Weiss et al., 2003; Yager & Penick, 1984).

Reforms-Based Decisions: Science Teacher Behavior Patterns

In contrast to teaching behaviors often exhibited in science classrooms, science education research indicates effective teaching behaviors that reflect how students learn and promote desired science education goals include, but are not limited to teachers:

- asking open-ended, thought-provoking questions;
- using questions to scaffold student thinking towards desired ends;
- Waiting 3-5 seconds after asking a question (wait-time 1) and after a student responds (wait-time 2);
- acknowledging and playing off of students’ responses rather than repeating their answers or overtly judging students ideas;
- moving around the classroom and among students; and
- using positive and encouraging facial expressions and body language.

Teachers ask many questions during lessons (Clegg, 1987; Goodlad, 2004); however, those that ask open-ended questions elicit more student answers, more student to student interaction, and more complex thinking (Brophy & Good, 1986; Clegg, 1987; Klinzing & Klinzing-Eurich, 1988). As students are more actively engaged with high-level questions, they are more likely to exhibit scientific thinking (Penick, Crow, & Bonnstetter 1996), confront misconceptions regarding scientific concepts (Clough, 2002), and have higher levels of student achievement (Klinzing & Klinzing-Eurich, 1988).

Although higher order questions are critical to students’ science achievement, pauses in classroom dialogue, known as wait-time, provide students an opportunity and encourage them to think about and develop a response to higher order questions (Tobin & Capie, 1983). Wait-time has been found to influence the quality and quantity of
classroom dialogue (Rowe, 1974) and has been shown to increase the number of students’ responses by 700 percent (Rowe, 1986).

How a teacher reacts to students’ responses can also greatly influence classroom dialogue. Teacher reactions can be classified as: “1) reflecting behaviors: acknowledgement… of an utterance; 2) sustaining: repetition of original question or probing; and 3) judging: praise, criticism (Klinzing & Klingzing-Eurich, 1988, p. 219).

Effectively responding to students entails reflecting behaviors, such as acknowledging student ideas (either verbally or non-verbally), and sustaining behaviors, such as using the ideas to move the conversation forward (Herman, 2008; Klinzing & Klingzing-Eurich, 1988).

Additionally, teachers need to carefully consider their non-verbal behaviors when attempting to promote a safe classroom environment necessary for dialogue. Clough (2007) lists many effective non-verbal behaviors, such as:

- smiling, appropriate eye-contact, movement around the room and among students, leaning forward when students are speaking, raising eyebrows to show interest, inviting hand-gestures (Bavelas, et al., 1995; Roth, 2001), equality of physical status, and wait-time I and II (p. 2).

Effective questioning, appropriate wait-time, encouraging non-verbal behaviors, and responding to students’ ideas in a way that seeks clarification and scaffolds understanding are collectively known as the “central core of effective teaching”, as teachers need to synergistically implement all of these behaviors simultaneously to effectively teach for conceptual understanding and other desired student goals (Clough et al., 2009). When effective teacher behaviors are implemented together, the whole is greater than the sum of the parts (Clough, 2007). Conversely, if a teacher is ineffective in one area, student learning is greatly impacted.
Traditional Decisions: Selection of Content, Tasks, Activities, and Materials

More than 25 years ago, F. James Rutherford noted the problems with science curricula when he wrote,

The present science textbooks and methods of instruction, far from helping, often actually impede progress toward science literacy. They emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, recitation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities (AAAS, 1989, p.2).

Unfortunately, not much has changed as science teachers’ selection of content materials, and activities are still often governed by science textbooks and are now influenced by high-stakes testing (Olson, 2007; Olson & Ihrig, 2011; Schmidt et al., 1999; Roseman, et al., 2001; Weiss et al., 2003). As teachers’ thinking is too often dominated by finding tasks and activities (Duschl & Gitomer, 1997), selection of content, tasks, activities, and materials is rarely thought of as a conceptual issue. As a result, science lesson planning often consists of finding topic-related activities with far too little attention given to the value and developmental appropriateness of the science content, the kinds of activities that require and promote mental engagement, and how to logically scaffold students towards conceptual understanding (Banilower et al., 2010; Olson & Ihrig, 2011). This topical approach to activities—also known as “activitymania”—rarely mentally engages students as the question, procedure, data collection, interpretation of data, and communication of results are largely, if not entirely, removed from students’ input (Moscovici & Nelson, 1998).
Reforms-Based Decisions: Selection of Content, Tasks, Activities, and Materials

Selection of Content. Clough (2015b) notes that effective content selection should be guided by “the structure of the discipline, how students learn, the importance of teaching science through and as inquiry” (p.68). Each discipline (e.g., Physics, Biology, Entomology) has a structure that helps organize the field and can provide insights for learners on how fundamental ideas within that field are interconnected (Bruner, 1960; Schwab, 1978). When learners organize and connect ideas around central concepts, they are better able to learn, transfer, and use the ideas more effectively than if they were to rote-memorize (Ambrose et al., 2010; Bransford et al., 1999). One way to teach learners how to organize and structure their knowledge is by teaching science through inquiry. Teaching science through inquiry refers to the pedagogical decisions and actions teachers make – asking open-ended questions, scaffolding students’ thinking, structuring experiences to mentally engage students, ask students to design ways to test and ways to explain ideas (Wilcox, Kruse, & Clough, 2015). When teachers select content that is fundamental to the discipline, in line with how people learn, and taught effectively, students are more likely to develop expertise (Ambrose et al., 2010; Bransford et al., 1999). In addition, student interest, socio-scientific issues, and local resources and issues should also play a role in the selection of content (Clough, 2015b; DeBoer, 2000; Lee et al., 2013; Zeidler, Sadler, Simmons, & Howes, 2005).

Selection of Activities and Tasks. Science teachers often judge activities and tasks by the extent to which they are “hands-on.” However, Driver (1997) points out, “It’s not just a matter of having hands-on experience in science, it’s important to have minds-on experience as well. The learner has to think things through and reconstruct their
interpretation of things.” Effective activities should require students to “make decisions, ask questions, consider alternatives, and think critically (Wilcox, Kruse, & Clough, 2015). Additionally, effective science teachers select activities that require students to access, use, and make apparent their understanding of prior concepts. Selected activities are appropriately situated so that along with teacher interaction, they assist in scaffolding students towards fundamental science ideas (Crawford, 2000). Selection of activities and tasks should also promote a spiraling curriculum that revisits science concepts using numerous concrete, developmentally appropriate experiences that foster connections between concepts (Clough, 2015b).

Selection of Materials. While the selection of materials is often viewed as intuitive, Olson & Clough (2001) point out materials—which are a technology—often negatively impact students’ scientific understanding of a phenomena, as “technology is often a ‘black box’ that either misleads students into thinking they need not understand conceptually what the technology is doing for them or, worse, promotes serious misunderstanding of the concept under investigation” (p.10). As an example, researchers (Annenberg/CPB, 1997) found students made the same mistakes in lighting a light bulb before and after a physics unit on electricity. When the researchers dug deeper, they realized some of the students believed a light bulb holder was necessary to complete a circuit. Even seemingly simple materials, such as a bulb holder, can create barriers to scientific understanding. Consequently, science teachers must select developmentally appropriate materials, ensure that selected materials will not hinder desired conceptual development, and scaffold students to understand the purpose of the materials used in the science classroom.
Traditional Decisions: Selection of Teaching Strategies & Teaching Models

Teaching models refer to the overarching instruction framework of lessons, whereas teaching strategies refer to “techniques and methods that may be used in any lesson irrespective of the overarching teaching model employed” (Clough, 2015c, p. 115). That is, teaching models provide structure to lessons and series of lessons, whereas a strategy is a way to engage students within the lesson. Goodlad (1990) studied over a thousand classrooms and noted the consistency of teachers’ teaching models and strategies when he wrote,

“Inside each [classroom], the teacher sat at a desk, watching the class or reading. The students sat at table-type desks arranged in rows. Most were writing, a few were stretching, and the remainder were looking contemplatively or blankly into space...In visits to several other academic classes that day, I witnessed no marked variation on these pedagogical procedures and student activities. Driving from the building, my companion commented, ‘I saw hardly any teaching all day.’ Was he right? Was there hardly any teaching—learning either?” (Goodlad, 1990, p.93).

More recently, Banilower et al., 2013 reported,

...despite research on learning that suggests otherwise, roughly 40 percent of science teachers at each grade level agree that teachers should explain an idea to students before having them consider evidence for that idea; and more than half indicate that laboratory activities should be used primarily to reinforce ideas that the students have already learned. And despite recommendations that students develop understanding of concepts first and learn the scientific language later, from 70 to 85 percent of science teachers at the various grade ranges indicate that students should be given definitions for new vocabulary at the beginning of instruction on a science idea (p. 21).

Unfounded pedagogical beliefs expressed by teachers are often corroborated by professional developments that promote one instructional model for all situations (e.g., gradual release of responsibility, Hunter lesson design, etc.). This narrow use of teaching models (as well as strategies) is analogous to Maslow’s (1966) statement: “I suppose it’s
tempting if the only tool you have is a hammer, to treat everything as if it were a nail” (p. 15-16). Myths regarding learning and teaching often serve as justification for prevalent pedagogical decisions and practices, and they interfere with efforts at promoting more appropriate research-based instructional choices (Tobin & McRobbie, 1996; Wilcox et al., 2015). Researchers (Alouf & Bentley, 2003; Tobin & McRobbie, 1996; Wilcox et al., 2015) identified numerous beliefs that impact teachers’ decisions to choose models and strategies inconsistent with reforms documents such as,

- seeing teaching as primarily the transmission of knowledge (Tobin & McRobbie, 1996);
- teaching too much to content too fast because the teacher wishes to “maintain the rigor of the curriculum” (Tobin & McRobbie, 1996);
- concentrating primarily on having students succeed on high-stakes recall examinations (Tobin & McRobbie, 1996);
- obsessing over classroom management issues (Alouf & Bentley, 2003; Wilcox et al., 2015); and
- maintaining that their failed efforts at implementing reforms-based models and strategies demonstrate that such practices aren’t as effective or efficient as traditional methods (Tobin & McRobbie, 1996; Wilcox et al., 2015).

Views of efficiency can be traced to teachers’ limited views regarding science teaching and learning. That is, if a teacher’s goal is to expose students to as much content as possible and primarily value and assess for recall of information, reforms-based teaching models and strategies, are not very efficient. However, as Kruse and Clough (2010), make clear, “Efficiency is a measure of accomplishment per time. Yet, if accomplishment is defined as deep, applicable, and transferable conceptual understanding of science content, teaching science through inquiry is more efficient than traditional science teaching practices” (p. 3, emphasis in original).
Reforms-Based Decisions: Selection of Teaching Strategies & Teaching Models

Teaching models that align to reforms-based decisions dating back to Herbart (1901) and Dewey (1910), when appropriately selected and effectively implemented, have been shown to “promote understanding science concepts and characteristics of science and scientists (Clough, 2015a, p. 114). These teaching models include, but are not limited to, the learning cycle (Atkin & Karplus, 1962) and its variations (5e model, Bybee, 1997; Bybee et al., 2006; 7E model, Eisenkraft, 2003), Search, Solve, Create, and Share (Pizzini, Shepadson, & Abell, 1989), the science writing heuristic (Keys, Hand, Prain, & Sellers, 1999), and the Generative Learning Model (Osborne & Wittrock, 1985). While these instructional models establish an instructional framework for promoting conceptual understanding, other models (e.g., gradual release of responsibility) promote the learning of skills. Consequently, effective science teachers have to carefully select a model that is suited for the type of understanding the teacher wishes students to develop.

Teaching Strategies. Much like teaching models, many effective teaching strategies exist, such as predict, observe, explain, Think-Pair-Share, Concept Attainment, and white-boarding. Whereas many students in science classrooms spend a majority of time doing seatwork and passively listening to the teacher talk, effective use of strategies push students to wrestle with science ideas, formulate questions, distinguish important concepts from supporting details, articulate current understanding, and connect new information to existing knowledge (Weiss et al., 2003). Importantly, how the strategies are used in the classroom is just as important as which strategies are used. For example, any of the strategies listed above could be used to merely assess how well students recall
information. Instead, teachers need to carefully consider how the strategy can be used to mentally engage students in a way that promotes student goals and learning.

**Reforms-based Teaching and the Current State of Public Schools**

The decisions teachers make—whether or not they are appropriate and effectively implemented—greatly impact students’ learning (Good, Biddle, & Brophy, 1975; Goodlad, 1990). Tillotson & Young (2013) explain,

“... the evidence is clear that science teachers who exhibit more reform-based teaching practices can have a powerful effect on improving students’ attitudes toward science, their likelihood of considering a career in science, and how they envision science influencing their everyday life. This is in stark contrast to science classrooms where teachers rely on a dissemination model of teaching with emphasis placed on memorizing factual information that results in students seeing few connections between science and their everyday life” (p 159).

While decades of reform efforts have sought to change science teaching practices, little has changed in science classrooms (Cuban, 1987; Banilower et al., 2013; Weiss et al., 2003; Goodlad, 2004). In order to change the culture of teaching, deliberate and purposeful teacher education must play an important role.

**The Perils and the Promise of Teacher Education**

Despite the important role of teacher education in preparing pre-service teachers to deeply understand research-based decision-making directed at desired goals (Olson, 2007) and how people learn, many teacher education programs do not effectively challenge or alter prospective teachers’ simplistic preconceptions of teaching (Zeichner, Tabachnick, & Densmore, 1987). This may, in part, be attributed to education faculty who themselves often fail to practice research-based teaching practices (Goodlad, 1990) and therefore reinforce the traditional views of teaching and learning. Even when teacher education is effective, it makes up only a fraction of the educational experience. Berliner
& Biddle (1995) point out most of pre-service teachers’ coursework is outside of departments/colleges of education where professors have little formal instruction on effective pedagogy. Furthermore, many teacher education programs only have one methods course (Olson 2007; Olson, Tippet, Milford, Ohana, & Clough, 2015), which does not afford the time necessary to confront and begin to overcome the thousands of hours of the apprenticeship of observation.

**Effective Teacher Education.** While many problems exist in teacher education, pockets of excellence do also exist. Darling-Hammond (2006a) found common features among seven exemplary teacher education programs including:

- a common, clear vision of good teaching that permeates all course work and clinical experiences, creating a coherent set of learning experiences;
- well-defined standards of professional practice and performance that are used to guide and evaluate course work and clinical work;
- a strong core curriculum taught in the context of practice and grounded in knowledge of child and adolescent development and learning, an understanding of social and cultural contexts, curriculum, assessment, and subject matter pedagogy;
- extended clinical experiences—at least 30 weeks of supervised practicum and student teaching opportunities in each program—that are carefully chosen to support the ideas presented in simultaneous, closely interwoven course work;
- extensive use of case methods, teacher research, performance assessments, and portfolio evaluation that apply learning to real problems of practice; explicit strategies to help students to confront their own deep-seated beliefs and
assumptions about learning and students and to learn about the experiences of people different from themselves;

- strong relationships, common knowledge, and shared beliefs among school- and university-based faculty jointly engaged in transforming teaching, schooling, and teacher education (Darling-Hammond, in press). (p. 6).

**Effective Science Teacher Education.** Many studies of science teacher education programs over the last 30 years echo Darling-Hammond’s (2006a; 2006b) findings (Bergman, 2007; Clough et al., 2009; Herman, Clough & Olson, 2013a & 2013b; Ihrig, 2014; Krajcik & Penick, 1989; Simmons et al., 1999; Tillotson & Young, 2013; Windschitl, Thompson, Braaten & Stroupe, 2012). A synthesis of these findings makes clear effective STEP programs include:

- Multiple science methods courses with well-developed learning progressions within and between the courses (Bergman, 2007; Simmons et al., 1999; Tillotson & Young, 2013).
- Coursework in the Nature of Science (Herman, 2010; Herman, Clough & Olson, 2013a, 2013b; Simmons et al., 1999; Tillotson & Young, 2013).
- An intentional, supportive peer cohort that spanned multiple semesters (Ihrig, 2014; Tillotson & Young, 2013).
- An integrated, coherent framework to help teachers develop a research-base for making decisions (Bergman, 2007; Clough et al., 2009; Darling-Hammond, 2006; Tillotson & Young, 2013; Windschitl et al., 2012).
• Key interventions (e.g., oral defense, a written research-based paper) designed to promote reflective thinking practices (Bergman, 2007; Simmons, et al., 1999; Tillotson & Young, 2013).

• Multiple, diverse field experiences where cooperating teachers’ beliefs and practices supported the science teacher education program (Simmons et al., 1999; Tillotson & Young, 2013).

Research from teacher education programs, and more specifically science teacher education programs, indicates effective science teacher education can be done and can produce highly effective science teachers.

**Socialization of Science Teachers into Traditional Practices: Institutional Constraints**

Even when science teachers leave effective teacher education programs, they are, with rare exceptions, given workloads that are equivalent to or exceed those of experienced teachers. Because beginning teachers don’t have “seniority”, they are often given difficult schedules, have to cart materials between classrooms, and given difficult sections of students, all while planning largely from scratch and learning the culture of the school, students, and community (Tobias & Baffert, 2010). Consequently, beginning teachers often have a “sink or swim” feeling that is “damaging… because it forces them to devote time to devising survival strategies rather than designing thoughtful instruction” (Brickhouse & Bodner, 1992, p. 483). As beginning teachers have to deal with complexities of teaching and the difficulties surrounding the teaching profession, approximately 50% of secondary science teachers leave within the first five years of teaching (Ingersoll, 2001; 2012). Wong and Luft (2015) point out the attrition of science
teachers indicates a great deal of dissatisfaction with the teaching profession when they write,

A link between science teacher attrition and dissatisfaction with the teaching career stems from inadequate preparation time, deficient faculty influence, class size, and lack of autonomy (Guarino et al., 2006; Ingersoll & Perda, 2009; Macdonald, 1999; Marvel et al., 2006). Additional reasons for teacher attrition include issues with student behavior, poor student motivation, inadequate administrative support, low appreciation for teachers’ intrinsic merits, little opportunity for advancement, and few rewards for experienced and inexperienced teachers (Guarino et al., 2006; Ingersoll & Perda, 2009; Macdonald, 1999; Marvel et al., 2006; Schlechty & Vance, 1983; Shen, 1997). (p. 621.

Many researchers have proposed mentoring beginning teachers to help them transition into the teaching profession (Paige, 2003) and research does indicate mentoring programs can help teachers in the induction years (Bianchini, 2012; Luft, Dubois, Nixon, Campbell, & Bang, 2014). However, many mentoring relationships work to socialize teachers into traditional practices rather than support teachers in implementing reform-based practices (Ihrig, 2014). As Goodlad (1990) wrote plainly,

Had there been recognition and understanding [of the array of circumstances impinging on teachers’ performance], surely reformers would not have prescribed once again that old bromide: Have today's teachers mentor tomorrow’s. Schools and teachers are not very effective, said report after report. Yet according to conventional wisdom, the best way to ensure a competent teaching force is to place neophytes in those same schools with those same teachers. Surely we can come up with better remedies than this (p. xiii).

Mentoring relationships, and the school environment more broadly, often work to socialize beginning teachers into the same traditional practices they experienced as students (Crow, 1987; Edgar & Warren, 1969; Lacey, 1977; Lortie, 1975; Zeichner & Gore, 1990) or “push teachers out of the profession” (Berliner, 1997, p. X). This socialization—an interaction between an individual and the environment of the school—“includes not only the skills of teaching, but the values, attitudes, norms, behavioral
patterns, and interests of the profession (Crow, 1987, p. 19). Those who exert socialization pressures, often referred to in the literature as “significant others”, include experienced colleagues and administrators, parents, and even students who often possess simplistic notions of what learning and effective teaching entails. Thus, research-based science teaching practices are often severely resisted by these significant others (Edgar & Warren, 1969). Attitudes and teaching practices of beginning teachers can be influenced by significant others due to the power dynamics present. Consequently, teacher socialization is often conflict laden as teachers often feel torn between maintaining what they have learned in their pre-service programs and adjusting to the norms of the school environment (Brickhouse & Bodner, 1992; Crow, 1987). The tensions many beginning teachers feel often undergird many science teachers’ perceived institutional constraints (Bergman, 2007; Brickhouse & Bodner, 1992; Ihrig, 2014; Kagan, 1992; Tobin & McRobbie, 1996). That is, the traditional structure of the institution can constrain teachers’ decision making (Brickhouse & Bodner, 1992) and “washout” reforms-based teaching practices teachers have learned in teacher education (Zeichner & Tabachnick, 1981).

While significant others can pressure new teachers to conform to traditional practices, teachers can control the degree to which they are impacted by these socialization efforts by choosing how they respond to constraints (Rozelle, 2010; Zeichner & Gore, 1990). In other words, constraints influence, but do not determine, teachers’ decision-making. Teachers can be resilient and persist in the face of constraints, but this requires: “individual attributes such as altruistic motives and high self-efficacy” (Beltman, Mansfield, and Price, 2011), a personal commitment and vision...
for how to implement reforms-based teaching practices (Tobin, Briscoe, & Holman, 1990), adequate skills, abilities, and experiences for teaching (Edgar & Warren, 1968), and a sufficient “order of consciousness” (Kegan, 1982 & 1994) to effectively navigate constraints.

**Decision-making and Orders of Consciousness**

**Introduction**

Persisting with effective teaching practices—despite socialization pressures—demands that teachers effectively navigate the complexities of teaching and the social environment in which they find themselves. Kegan (1982 & 1994) puts forth five qualitatively different levels, called orders of consciousness, to describe how an individual’s approach to meaning-making and self-complexity grow and change throughout his or her life. While learning involves gaining understanding and skills, orders of consciousness are “principles for the organization (the form or complexity) of one’s thinking, feeling, and social-relating, not the content of one’s thinking feeling, or social-relating” (Kegan, 1994, p. 32). In a sense, orders of consciousness addresses the way someone knows something. It is considered a “constructive-developmental theory because it is concerned both with the construction of an individual’s understanding of reality and with the development of that construction to more complex levels over time” (Berger, 2002, p. 34). As a person develops, their self-complexity can gradually transform towards more complex meaning making systems that allow a person to deal with more demands and uncertainties in life (Kegan, 1994).

**Subject and object.** A key aspect of transformation is how an individual distinguishes between subject and object, or self and other (Kegan, 1982). “Subject’
refers to the basic principle of organization; ‘object’ refers to that which gets organized. That which gets organized can be reflected upon; we can take it as an object of attention” (Lahey, Souvaine, Kegan, Goodman, and Felix, 2011, p. 8). In other words, subject refers to what someone considers to be part of themselves (e.g., personality, attitude, preferences, unquestioned beliefs, impulses) and thus are difficult to reflect upon because they are held internally. Object refers to something outside of the individual. Kegan (1994) succinctly writes, “We have object, we are subject” (p. 32).

**Kegan’s Orders of Consciousness**

Kegan’s theory involves the transformation of entire systems from subject to object throughout the life of an individual. These transitions distinguish the five orders of consciousness where each successive order subsumes the prior order (Kegan, 1994). In Euclidean geometry, a point can be transformed into a line and a line can be transformed into a plane; however, a plane can be described as a series of lines and a line as a series of points. Similarly, a transition from one order of consciousness to another involves adapting a more complex way of meaning-making (planes) while maintaining the benefits of the previous order/s (points and lines) (Kegan, 1994). This is a life-long development of “successive triumphs of ‘relationship to’ rather than ‘embeddedness in’” (Kegan, 1982). Below each order of consciousness will be described, but orders two through four receive the most attention, as they more directly relate to teacher decision and meaning-making. Additionally, Table 2.3 summarizes orders two through four.

**First order consciousness.** First order consciousness applies primarily to young children (ages 2-6) working to make sense of the world around them. In this order, children have developed object permanence—an understanding that objects exist
independent of sensing them. However, children do not understand the notion of durable objects—properties of an object remain constant despite an individual’s perception (Kegan, 1994). A first-order achievement is children understanding that people exist separately from themselves; however, they have not developed the ability to take another person’s point of view or deeply recognize that others have different perspectives, desires, and wishes than themselves. Children in the first order are driven by their impulses and desires.

Three examples of my two-year-old son’s thoughts and actions illustrate first order consciousness: (1) when my son is finished taking a bath, my wife and I have to take him out before draining it because he is afraid he will go down the drain along with the water; (2) my son often talks to his toys as if they were people and could come alive and play alongside him; and (3) unannounced changes to the daily schedule are often met with fierce objections. These examples exemplify first order thinking regarding how impulses and the rules of the natural world itself can change from moment to moment (Berger, 2002). As few adults are in this order of consciousness, the implications for science teachers in first order are not addressed.

Second order consciousness. Second order consciousness typically occurs from age six to the teenage years, but studies have found between 13% and 36% of adults also make meaning at the second order (Berger, 2002; Kegan, 1994). At the second order, people have undergone a “change in the way they organize their thinking, their feeling, and their social-relating. They move past a fantasy-filled construction of the world… [and] begin to construct a concrete world that conforms for the first time to the laws of nature…” (Kegan, 1994, p. 20). People in the second order are no longer governed solely
by their desires and instead organize desires and attributes as things that persist through
time (e.g., “I like ice cream.” “I am good at math.”). People in the second order shift from
regulating meaning from how something appears towards durable properties of objects
(e.g., “When I see an airplane in the sky, the plane isn’t actually small”). “This insight
lets them know that other people have opinions and beliefs that remain constant, too”
(Berger, 2002, p. 42). While people in the second order recognize the beliefs and
opinions of others, they have difficulty taking two viewpoints simultaneously and
additionally struggle to reason abstractly and distinguish their needs from their self
(Kegan, 1994).

Science teacher decision-making and the second order of consciousness.

Teachers in the second order of consciousness will have difficulty handling the
complexities and abstractions that effective teaching entails. These teachers have many
concrete experiences with traditional teaching and have not yet developed the abstract
reasoning abilities to transcend their experiences. As a result, a teacher in the second
order would likely:

- Make decisions based on perceived extrinsic rewards and punishments
  rather than grounding decisions in research (Berger, 2002).
- Have difficulty managing and relating to students because they can’t
  simultaneously hold their perspective and the student’s perspective at the
  same time.
- Resort to rote-learning and cookbook laboratory experiences with pre-
determined answers.
• Rely upon external authorities (e.g., textbooks, standards, colleagues) to make decisions regarding the selection of content, materials, activities, and tasks (Hammerman, 2002).

**Third order of consciousness.** The third order of consciousness often develops in the teenage years, and between 43% and 46% of adults continue to make meaning at this order (Berger, 2002; Kegan, 1994). One major shift from the second to third order is the ability to reason abstractly or reason about reasoning (Kegan, 1994) and take more than one viewpoint simultaneously. These abilities help third-order thinkers to internalize “one of more systems of meaning (e.g., their family’s values, a political or national ideology, a professional or organizational culture)” (Berger, 2002, p. 43). Consequently, third-order thinkers have internalized ideologies, values, and cultures that serve as a “board of directors” (Berger, 2002; Kegan, 1994) to help them govern meaning and decision-making. One limitation of the third order of consciousness is if a situation results in a conflict between a person’s ideologies, values, or cultures—a disagreement among members of the board—they often feel stuck. People in the third order are “unable to develop their own philosophies or to combine the best parts of several different ideas into their own new one” (Berger, 2002, p. 46). They are not the authors of themselves and instead rely upon external sources for esteem and cues to make decisions (Kegan, 1982).

**Science teacher decision-making and the third order of consciousness.** Whereas teachers in the second order struggle to understand and apply effective teaching practices, those in the third order have the abstract reasoning necessary to comprehend and implement effective science teaching. Effective teachers make more non-trivial decisions
per minute than most other fields (Berliner, 1987; Good, Biddle & Brophy, 1975), and the third order teacher can begin to handle the mental demands effective science teaching requires.

“Teachers at this order are excellent followers of strong cultures because they have internalized the ideas and philosophies of others and work out of their loyalty to a larger group” (Berger, 2002, p. 45). As people in the third order often identify with a primary ideology, they don’t necessarily change positions based on their context, but instead hold on to their primary ideals regardless of context (Kegan, 1994). If a school’s norms align to the teacher’s ideology to a large degree, a teacher may easily conform to the school culture. On the contrary, if the school’s culture is different than the teacher’s, the teacher may feel torn between the school and his or her own beliefs and therefore may perceive a great deal of institutional constraint.

**Fourth order of consciousness.** Fourth-order thinking, if it develops at all, generally does not appear to a significant extent until a person is in their twenties, and research indicates that only 18% to 34% of adults make meaning at this order (Berger, 2002; Kegan, 1994). Whereas in the third order people are subject to their ideologies, those in the fourth order have become the authors of their ideologies—the chairman of the board (Berger, 2002; Kegan, 1994). While people in any order can have multiple identities (e.g., father, son, professional), people in the fourth order have now developed “multiple-role consciousness,” or the ability to hold multiple roles at once without having to designate a primary role (e.g., “I most strongly identify as a teacher”). People in the fourth order can now mediate various expectations that come with multiple roles because they have developed a self-governing system—an internal, self-authored system that
generates, “larger goals, principles, and commitments that transcend any one particular culture of embeddedness” (Berger, 2002, p. 52).

**Science teacher decision-making and the fourth order of consciousness.** Third-order consciousness teachers often have a primary ideology governing their decision-making process (e.g., what was learned from a teacher education program or what is promoted in the teacher’s school), whereas a person in the fourth order would transform his or her relationship to the ideology (Berger, 2002; Kegan, 1994). Instead of appearing like an “unquestioning devotee” to an ideology, teachers in the fourth order hold a guiding ideology differently. For example, a third order teacher might scoff at approaches to science education that differ from his or her ideology and may feel uncomfortable with discussing alternatives that deviate from that ideology. The fourth order teacher will be more likely to look for commonalities between different ideologies without feeling threatened. Interestingly, a teacher in the fourth order will likely have a more complex understanding of an ideology even though he or she doesn’t hold on to the ideology unquestioningly.

**Fifth order of consciousness.** The fifth order of consciousness develops around midlife, but only 3%-6% of adults develop to this order (Berger, 2002; Kegan, 1994). While fifth order of consciousness is rarely seen, many adults are in a transition phase between fourth and fifth order. The fourth order person has developed the ability to be a self-author, but their authorship is bound by their ideologies. That is, the fourth order person is comfortable within a culture or identity, and while they can “visit” other ideologies, perspectives, and cultures, they are an exchange student rather than a resident. Instead of being embedded in an inner system of thinking (board of directors)—and
viewing others as people with separate inner systems—people in the fifth order can look across systems of thinking. They can analyze, use, and consider other systems of thinking, which allows for an increased field of alternatives and a deeper way of relating to people than available in previous orders (Berger, 2002; Kegan, 1994).

**Transition between the orders.** The five orders of consciousness are not discrete, and growth from one order to another isn’t a jump, but rather a gradual transition. Berger (2002) relates this transitional period to aging in that we keep track of the whole numbers (“I’m thirty two years old”), but don’t often name the transitions in between (“I’m thirty two and eleven twelfths”). Similarly to aging, orders of consciousness is a continual development process where movement between stages can take many years.
Table 2.3. *Three Orders of Consciousness and Corresponding Teacher Self-Complexity* (adapted from Drago-Severson, 2007; Herman, Olson, & Clough, In Press).

<table>
<thead>
<tr>
<th></th>
<th>2nd Order: Instrumental</th>
<th>3rd Order: Socializing</th>
<th>4th Order: Self-Authoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cognitive Development</strong></td>
<td>• Subject: Concrete thinking, needs, interests, wishes</td>
<td>• Subject: Abstractions, hypothetical reasoning</td>
<td>• Subject: Abstract systems</td>
</tr>
<tr>
<td></td>
<td>• Object: Impulses, perceptions, conservation of properties</td>
<td>• Object: Concrete thinking, needs wishes, interests</td>
<td>• Object: Abstractions, hypothetical reasoning</td>
</tr>
<tr>
<td></td>
<td>• Similar to Piaget’s Concrete Operational Stage</td>
<td>• Similar to Piaget’s Early Formal Operational Stage</td>
<td>• Similar to Piaget’s Formal Operational Stage</td>
</tr>
<tr>
<td><strong>Self-definition and Orienting Concerns</strong></td>
<td>• Orients to self-interests, purposes, wants, concrete needs.</td>
<td>• Orients to external expectations, values, and opinions.</td>
<td>• Orients to self’s values, internal authority.</td>
</tr>
<tr>
<td></td>
<td>• Dependence on concrete rules</td>
<td>• Criticism and conflict are threats to the self.</td>
<td>• Criticism is evaluated according to internal standards.</td>
</tr>
<tr>
<td></td>
<td>• Decisions are based on what the self will acquire.</td>
<td>• Creates a “Board of Directors” to guide decisions.</td>
<td>• Concern with one’s own competence and performance.</td>
</tr>
<tr>
<td><strong>Interpersonal Development</strong></td>
<td>• Different points of view are held external (what I want vs. what they want).</td>
<td>• Holds multiple points of view within oneself.</td>
<td>• Becomes the “Chairman of the Board.”</td>
</tr>
<tr>
<td></td>
<td>• Often feels stuck if sets of values are in conflict.</td>
<td>• Feels responsible for other’s feelings; holds others responsible for own feeling.</td>
<td>• Does not make others responsible for one’s feelings.</td>
</tr>
<tr>
<td><strong>Examples of thinking about teaching</strong></td>
<td>• Will I get punished if I don’t implement this strategy?</td>
<td>• How will my colleagues feel about me if I didn’t collaborate with them and do as they do?</td>
<td>• To what extent does implementing the strategy required by the administration align with my teaching values?</td>
</tr>
<tr>
<td></td>
<td>• What skills can I gain from my colleagues?</td>
<td>• What should I do if one authority tells me one thing and another authority tells me another?</td>
<td>• How will I implement the desired curriculum while achieving my teaching goals?</td>
</tr>
<tr>
<td></td>
<td>• Who can give me the best skills and information that benefits me the most?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Effective Teaching and Orders of Consciousness

A great deal of evidence exists that pre-service teacher education programs can prepare effective teachers (Bergman, 2007; Clough et al., 2009; Darling-Hammond 2006a, 2006b; Herman, Clough & Olson, 2013a & 2013b; Ihrig, 2014; Krajcik & Penick, 1989; Simmons et al., 1999; Tillotson & Young, 2013; Windschitl, Thompson, Braaten & Stroupe, 2012), but school systems, which are often steeped in traditional practices, exert instructional constraints on teachers and often end up eroding their reforms-based teaching practices (Brickhouse & Bodner, 1992; Beltman et al., 2011; Goodlad, 2004; Zeichner & Tabachnick, 1981). A deep understanding of teaching and learning and order of consciousness may be important to understanding how to prepare teachers to more effectively manage the complexities of teaching, navigate institutional constraints, and not succumb to socialization pressures. Ultimately, if the barriers and pressures of the induction years of teaching can be effectively navigated by beginning teachers, reforms-based instruction might become more prevalent in public schools.
CHAPTER 3: METHODOLOGY

Introduction

The professional preparation for teaching, unlike many professions, begins when a student enters the classroom (Grossman, 1990; Feiman-Nemsar, 1983, 2001; Munby, Russell, & Martin, 2001; Zeichner & Gore, 1990). As the average student has over 13,000 hours of experience with teachers by the time they graduate, they have undergone an “apprenticeship of observation” (Lortie, 1975, p. 61). While students have observed first-hand what teachers do, they are doing so through a limited framework and are not privy to the pedagogical decision-making and expertise of the teacher (Lortie, 1975; Munby et al., 2001). Nonetheless, these early interactions with teachers, and consequently intuitive ideas regarding teaching, often serve as a point of reference for those students who decide to become teachers themselves (Feiman-Nemsar, 1983, 2001; Grossman, 1990; Lortie, 1975; Stephens, 1967; Wright & Tuska, 1967, 1968; Zeichner & Gore, 1990).

The apprenticeship of observation is perhaps one reason why teaching practices have remained stagnant for the past 100 years (Cuban, 1984; Goodlad, 2004). Teachers often emulate the practices they observed when they were students, despite a great deal of research that shows those practices to be ineffective in promoting conceptual understanding (Goodlad, 1990; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Moreover, socialization pressures that exist within schools often favor traditional, time-honored teaching practices over research-based practices (Brickhouse & Bodner, 1992; Tobin & McRobbie, 1996). Therefore, traditional teaching practices are observed and internalized by students (Feiman-Nemsar, 1983, 2001; Grossman, 1990; Lortie, 1975;
Stephens, 1967; Wright & Tuska, 1967, 1968; Zeichner & Gore, 1990), rarely challenged in pre-service teacher education programs (Wideen, Mayer-Smith, & Moon, 1998), and are often promoted by the school’s political structures and stakeholders when a teacher enters the profession (Brickhouse & Bodner, 1992; Edgar & Warren, 1969; Tobin & McRobbie, 1996; Wideen et al., 1998). The socialization experiences of a teacher are powerful, cyclical, and often life-long.

Despite the socialization pressure and institutional constraints, effective teacher education can help pre-service teachers understand, value, and implement research-based practices (Darling-Hammond, 2006a; Ihrig, 2014). Programs that succeed in this endeavor share common features such as: a coherent intellectual framework that spans the program, an emphasis on how people learn, field placements that support the framework of the program, a cohort or support structure for pre-service teachers throughout the program, and effective modeling of reforms-based practices by the professors and cooperating teachers (Darling-Hammond, 2006a, 2006b; Goodlad, 1990; Herman, Clough & Olson, 2013a & 2013b; Ihrig, 2014; Krajcik & Penick, 1989; Simmons et al., 1999; Tillotson & Young, 2013; Windschitl, Thompson, Braaten & Stroupe, 2012). Additionally, effective teacher education programs help pre-service teachers deeply understand the complexities of teaching and work to implement practices that result in deep learning for their students.

Even when teachers leave a pre-service program valuing and understanding research-based practices, institutional constraints can act as a barrier to implementation (Bergman, 2007; Brickhouse & Bodner, 1992; Beltman, Mansfield, & Price, 2011; Tobin & McRobbie, 1996). Effectively navigating institutional constraints and socialization
pressures in order to implement intricate teaching practices requires beginning teachers to handle a great deal of complexity (Clough, Berg, & Olson, 2009). The purpose of this study is to explore how beginning science teachers handle the complexities of teaching and socialization pressures by understanding more about how they construct meaning—their order of consciousness.

**Research Questions**

**Teaching practices**

1. To what degree do participants understand research-based teacher decision-making?
2. To what extent do participants implement research-based science teacher decisions?

**Institutional constraints**

3. To what extent do participants perceive institutional constraints impact their teaching decisions?
4. How constraining and pervasive are participants’ perceived institutional constraints?
5. How do participants navigate perceived institutional constraints?

**Orders of Consciousness**

6. What are the participants’ orders of consciousness?
7. To what extent do teachers’ orders of consciousness relate to their perception and navigation of institutional constraints and teaching practices?
Research Framework

This study uses mixed methods to answer each of the research questions. As different research traditions approach the nature of knowledge and central questions of the discipline differently, researchers need to make explicit the assumptions and traditions that undergird the study (Crewell, 2013; Crotty, 1998; Esterberg, 2002; Merriam, 2002; Patton, 1990). As Patton (1990) succinctly writes, “How you study the world determines what you learn about the world” (p. 67). Therefore, prior to discussing the design of the study, elements (i.e., epistemology and methodology) that frame the assumptions made in conducting research will be explored (Crotty, 1998).

Epistemology: Pragmatism

Epistemology, from a qualitative research perspective, is a “way of explaining and understanding how we know what we know” (Crotty, 1998, p. 3). Pragmatism, as an epistemology, “orients itself toward solving practical problems in the real world” (Feilzer, 2009) and therefore pragmatists often value utility and flexibility when deciding upon research methods (Creswell & Clark, 2007). Indeed, pragmatists often use mixed method approaches, utilizing both qualitative and quantitative traditions in their research (Feilzer, 2009).

A pragmatist epistemology was selected because it best matches the purposes and objectives of this study. Specifically, institutional constraints refer to the perceived obstacles teachers face in becoming effective teachers (Brickhouse & Bodner, 1992). These obstacles are the result of a complex interplay between an individual and the context in which the individual is positioned. In using the pragmatist epistemology, the values, complexity, contexts, and interrelated factors can be explored productively. An advantage to pragmatism is that it allows for the use of a variety of methods to
understand the complexities of teaching, institutional constraints, and orders of consciousness. In addition, pragmatism is the epistemological foundation of the teacher education program the participants completed. Therefore, a lens of pragmatism is congruent with the program’s emphasis on framing teaching as decision-making, involving the framing and solving of practical problems within their nuanced contexts.

**Methodology: Naturalistic Inquiry**

Naturalistic inquiry is a methodology in which the researcher attempts to study a natural setting (Lincoln & Guba, 1985). Because of the emphasis on authentic environments, naturalistic inquiry views the researcher as the primary research instrument by seeking to understand the complex relationship between the participants and the context (Erlandson, Harris, Skipper, & Allen, 1993). Naturalistic inquiry can use both qualitative and quantitative methods, which provides the researcher a number of options regarding the methods most appropriate to answer the research questions (Erlandson et al., 1993).

Naturalistic inquiry methodology assumes a complex relationship between participants and their context, making this methodology well-suited to explore the way beginning science teachers structure meaning-making (order of consciousness) regarding their school context, their pre-service program, and their teaching practices. Erlandson et al. (1993) expand on the assumptions of naturalistic inquiry when they write,

This stems from its fundamental assumption that all the subjects of such an inquiry are bound together by a complex web of unique interrelationships that results in the mutual simultaneous shaping... This restricts and extends the applicability of the research. On the one hand, full generalizability to other settings becomes impossible because no two contexts are identical and attempting to generalize about one phase of the context to other settings ignores the unique shaping forces that exist in each context. On the other hand, the intricacy of the context that is revealed by naturalistic
inquiry permits applications to interpersonal settings that are impossible with most studies that follow prevailing research strategies (p. 17).

Consequently, naturalistic inquiry is both limited and enhanced by context. That is, interpretation leads to greater specificity, yet specificity can provide a thick and rich description of the context (Erlandson et al., 1993, p. 18). Therefore, the context of this study is important to deeply explore.

**Participant Selection**

Recruitment of participants began after Institutional Review Board approval. Letters explaining the purpose of the study, participants’ commitments, the protocol of the study, and voluntary informed consent forms were sent to potential participants (See Appendix A). Criterion-based sampling (Isaac & Michael, 1995) was used to select ten teacher participants for this study. The criteria for selection included: all participants were graduates of the Midwestern University Science Teacher Education Program (MU-STEP), participants had to be either in their first or second year of teaching science, and participants had to be within a reasonable geographic distance to the researcher. Participants had to be graduates of the MU-STEP in order to provide a common context for this study, and the MU-STEP is well-known for being highly effective and capable of achieving the conceptual change regarding science teaching practices necessary for this study (Bergman, 2007; Clough, Olson, and Berg, 2009; Herman, 2010; Herman, Clough, and Olson, 2013a; Ihrig, 2014). Participants in their first or second year of teaching were purposefully selected because the transition from pre-service to in-service teaching contexts tends to be an intense time for institutional constraints to exert influence (Luft, Roehrig, & Patterson, 2003) and formative to the development of research-based teaching practices (Feiman-Nemser, 1983; Luft & Roehrig, 2005). Lincoln & Guba (1985) assert
that sampling should be done purposefully and until the point of redundancy. Therefore, all members of two cohorts were asked to participate to gain a representative sample from the MU-STEP program.

**Demographic Information**

Ten beginning secondary science teachers (five first-year and five second-year teachers) out of nineteen agreed to be a part of the study. Participants in this study included rural, urban, and suburban teachers from two Midwestern states. Nine of the ten participants were female and in their mid-twenties, and one male participant was in his early thirties. Participant demographic information can be found in Table 3.1.

**Table 3.1. Participant Demographic Information.**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Year</th>
<th>Preps</th>
<th>Community</th>
<th>Grades</th>
<th>Enrollment*</th>
<th>Free and Reduced Lunch*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>Female</td>
<td>1st</td>
<td>3</td>
<td>Rural</td>
<td>7-12</td>
<td>243</td>
<td>29%</td>
</tr>
<tr>
<td>Megan</td>
<td>Female</td>
<td>1st</td>
<td>3</td>
<td>Rural</td>
<td>7-12</td>
<td>425</td>
<td>52%</td>
</tr>
<tr>
<td>Jamie</td>
<td>Female</td>
<td>1st</td>
<td>2</td>
<td>Rural</td>
<td>9-12</td>
<td>515</td>
<td>42%</td>
</tr>
<tr>
<td>Kevin</td>
<td>Male</td>
<td>1st</td>
<td>4</td>
<td>Rural</td>
<td>9-12</td>
<td>527</td>
<td>46%</td>
</tr>
<tr>
<td>Rachel</td>
<td>Female</td>
<td>1st</td>
<td>1</td>
<td>Suburban</td>
<td>7-8</td>
<td>1008</td>
<td>29%</td>
</tr>
<tr>
<td>Grace</td>
<td>Female</td>
<td>2nd</td>
<td>1</td>
<td>Suburban</td>
<td>9-12</td>
<td>1260</td>
<td>24%</td>
</tr>
<tr>
<td>Maddie</td>
<td>Female</td>
<td>2nd</td>
<td>1</td>
<td>Urban</td>
<td>6-8</td>
<td>735</td>
<td>64%</td>
</tr>
<tr>
<td>Greta</td>
<td>Female</td>
<td>2nd</td>
<td>4</td>
<td>Rural</td>
<td>7-12</td>
<td>583</td>
<td>50%</td>
</tr>
<tr>
<td>Hannah</td>
<td>Female</td>
<td>2nd</td>
<td>2</td>
<td>Suburban</td>
<td>9-12</td>
<td>1939</td>
<td>24%</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Female</td>
<td>2nd</td>
<td>2</td>
<td>Suburban</td>
<td>9-12</td>
<td>775</td>
<td>15%</td>
</tr>
</tbody>
</table>

^ Pseudonyms used for participants
* Data obtained from National Center for Education Statistics
Study Context

The context of this study takes place one to two years after science teachers completed the MU-STEP. The quality of the teacher education program is an important factor in preparing beginning teachers to understand and implement effective science teaching within the constraints and socialization pressures of the school in which they work (Darling-Hammond, 2006a, 2006ba; Goodlad, 1990; Herman, Clough & Olson, 2013a & 2013b; Ihrig, 2014; Krajcik & Penick, 1989; Simmons et al., 1999; Tillotson & Young, 2013; Windschitl, Thompson, Braaten & Stroupe, 2012). Therefore, the essential features of the MU-STEP program are described.

The MU-STEP is an extensive 15-month teacher education program at a research-extensive university located in the Midwestern United States. While the MU-STEP is comprised of both undergraduate and graduate students that complete coursework together, the study participants were all graduate students. Therefore, the description of the requirements of the MU-STEP was limited to the Master of Arts in Teaching (MAT). The MU-STEP program consists of four methods courses and a nature of science course that holistically integrate research and practice (Clough et al., 2009). A summary of the science education components of the MAT program can be found in Table 3.2.
Table 3.2. Summary of the MU-STEP program (Adapted from Herman et al., 2013a p. 277).

<table>
<thead>
<tr>
<th>Graduate Science Teacher Education Program (Masters of Arts in Teaching)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer 1 Semester</strong></td>
</tr>
<tr>
<td>• Introduction to the complexities of learning and teaching science (2 credits, 20 contact hours)</td>
</tr>
<tr>
<td>• 20+ observation hours</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

* Optional Course

As explored in detail in chapters one and two, much is known about effective teacher education programs—including science teacher education programs (Bergman, 2007; Clough et al., 2009; Darling-Hammond, 2006a, 2006ba; Goodlad, 1990; Herman et al., 2013a & 2013b; Ihrig, 2014; Krajcik & Penick, 1989; Simmons et al., 1999; Tillotson & Young, 2013; Windschitl et al., 2012). Herman et al. (2013a) point out how the MU-STEP is aligned to the research-base on effective science teacher education programs when they write that the MU-STEP was designed to prepare highly qualified secondary science teachers who understand how people learn (Bransford, Brown, & Cocking, 2000) and employ reforms-based practices (AAAS, 1990; 1993; NRC, 1996, 2011) based on the best available educational research implanted in a holistic manner (Clough, Berg, & Olson, 2009) to create powerful learning environments” (p. 276).

More specifically, the MU-STEP has been modeled after this research-base on effective science teacher education in the following ways:

- The MU-STEP has a coherent intellectual framework that views teaching as decision making, considering multiple knowledge bases and classroom context.
This framework is consistent with the work of Dewey, Rousseau, and Schwab, and reflected in an organizer given to students—the Decision-making Framework (Clough et al., 2009, p. 828) – that permeates all aspects of the program (Darling-Hammond 2006a, Tillotson & Young, 2013).

- The program has a sequence of four tightly connected methods courses that scaffold students towards more complex understandings of science teaching and student learning (Herman et al., 2013; Tillotson & Young, 2013).

- The duration of the program—15 consecutive months with multiple methods courses—provides the time necessary for pre-service teachers to undergo conceptual change regarding what it means to teach and learn (Bergman, 2007; Tillotson & Young, 2013).

- The program requires a nature of science course, and the integration of nature of science concepts occurs throughout the program (Herman et al., 2013a; Tillotson & Young, 2013).

- Extensive field placements occur throughout the program alongside methods courses, and, to the extent possible, students are placed with cooperating teachers who promote research-based science teaching practices modeled in the MU-STEP (Darling-Hammond, 2006a; Herman et al., 2013a; Tillotson & Young, 2013).

- The assignments given in the methods courses are designed to foster reflective thinking (Tillotson & Young, 2013), articulate a research-based rationale (Penick & Harris, 2005; Tillotson & Young, 2013), and require pre-service teachers to “apply learning to real problems of practice; [develop] explicit strategies to help
[pre-service teachers] to confront their own deep-seated beliefs and assumptions about learning” (Darling-Hammond, 2006a, p. 305).

- The science educators who teach in the MU-STEP model the same research-based science teaching practices they expect from pre-service teachers and consistently draw pre-service teachers’ attention to the pedagogical decisions made (Bergman, 2007; Goodlad, 1990).

- The MU-STEP has a cohort system, which provides support throughout the program and often continues when pre-service teachers enter the profession (Herman, 2010; Ihrig, 2014; Tillotson & Young, 2013).

- To limit “wash-out” of effective science teaching practices (Zeichner & Tabachnick, 1981) that often occurs in student teaching, students in the MU-STEP take the third methods course during their student teaching experience and the fourth methods course after student teaching.

As the MU-STEP is informed by the research-base on effective science teacher education programs, many graduates from the program tend to value, understand, and implement research-based practices (Bergman, 2007; Herman, 2010; Ihrig, 2014). Further, the MU-STEP promotes deep levels of reflection on teaching practices through the methods courses, the practicum experiences, and the assignments. As a result, many teachers who leave the MU-STEP have undergone the conceptual change necessary to see the complexities of effective teaching and work to teach in a manner consistent with research-based teaching practices (Bergman, 2007; Herman, 2010; Ihrig, 2014).

Additionally, the MU-STEP works to help pre-service teachers deeply understand and navigate institutional constraints. Each science methods course explicitly addresses
what institutional constraints exist in schools and teaches pre-service teachers how to effectively navigate constraints while effectively teaching science.

As this study is investigating the institutional constraints, teaching practices, and orders of consciousness, the MU-STEP was selected for this study due to the high degree of alignment to the research on effective science teacher education programs and the explicit instruction throughout the program on institutional constraints. That is, the participants’ common experience within an exemplary science education program reduces a potential variable (the pre-service education experience) impacting science teacher decision-making.

**Data Collection**

Effective science teaching requires teachers to understand synergistic relationships between numerous aspects of science education research (Clough et al., 2009). While deeply understanding effective science teaching practices is necessary for teachers to implement research-based practices, it is also insufficient. The school environment can exert a powerful influence on the practices of the science teacher and requires the teacher to have an understanding of the social environment and navigate aspects of the environment that constrain the teacher’s ability to teach (Brickhouse & Bodner, 1992). Therefore, multiple sources of data were collected—classroom observations, semi-structured interviews, documents— in an attempt to capture some of the complexities facing beginning science teachers.

**Classroom Observations**

Classroom observations occurred in participants’ classrooms to determine their implementation of research-based science teaching practices (research question 2). Throughout the course of the study, participants were observed three school days.
Multiple observations took place to work to ensure the teaching observed was representative of the participant’s teaching practice. To understand the extent to which teachers implement research-based teaching, classroom observations were scored using the Local Systemic Change Classroom Observation Protocol (LSC-COP) (Horizon Research, Inc., 2006) and the Schlitt/Abraham Teacher Interaction Coefficient (SATIC) (Abraham & Schlitt, 1973). Field notes and semi-structured lesson reflection interviews were also used to provide triangulation with the LSC-COP and SATIC. During the observations, the researcher worked to minimize interactions with students and the participant to reduce distractions.

**LSC-COP.** The LSC-COP provides a guide to score the effectiveness of a lesson and the likelihood the lesson impacts student learning by looking at the design, implementation, science content, and the classroom climate. Each domain is comprised of key indicators the researcher used to rate the lesson from a scale of 1 (not at all) to 5 (to a great extent) and also included a “Don’t know” and “Not Applicable” category. The key indicators were then used as a guide to determine a synthesis rating for each domain from 1 (not at all reflective of best practice in science education) to 5 (extremely reflective of best practice in science education). Finally, scores across the four categories are used as guides to generate a capsule description of the overall effectiveness of the lesson consisting of seven levels that range from ineffective instruction to exemplary instruction (see Appendix C). An LSC-COP was completed for each participant for each lesson observed and these data were condensed into a mean capsule score for each participant.
SATIC. Abraham and Schlitt (1973) developed an instrument to code the teacher interactions that occur within a lesson (Appendix D). These interactions are broken down into initiatory behaviors (the teacher starts an interaction), response behaviors (the teacher responds to students’ comments), and the teachers’ non-verbal behaviors. A teacher can initiate an interaction by talking (SATIC code 1-2) or by asking the students a question (SATIC codes 3-4). Likewise, a teacher can respond to students by making different types of statements (SATIC codes 5-10) or by asking students a follow-up question (SATIC codes 11-12). Non-verbal behaviors (wait-time, passive non-verbals, and annoying mannerisms) make up the SATIC codes 13-15.

Each interaction a teacher has with a student is categorized into one of the fifteen SATIC codes, numbered chronologically over three five minute segments, and then tallied. The total for each of the fifteen SATIC codes is then used to create an interaction pattern that reflects how the teacher tends to interact with his or her students. As mentioned in the literature review, how a teacher interacts with students greatly impacts student learning and student goals. A SATIC analysis was completed for each course the participant taught during each of the three observation days. SATIC patterns were then reduced into a graphic representation and used to generate an overall interaction pattern of each participant.

Field Notes. Field notes were taken regarding the layout of the classroom, general observations of the lesson (e.g., inquiry-based, lesson structure, selection of tasks, selection of activities) as well as general observations of the interactions (e.g., unique interactions with students, wait-time, non-verbals of the teacher/students).
Lesson Reflection Semi-structured Interview. After each lesson observation, the participants were asked to describe what they hoped students would gain, if the lesson went differently than planned, and where the class was in the sequence of instruction. The participants’ responses to these questions were audio-recorded and used to provide context for field notes. For example, questions were often asked about why the teacher chose to make the decisions he or she made regarding activities, content, strategies, or interactions, and the responses to these questions were recorded in the field notes. The lesson reflection often provided an opportunity to learn more about the teacher’s decision-making process and sequence of the course the researcher was not privy to otherwise.

Semi-structured Interviews
To evaluate participants’ understanding of research-based science teaching practices, perceived institutional constraints, navigation of those constraints, and order of consciousness (research questions 1, 3, 5, and 6, respectively), the researcher conducted five semi-structured interviews including one post-MAT interview, one interview after each observation, and a final interview. One semi-structured interview was also conducted with the participants’ mentors and /or administrators to help triangulate how constraining and pervasive institutional constraints were in the participants’ schools (research question 4). All interviews were audio-recorded and later transcribed.

Post-MAT Interview. Prior to the start of the study, nine out of ten participants agreed to be a part of a post-program interview that occurred before they began their teaching assignments. All nine participants agreed to allow those interviews to be included in the study. The purpose of the interview was to gain insight into teachers’ understanding of research-based science teaching practices and to what extent they
valued the MU-STEP program. This interview provided insight into the life history and experiences of the teachers.

**Interviews during observation visits.** The topical semi-structured interview sequence (Dolbeare & Schuman, 1982; Seidman, 2006), Teacher Belief Interview (Luft & Roehrig, 2007), and the Subject-Object Interview Protocol (Lahey et al., 2011) informed the structure and the sequence of the semi-structured interviews with the participants throughout the study. The topical sequence is comprised of three interviews: focused life history, details of the experience, and reflection. Below, the purpose of each interview will be briefly explained. The full semi-structured interview protocols can be found in Appendix B.

*Interview one: Focused life history and Teacher Belief Interview.* The purpose of the focused life history is to gain information regarding the participants’ life experiences related to the research. As mentioned in the literature review, teachers’ prior experiences as students influence their perceptions as teachers. Therefore, the interview began with questions targeting the background of the teacher. To build upon the history, the researcher drew from the Teacher Belief Interview (Luft & Roehrig, 2007) and asked questions regarding teachers’ views on science teaching and student learning. Finally, the last part of the interview targeted how well teachers felt they were acclimating to the school environment (i.e., institutional constraints). As the researcher didn’t want to direct teachers’ thinking or reveal this purpose of the study, the phrase “institutional constraints” was avoided until the final interview.

*Interview two: Subject-Object Interview Protocol.* The purpose of the second interview in the Topical Interview Sequence is to focus on teachers’ order of
consciousness. To accomplish this, the Subject-Object Interview Protocol (SOI) was conducted with participants during the second interview. The purpose of the SOI is to probe participants’ order of consciousness and thus attempt to go beyond what participants think to why they think what they think (Lahey, 2011). The SOI uses emotions as a way to explore participants’ order of consciousness. The interview started by giving participants 24 index cards with various emotion words on it (See Appendix B). Participants were given time to think about the cards and then were asked to select at least three “negative” emotion cards and three “positive” emotion cards to discuss. Each card was discussed, and the interviewer asked the participants the follow-up questions about why and how they felt what they felt in order to learn what each participant placed as subject and object such as: “Why do you think you felt that way?” “What situations do you feel that way the most often?” “What types of things do you do when you feel that way?”

Interview 3: Reflection questions. The topical interview sequence concludes with a reflection interview to ask participants to make meaning of their experience. Participants were asked to reflect upon their teaching practices and how they compare to their perception of the ideal.

Interview 4: Final interview. The final interview was conducted after all observations of the participant were complete. During the interview, participants were again asked questions from the Teacher Belief Interview to provide a post-study comparison. Additionally, explicit questions were asked regarding what institutional constraints teachers faced and how they navigated them. Finally, scenarios and Venn diagrams were used to provide triangulation to teachers’ understanding of research-based
teaching practices (research question 1), identification and navigation of constraints (research questions 3 and 5), and their order of consciousness (research question 7).

*Interview with mentor/administrator.* Semi-structured interviews with the administrator and/or the mentor teacher were conducted during an observation day of the participant. The purpose of the interview was to understand the school environment and how constraining and pervasive institutional constraints were for the participant (research question 4). Specifically, the interview sought to understand the mentor/administrator’s perspectives on professional development, effective science teaching, the participant’s teaching practices, and the role of teacher education programs.

*Artifacts*

During the informed consent process, participants were asked if they would be willing to grant access to their assignments they completed during the MAT program at MU-STEP to inform the study, and all participants agreed. Archived artifacts included the research-based framework papers, reflection papers that accompanied MAT students’ SATIC analyses, lesson plans, and Science Methods II course grades. These artifacts were used in conjunction with the Post-MAT interview to ascertain the extent to which teachers understood and implemented research-based teaching practices while in the MAT program at MU-STEP.

Participants often gave the researcher documents (e.g., assignments, rubrics, worksheets) during the classroom observations that provided context for what the class was working on and helped guide field notes.
Data Analysis

Participant Descriptions

Following the structure of other accounts of participants after graduating from exemplary teacher education programs (Berger, 2002; Bergman, 2007; Hammerman, 2002; Herman, 2010; Ihrig, 2014; Madsen, 2005), chapter 4 begins with a rich description of each participant’s experience related to science teaching, including understanding of research-based science teaching practices, implementation of science teaching practices, institutional constraints, and order of consciousness. Collectively, the descriptions and analyses set the stage for the subsequent analysis of themes that cut across the participants. Specifically, the analysis will examine any relationship that may exist between orders of consciousness, teaching practices, and institutional constraints across the participants. Using the data sources described above, participant summaries and data analysis occurred as described in the following sections.

General analysis. All semi-structured interviews from participants were transcribed and then coded using initial coding (Charmaz, 2006; Corbin & Strauss, 2008; Glaser & Strauss, 1967; Saldaña, 2013; Strauss & Corbin, 1990). Document analysis (Bowen, 2009; Denzin, 1970) was used to analyze archived artifacts collected from the MAT program (see Appendix E) in combination with the interview analysis for triangulation (Denzin, 1970). During the document analysis, analytic memos (Corbin & Strauss, 2008; Saldaña, 2013) were used to document emerging patterns and themes within the artifacts.

Analysis of participants’ understanding of research-based science teaching practices. Initial codes of all interview transcripts along with the artifacts from the MAT program (Appendix E) were used to categorize participants’ understanding of science
teaching practices (research question 1) using the Teacher Belief Interview (Luft & Roehrig, 2007) as a guide. Specifics of the categorizations are discussed further in chapter 4.

**Analysis of classroom observations.**

*LSC-COP.* A LSC-COP was used for each classroom observation for each participant. The scores for each indicator (design, implementation, content, classroom culture) as well as the capsule score was reduced into a summary LSC-COP table for each participant. Additionally, all capsule scores for each participant were reduced into a mean score. Mean scores were then compared to the capsule score ratings on the LSC-COP and were used to generate an overall description of each participant’s teaching.

*SATIC.* Each SATIC analysis conducted during the classroom observations was collectively summarized into a graphic representation of the percent occurrence of each interaction code for the participant. These graphs were used to determine the participant’s interaction pattern—the interactions that occurred most frequently. These interaction patterns were then compared to the research literature outlined in chapter two to determine the degree of congruence (i.e., thought-provoking, open-ended questions (SATIC 3c & 4), acknowledging students’ ideas (SATIC code 6), and asking students to clarify, or using the students’ ideas (SATIC codes 11&12).

*Field notes.* Field notes were used for triangulation with the SATIC and LSC-COP. Additionally, field notes provided context of the lesson and observations not represented in the SATIC or LSC-COP (e.g., physical arrangement of the room, tone of the teacher, content specific observations).

**Analysis of perceived intensity of institutional constraints and degree to which the institutional constraints were constraining and pervasive.** After initial
coding was complete, the data were reduced to five categories of participants’ perceptions of institutional constraint. Magnitude coding (Miles & Huberman, 1994; Miles, Huberman, & Saldaña, 2014; Saldaña, 2013; Weston et al., 2001) was used to categorize the participants’ perceived intensity of institutional constraints (research question 3). The participants’ perceptions of constraints were then ranked, using magnitude coding, from 0 (no constraint) to 3 (intense constraints) in each of the categories. These codes were then added to determine an overall perceived constraint score. These categorizations were then compared to the interview data and field notes for triangulation before determining the final level of perceived constraint (i.e., low, medium, or high).

Magnitude coding was also used on the interviews with mentor teachers and administrators of the participants to understand how constraining and pervasive the institutional constraints were for the participants (research question 4). Put differently, the interviews were evaluated to determine to what extent the school environment was supportive of research-based science teaching practices. The mentor/administrator interviews data were then reduced to the codes: unsupportive, neutral, or supportive.

**Analysis of participants’ navigation of constraints.** Process coding (Bodgan & Biklen, 2007; Charmaz, 2002; Corbin & Strauss, 2008; Saldaña, 2013) was used to analyze participants’ navigation strategies if and when they face institutional constraints (research question 5). Process coding was selected due to the emphasis on “ongoing action/interaction/emotion taken in response to situations, or problems, often with the purpose of reaching a goal or handling a problem” (Corbin & Strauss, 2008, p. 96-97).
The process codes were then reduced into broad categories that summarized the most pervasive approach or feelings the participant used in response to institutional constraints.

**Analysis of participants’ order of consciousness.** The interviews with the participants and their mentor/administrator provided a context for exploring how the participant made sense of his or her experience or order of consciousness. Put differently, this study attempts to explore *what* the teachers are experiencing (the descriptions), but also *how* the teachers make meaning of this experience (order of consciousness). Specifically, the Subject-Object Interview was used to analyze each participant’s order of consciousness by examining whether and how the participant is able to: take on multiple points of view, take on a wider view, reflect upon a situation, and navigate the school environment (Lahey, et al., 2011).

While the Subject-Object Interview was conducted with each participant (Interview 2, Appendix B), all semi-structured interviews were used as triangulation to better understand each participant’s order of consciousness. For example, in interview 4, participants were asked to draw two Venn diagrams to discuss how they believed their understanding of science teaching practices aligned to the MU-STEP and their current school. In addition, questions throughout the interviews (e.g., “What is your relationship like with your colleagues?”) along with asking participants to discuss how they would respond to various scenarios (see Appendix B) provided triangulation regarding their order of consciousness. A subject-object analysis sheet was used (Appendix F) to determine each participant’s order of consciousness and if the participant was transitioning between two orders.
Lahey et al. (2011) outline the transition between the orders with different symbols. The following is the transition from orders three to four: \(3, 3(4), 3/4, 4/3, 4(3), 4\). The number in parentheses indicates an order that is just beginning to appear (i.e., \(3(4)\) means that three is dominant with four beginning to appear). The backslash indicates that both orders are present, but one is still prevalent over the other. Therefore, the example above shows a gradual shift away from the third order towards the fourth order. To improve the reliability of coding participants’ orders of consciousness, the researcher used two transitions between the orders that consisted of: \(X, X/Y, Y/X, Y\).

Trustworthiness

As the researcher was the primary instrument in this study (and therefore subject to bias in all aspects of the research) a need exists to ensure the study was trustworthy and credible (Creswell & Miller, 2000). Qualitative researchers have outlined numerous criteria for establishing the trustworthiness of a study including: making clear the researcher’s positionality, variation in the sample, ensuring adequate engagement with participants, conducting member checks, establishing an audit trail, triangulating data, engaging in peer debriefing, and including thick, rich descriptions (Creswell, 2013; Creswell & Miller, 2000; Merriam, 2002; Miles et al., 2014).

Positionality of the Researcher

Just as the context of the participants is important to make clear in a naturalistic study (Erlandson et al., 1993; Lincoln & Guba, 1985), the researcher’s context, biases, and perspectives are also important to explore as the researcher is the “primary instrument” in all phases of the research process (Lincoln & Guba, 1985; Merriam, 2002).
I am a Caucasian male who is from the Midwest and I have been a teacher for ten years. I completed my Masters of Arts in Teaching (MAT) through Midwest University Science Teacher Education Program (MU-STEP), which is the same program the participants completed. Because I went through the same program, I was very familiar with the structure, goals, and approach of the program. I valued what the MU-STEP program promoted to a very large degree; therefore, my interpretations of my participants and their beginning years of teaching are also influenced by my knowledge and value of the MU-STEP. Furthermore, I interacted with each of the participants while they were MAT students and I was a Ph.D. student. While these extensive interactions throughout the MAT and the first years of the participants’ teaching are certainly a source of bias, they also demonstrate a prolonged engagement with the participants.

My interest in studying beginning science teachers started with my own struggles as a beginning classroom teacher. Despite my best efforts to understand and implement effective teaching, I found a few of my students didn’t want to participate or engage in class discussions and activities. Even when I encouraged students privately to engage in class, I still was not satisfied with the level of engagement of some of my students. A colleague of mine and I decided to develop a grounded ethnographic study to find out why students were choosing to participate or not participate in class (Kruse & Wilcox, 2009). We found some promising results that indicated the more students believe learning is being told the answer instead of a process that requires a great deal of mental effort, the more they resist becoming active participants in classroom discussions. We developed numerous strategies that were embedded within the science content to help students deeply understand what it means to learn and know. The results of our study
indicated that students can modify their views about learning and knowing and undergo a 
process of conceptual change like they do when they are learning science content that 
conflicts with their preconceived notions.

Throughout my experiences as a teacher, I came to understand that students can 
be obstacles to teachers enacting research-based teaching practices. Additionally, other 
stakeholders in the school (e.g. administration, colleagues, parents, etc.) can also be 
Sources of constraint that can erode teachers’ use of research-based practices. However, 
I came to understand that I could navigate institutional constraints while making small 
steps towards changing the system to be more open to research-based teaching practices. 

My experiences as a teacher, a Ph.D. student, and a teacher educator have led me 
to believe that traditional teaching practices will persist unless we help teachers deeply 
understand, value, enact, and persevere with research-based teaching practices. My hope 
is that this study can shed some light (as small as it may be) on how to help beginning 
teachers become and remain effective.

**Variation in the Sample**

To provide the greatest amount of generalization of qualitative studies possible, 
many qualitative researchers suggest purposefully seeking variation in the sample 
(Creswell & Miller, 2000; Merriam, 2002; Miles et al., 2014). While generalizability in a 
qualitative study is an elusive concept, a diverse population of participants can add to the 
trustworthiness of the study by improving the case-to-case transfer, known as user 
generalizability, where the reader decides to what extent the study fits his or her present 
circumstances (Firestone, 1993).
The selection criteria used for this study employed variation in the sample through recruiting all members of the MU-STEP cohorts that were in their first or second year of teaching. Ten out of nineteen participants agreed to be part of the study. However, as explored more deeply in chapter four, the ten participants ranged in ability throughout the program, taught in a variety of school settings (e.g., urban, suburban, rural), and had varying degrees of support, thus providing evidence that adequate variation of graduates of the MU-STEP and their school contexts was achieved.

**Adequate Engagement with Participants**

Merriam (2002, p. 31) notes that researchers should be engaged with the participants in data collection long enough that “the data become ‘saturated’.” Saturation ensures the phenomena are well understood and the claims made from the study are representative of the participants’ experiences. Perhaps more importantly, adequate engagement with participants can build trust necessary for participants to feel comfortable sharing information (Creswell & Miller, 2000).

As a Ph.D. student, the researcher interacted extensively with each participant by serving as the academic advisor for the MU-STEP program, co-teaching courses with the science education faculty, supervising many of the participants in their student teaching experience, and serving as an advisor for the science education club in which many participants were involved. Beyond the program, the researcher interacted with many of the participants informally at science teacher conferences. At the time the study began, the researcher had known each participant for at least fifteen months.

During the study, the researcher visited with each participant a minimum of five times, including one initial interview, three classroom observations each with an
interview, and a final interview. When observing, the researcher would watch the teacher teach at least one period for each course that they taught. Throughout the course of the observation day, the researcher would often talk informally with the participant between classes, during breaks, and before and after school. While these interactions were not recorded, they did help the researcher understand each participant’s thinking, situation, and feelings. Further, these informal conversations served as important moments to improve the relationship between the participants and the researcher, which seemed to add a great deal of trust and openness. Additionally, the researcher frequently corresponded with participants to conduct member checks and coordinate observation visit dates.

**Member Checks**

Lincoln & Guba (1985) contend that member checks are “the most crucial technique for establishing credibility” (p. 314) as they shift the focus from the researcher to the participant. Specifically, member checks involve participants in the meaning making process by having them review data and interpretations so they can check the credibility of what has been written about them (Creswell & Miller, 2010).

Member checks occurred at two primary phases throughout the research process. First, after each classroom observation, participants were asked about the purpose of the lesson, what was different than they had planned, and what the class had been studying. In this sense, participants provided context for their lessons the same day they were observed. This process helped to shape the field notes and included the participant in the process of making meaning of his/her teaching practices. Second, participants were sent transcripts of their interviews once all interviews had been completed and had the
opportunity to comment on any errors they perceived or areas in which they wanted to expand upon. Three participants responded with clarifications to the interviews.

The researcher did not send interpretations of the data to the participants for two major reasons. First, participant evaluations of his or her order of consciousness is limited by the order of consciousness the person holds. In other words, participants with a forth order consciousness may provide substantially different kinds of feedback than those who have not yet achieved fourth order, thus creating an additional source of bias to the research. Second, researchers have pointed out a member check can censor the researcher’s interpretations of the study and therefore limit the impact of the findings (Bradshaw, 2001; Burawoy et al., 1991).

**Audit Trail**

An audit trail is “a detailed account of methods, procedures, and decision points in carrying out the study” (Merriam, 2002, p. 31). Much like a fiscal audit is used to ensure accuracy and credibility, the audit trail ensures the process of documentation was thorough and logical, the researcher acknowledged and attempted to bracket —working to suspend bias, emotions, and preconceptions (Tufford & Newman, 2012). Additionally, the researcher worked to ensure the findings were grounded in data and the inferences in the study are logical and in line with the research framework (Creswell & Miller, 2000).

The audit trail for this project consisted of two major parts. First, a spreadsheet was used to record when and what data were collected for each participant and their mentor/administrator throughout the process. Second, a reflexive journal was used throughout the data collection and analysis process that guided subsequent interviews,
meaning-making of the data, and afforded opportunities to make explicit and help bracket the researcher’s biases.

**Triangulating Data**

Another way to ensure trustworthiness of the study is to ensure the findings of the study are consistent across multiple sources of data, known as triangulation (Miles et al., 2014). Specifically, triangulation can involve using multiple researchers, sources of data, or data collection methods to corroborate research findings (Denzin, 2001; Merriam, 2002; Miles et al., 2014). Miles et al. (2014) suggest including “triangulation sources that have different foci and strength, so that they complement each other” (p. 299).

This study used triangulation in numerous ways across the research questions. An understanding of participants’ views of research-based decision-making (research question 1) was triangulated between all five interviews and classroom observations. When teaching practices of the participants were observed by the researcher (research question 2), the researcher took field notes, filled out a SATIC form, and performed an LSC-COP for each different course the participant taught throughout the day. Further, the researcher collected artifacts (e.g., worksheets, assignments, assessments) from each participant during each observation. The variety of data sources and types of collection were triangulated to glean a more holistic picture of the teachers’ understanding and implementation of research-based teacher decision-making.

The perception and navigation of institutional constraints (research questions 3 and 5) were triangulated between the five interviews and also compared to the classroom observations. The administrator and/or mentor teacher of each participant was interviewed to gain insight into the school culture and how constraining and pervasive the
constraints were on the teacher (research question 4). Furthermore, the researcher often debriefed with other researchers on IRB for this project to gain perspective on the degree to which the school cultures were constraining the participants’ ability to enact research-based science teaching practices.

**Peer Debriefing**

Peer debriefing refers to discussing the research process, findings, data, and tentative interpretations with colleagues that are external to the study but familiar with the research being explored (Merriam, 2002 & Creswell & Miller, 2000). Creswell & Miller (2000) write, “a peer reviewer provides support, plays devil’s advocate, challenges the researchers’ assumptions, pushes the researchers to the next step methodologically, and asks hard questions about methods and interpretations (Lincoln & Guba, 1985)” (p. 129). Throughout the study, the researcher had frequent meetings with researchers on the IRB for this project regarding all aspects of the study.

**Thick, Rich Descriptions**

Effective qualitative studies provide detailed accounts of the participants, their experiences, and their context (Miles et al., 2014), which results in user generalizability (Firestone, 1993), and therefore improves the trustworthiness. One way to improve user generalizability is to provide thick, rich descriptions that can help researchers “determine the extent to which their situation matches the research, context, and hence, whether findings can be transferred” (Merriam, 2002, p. 31).

Thick, rich descriptions were achieved in this study through describing the MU-STEP (see above) as well as the participants and their contexts once they left the MU-STEP. Chapter four provides a detailed account of each participant’s context, teaching
practices, institutional constraints and school culture, and their order of consciousness. The teaching practices, institutional constraints, and orders of consciousness is then compared across all ten participants.

Limitations

The researcher is a Caucasian male from the Midwest largely studying a Midwestern, female Caucasian demographic. As a result, the conclusions from this study may be transferred to other populations with similar demographics, but due to these limitations may not be generalizable to a more diverse population of beginning science teachers.

Related to the demographics, this study assumes the beginning science teachers are representative of all beginning science teachers that go through the MU-STEP program. While this assumption cannot be verified, two cohorts of MU-STEP graduates were intentionally invited to participate in the study to help maximize variation. Geographic barriers (e.g., one teacher taught in Africa), attrition (e.g., three graduates did not pursue teaching), alternative graduation (e.g., two participants did not graduate with their cohort), and willingness (e.g., four teachers declined to participate) did limit the researcher’s ability to study two entire cohorts. As participants had different contexts (e.g., supportive/unsupportive schools, rural, suburban, urban) and had varying success in the MAT program, the participants seem to be representative of MU-STEP graduates.

The researcher’s extensive interactions with the students during the MU-STEP as a teacher and mentor and as a researcher may have impacted participants’ teaching practices and their responses to interview questions. To mitigate this limitation, multiple interviews were conducted over a period of time along with multiple observations of
participants’ teaching, yet this study assumes the observations of participants’ teaching and their interviews were accurate depictions of their experiences.

This study is limited in scope to research-based science teaching practices, institutional constraints, and orders of consciousness. As the socialization process is a multi-faceted, complex, and unique experience for each teacher, more factors than this study explores could be operating. However, those additional factors are beyond the scope of this study.
CHAPTER 4: FINDINGS

Overview

Qualitative research must establish a transparent link between the data and findings derived from those data. Due to the extensive nature of the data collected in this study, the data were reduced for each participant into individual profiles for display in this chapter. Findings, however, were developed from the original data sources using the methods described in chapter three, and original data from each data source is available upon request. Therefore, chapter four is organized into two sections. The first section provides profiles of each participant, and the second section provides the findings for each research question.

Research Questions

Teaching practices

1. To what degree do participants understand research-based teacher decision-making?
2. To what extent do participants implement research-based science teacher decisions?

Institutional constraints

3. To what extent do participants perceive institutional constraints impact their teaching decisions?
4. How constraining and pervasive are participants’ perceived institutional constraints?
5. How do participants navigate perceived institutional constraints?
Orders of Consciousness

6. What are the participants’ orders of consciousness?

7. To what extent do teachers’ orders of consciousness relate to their perception and navigation of institutional constraints and teaching practices?

Participant Profiles

The data trail for the participant profiles followed the approach of Ihrig (2014) as superscripts are used throughout the profile to indicate a specific quotation that supports the claims made. The footnotes for each participant can be found in between the references and the appendices. The participant profiles also include an abbreviated system that corresponds to the data source and page number of that source. For example, (Taylor, 1, 8) means Taylor, post-MAT interview, page 8. The data source abbreviation key can be found in Table 4.1.

Table 4.1. Data Source Abbreviation Key.

<table>
<thead>
<tr>
<th>Number</th>
<th>Data Source Abbreviation</th>
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<tbody>
<tr>
<td>1</td>
<td>Post-MAT Interview</td>
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<td>2</td>
<td>Interview 1</td>
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<td>3</td>
<td>Interview 2</td>
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<td>4</td>
<td>Interview 3</td>
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<td>5</td>
<td>Final Interview</td>
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<td>6</td>
<td>Administrator Interview</td>
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<td>7</td>
<td>Mentor Interview</td>
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<tr>
<td>8</td>
<td>Field notes</td>
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<tr>
<td>9</td>
<td>Research-based Framework (MU-STEP Assignment)</td>
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<tr>
<td>10</td>
<td>Self-analysis of Teaching Behaviors (MU-STEP Assignment)</td>
</tr>
<tr>
<td>11</td>
<td>Lesson Plan (MU-STEP Assignment)</td>
</tr>
<tr>
<td>12</td>
<td>Teacher Artifacts</td>
</tr>
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Taylor

Background. Taylor earned an undergraduate degree in biology and began pursuing a graduate degree in entomology. When the entomology project she worked on didn’t receive funding, Taylor decided to go into the workforce in wildlife conservation
and then the zoo. Part of Taylor’s role at the zoo was providing informal education for students. A colleague, who was a former teacher, suggested to Taylor that she pursue science teaching as a career, and Taylor joined the MAT program at Midwestern University.

Although Taylor valued the MAT program and thought the cohort structure was helpful, she often struggled in her coursework and didn’t effectively manage her time between her coursework and field experience. Taylor attributed her struggles in the MAT to the instructor having favorites and to her not being on the same “brainwave” as the professor (Taylor, 1, 8). The assignments Taylor turned in often reflected a lack of understanding regarding research-based science teacher decision-making, and Taylor’s final grade of B- in Secondary Science Methods II also reflected that Taylor had basic competencies for teaching but was not demonstrating research-based practices consistently (Appendix E). Despite her understanding, Taylor thought the MAT prepared her to teach well, and she valued what she learned. During the study, Taylor was a first-year teacher in a rural school district and taught three different courses. Taylor taught 7th grade science, biology, and advanced biology.

**Understanding of research-based teacher decision-making.** Taylor recognized the need to start with concrete activities and incorporate the nature of science into her lessons. Specifically, she thought a lot about activities and the degree to which the students would be excited by them. Taylor often mentioned how much she enjoyed learning about the nature of science and tried to incorporate history into her lessons. When Taylor assessed the students, she stated that she works to make the assessment
“thought-provoking” (Taylor, 4, 1) and be a mix of “essay, short-answer, and fill-in-the-blank” items (Taylor, 2, 10).

Taylor verbalized a rudimentary understanding of research-based teaching practices; however, what wasn’t said was, perhaps, more indicative of her understanding than what was said. That is, throughout the interviews, Taylor was asked about her understanding of science teaching and student learning, but she often went to trivial issues (e.g., science materials, calling on students) rather than focusing on the big ideas regarding teaching and learning. Specifically, she rarely discussed her interactions in the class, her student goals, relationship building, or the synergistic relationships between them. For example, Taylor seemingly didn’t understand the connection between her lack of relationship building and her difficulties in managing the classroom. When pressed on how she will improve her management, Taylor stated, it will get “easier with experience” (Taylor 4,4). Throughout all of the interactions the researcher had with Taylor, she demonstrated a limited understanding of research-based science teaching practices.

**Implementation of science teaching practices.** Typically, Taylor started each class immediately after the bell rang by lecturing or talking with students about a particular science topic. Taylor sometimes transitioned from lecturing to a concrete activity (e.g., dissecting lima beans, designing a zoo); however, these activities were often either overly structured (e.g., laboratory worksheets) or completely open-ended (e.g., “design a zoo”). Related to this, Taylor often did not scaffold student thinking to help them link the activity to fundamental science ideas (Taylor, 8, 59). Students were often frustrated with her approach and often verbally expressed their frustrations. For example, students said, e.g., “This is the worst class ever” and “I would rather shoot
myself in the foot [than do this activity]” (Taylor, 8.59). Taylor often responded with sarcasm (“I wouldn’t be opposed [if you shot yourself in the foot]”), or threats (If you can’t handle [this activity], we won’t do them as much) (Taylor, 8, 59). Frequently, the class activity or discussion would end early and students were told to “work on other school work” or were given unstructured time until the bell rang (Taylor, 8.11).

Fifty percent of Taylor’s lessons (see Figure 4.1) were coded on the LSC-COP as “not at all reflective of best practice in science education” and often involved passive learning or doing an activity for activity’s sake (Horizon Research Inc., 2005, p.11). The other fifty percent of her lessons had elements of effective instruction but were “very limited in their likelihood to enhance students’ understanding of science”. Taylor rarely asked extended answer questions (SATIC 4) and rarely used students’ ideas or asked them to elaborate (SATIC 11’s and 12’s) (Figure 4.2). Instead, Taylor’s SATIC pattern was 1/2/3b/10, indicating that she lectured, made statements, asked short-answer questions, and answered student questions.
* Maximum capsule rating is 7; maximum rating for other categories is 5.

**Figure 4.1.** Average LSC-COP scores of Taylor’s teaching practice during classroom observations.

**Figure 4.2.** Average occurrences of Taylor’s verbal interactions during classroom observations.

**Perceived constraints.** Despite acclimating to a new school environment, teaching numerous subjects, and struggling with classroom management, Taylor didn’t perceive her environment as constraining. For example, Taylor expressed she “hadn’t
been told she couldn’t teach anything” (Taylor, 2,15) and often framed her success at the school by what she had heard from her colleagues, as she mentioned “[my colleagues] are just excited to have a real science teacher” (Taylor, 2,15). When Taylor was asked to explain what she meant, she said that she felt whatever teaching decisions she made were better than the person she replaced.  

**School environment- constraints and their pervasiveness.** Taylor’s school environment did not seem to be constraining nor does it have pervasive constraints. During an interview with the principal, he stated the school was focused upon improving reading, high-stakes test scores, and the inclusion of technology (e.g., one-to-one iPads). While these initiatives could run contrary to research-based science teaching practices, depending upon their implementation, when asked about science teaching more specifically, the principal expressed his desire to see students engaged and know what they are learning. In discussing Taylor in particular, he believed she was passionate about science and engaged students better than her predecessor but admitted she sometimes struggled to manage the classroom.  

Taylor didn’t interact with her colleagues very frequently, and this was a source of frustration for her. Specifically, Taylor wished her mentor took a more active role in showing her how to do tasks around the school (e.g., work the copier) as well as interact with her more regarding her science teaching. When Taylor was asked how she might overcome her frustration, she mentioned she could maybe go talk to teachers during her preparation time but wished her mentor would tell her when other teachers had their preparation time. While Taylor often felt isolated, she admitted she had a lot of power
over her decisions in the classroom\textsuperscript{16}, and she had very little pressure from colleagues to teach a certain way.

In summary, Taylor’s school environment was not constraining; however, the environment was not supporting Taylor in improving her science teaching either. Therefore, the school environment might best be described as “neutral.”

**Navigation of constraints.** Taylor did not find her teaching environment constraining; consequently, Taylor was unaware of decisions she could make to navigate the constraints she did face. When Taylor spoke about her frustrations, she often wished things would be different, someone would tell her what to do, or thought things would get better with time. In this sense, Taylor did not actively navigate her environment to make the workplace less frustrating. Instead, Taylor used external cues from her principal and colleagues along with the perceptions of her predecessor to guide the decisions she made.

**Order of consciousness.** Taylor displayed meaning-making at the second order of consciousness with some initial signs of third order (Order 2/3). While Taylor recognizes that others have different opinions and ideas than herself\textsuperscript{43} (an achievement of the second order), she often struggled to hold multiple perspectives in her mind simultaneously, didn’t own responsibility for her role in interactions, used external sources (e.g., principal, colleagues) to judge her effectiveness, and held her personality as subject. As a result, Taylor had not yet transitioned fully to third order consciousness.

As noted above, Taylor often struggled to effectively manage the classroom and play off of students’ ideas. Both of these require a teacher to hold the students’ perspective and his/her own perspective at the same time to effectively navigate complex social interactions that go beyond second order consciousness. Taylor also struggled to
take responsibility for her own actions and her role in creating the social environment in which she struggled to navigate. For example, Taylor stated the professor didn’t think the work she turned in was of high quality. Instead of working to improve her understanding, Taylor stated she didn’t feel she had a whole lot of time. Additionally, when Taylor was pressed on how she might manage her classroom more effectively, she stated, it will get “easier with experience” (Taylor 4,4).

Taylor often used the perspectives of her principal and colleagues to judge her effectiveness in the classroom. Additionally, Taylor often compared her actions to her perceptions of what her predecessor would have done to determine if she was effective rather than basing her effectiveness on science education research. While Taylor has seemed to internalize others’ perspectives (an achievement of third order), Taylor had not yet demonstrated the capacity to internally reflect on those perspectives in ways that could help her practice improve.

Taylor’s methods professor, had warned Taylor that he was concerned she would rely upon her positive personality rather than work hard to effectively implement research-based science teaching practices. Taylor mentioned, months later, that she was deeply offended by those comments. Taylor didn’t seem to have the ability to reflect on her personality as object, which likely made her feel powerless to change her circumstances.

**Megan**

**Background.** Megan joined the MAT program at Midwestern University shortly after completing her degree in Chemical Engineering. Throughout Megan’s undergraduate and into the MAT, she worked in the engineering field. Megan’s favorite
part of her engineering job was training new people, and, with her boss’s encouragement, Megan decided to pursue science teaching.

Megan did not like the MAT program and stated, “The MAT program was probably one of the hardest things that I have ever done and that's from somebody that went through an engineering program that I hated every step of the way” (Megan, 5, 4). Megan’s experience in the MAT seemed to be rife with contradictions. For example, when talking about the second methods course, Megan expressed she felt the assignments were difficult, but at the same time, thought the content was repetitive. Similarly, Megan said she bought in to the program because it was research-based but was frustrated that she had to redo assignments to align them better to the research base.

Part of Megan’s dislike of the program seems to be situated in her belief that teaching should be easier than her engineering degree and she deeply valued her engineering degree and the associated content she learned. Often, when talking about the difficulty of the MAT, she framed that difficulty alongside her success with engineering\(^2\). Instead of recognizing that teaching is complex, Megan often attributed her struggles in the MAT to external circumstances such as perceiving Dr. Clark to favor students, the doctoral student grading more work than the professor, unclear grading criteria, and lack of time. At one point, Megan considered quitting the MAT, but decided to persevere, as the MAT was only 15 months and she liked interacting with secondary students.\(^3\) Megan earned a C+ in Secondary Science Methods II, which indicated Megan understood the basic competencies but struggled in understanding the complexities of science teaching (Appendix E).
During the study, Megan was a first-year teacher in a rural school district and taught three courses. The high school and middle school were physically connected to each other, and Megan split time teaching 8th grade Physical Science and high school Physics and Biology.

**Understanding of research-based teacher decision-making.** Megan understood some basics regarding effective science teaching practices, which included: starting with concrete experiences⁴, using formative assessment strategies (i.e., white boarding, exit tickets, asking questions)⁵, and needing to have a clear progression of objectives⁶.

While Megan did understand some basic pedagogical practices, she rarely expressed a deeper understanding of the underpinnings regarding how and why those practices were effective. For example, when Megan was asked why teachers might engage in formative assessment practices, she stated, “They have the clear objective in their mind of where they want their kids’ understanding to be and they also know where their stretch goal is. So if they get all their kids there, where can we go next, so they have that objective milestone out, I guess.” (Megan, 5,3). Although this statement isn’t inaccurate, it is indicative of her viewing decisions only from her perspective rather than thinking deeply about how the students are constructing knowledge, the extent to which student goals (i.e., creativity, problem-solving, effective communication) are promoted, and how the decisions interact with her student goals and how people learn. In short, Megan’s understanding of teaching seems to be a collection of piecemeal ideas rather than a synergistic connection between the parts.

**Implementation of science teaching practices.** Despite Megan having an understanding of some foundational practices for effective science teaching, her teaching
often did not reflect her statements in her interviews. For example, in four out of nine observed lessons, Megan’s lessons were not reflective of best practice in science education and were coded as a one, the lowest LSC-COP capsule rating (Figure 4.3). These lessons were characterized as “passive learning” (Horizon Research Institute, 2005, p.11) where students worked on making vocabulary flash cards, reading the book, or working on worksheets independently. Students in these lessons rarely interacted with the teacher or each other in any meaningful way. All three biology lessons observed were coded as a one.

Four out of nine observed lessons in physical science and physics had elements of effective instruction, but were “somewhat limited in the likelihood to enhance students’ understanding” of science (Horizon Research Institute, 2005, p.11). Most often in these lessons, Megan engaged students with a concrete, hands-on activity. However, when Megan debriefed the activity, she often either told students what they should have found and didn’t scaffold students’ thinking of the experience to help them understand the science concept behind the activity.

One out of the nine observed lessons had a number of effective elements with a capsule rating of five. In this lesson, students were given a scenario regarding when the crew on an airplane should drop the cargo if they wanted it to land in a certain spot (Newton’s first law). While the lesson was logically structured, engaging, and scaffolded students’ thinking, this same lesson was modeled for Megan during her MAT experience at MU-STEP.

Although Megan valued questioning strategies, her teaching was not consistent with this value (Figure 4.4). Megan most often made statements (SATIC 2), answered
student questions (SATIC 10), and lectured (SATIC 1). When Megan did ask questions, these were often dichotomous or short-answer questions rather than asking students thought-provoking questions (SATIC 3c/4) that scaffolded their learning based on their understanding (SATIC 11 & 12).

* Maximum capsule rating is 7; maximum rating for other categories is 5.

Figure 4.3. Average LSC-COP scores of Megan’s teaching during classroom Observations

Figure 4.4. Average occurrences of Megan’s verbal interactions during classroom observations.
**Perceived constraints.** Megan didn’t perceive her school environment to be constraining, as she stated, “There aren’t a lot of constraints at my school in the sense that things that I have to do or things that are in my way. I think there's almost too much freedom at my school” (Megan, 5,17). When asked to expand on her statement, Megan said, “On one hand [the administration and faculty] really trust [their] teachers I guess. [On] the other, a little guidance would be nice” (Megan, 5, 18). Although Megan had a great deal of freedom in deciding how and what she taught, dividing her time between three different courses was a challenge for her. Megan often dealt with this constraint by not putting much time into Biology, as it wasn’t her content area and the students were difficult to manage.

**School environment--constraints and their pervasiveness.** Through conversations with Megan’s principal and mentor, the researcher determined the school environment did not seem to be constraining or have pervasive constraints. Instead, Megan’s middle school principal was focused on English/Language Arts and Math initiatives and didn’t seem to spend much attention on how the teachers are teaching science. When asked directly about science, the principal remarked,

> To me, science is one of those things that you want the students to have to think. You don't want just to say this is the scientific concept and it is because it is. You want the kids to understand and say why. You want them questioning it to say let me understand the process, because then I will actually know science versus you're spoon feeding me and I'm just going to spit it back out at you come test time (Megan’s MS principal, 6, 6).

When the principal was asked specifically about Megan’s progress, he liked that she taught at both the middle school and high school level because he saw middle school as a preparation for the next level. Further, he saw Megan as working to engage the
students and thought “she does probably a little bit better [at teaching and managing kids] than I see newer teachers” (Megan’s MS principal, 6, 10).

Megan’s mentor valued starting with rote memory and lower learning skills and spending a lot of time working to take the facts and have students apply them. Specifically, he mentioned, “You move up and down the different levels of Bloom’s Taxonomy. When they’re always used to working at those very low levels, rote memorization and reciting definitions, they think that is learning… I try to explain to my students that there are different levels of learning” (Megan’s Mentor, 7, 2). Although Megan’s mentor had some views that departed from research-based practices on effective science teaching practices, he was open-minded to Megan’s ideas and thought she was acclimating to the school environment well.

Megan’s school environment didn’t seem to be overly constraining nor did it have pervasive constraints. Although Megan sometimes felt distant from her colleagues—she taught in both the middle school and the high school—teaching in both places seemed to be advantageous. The middle school principal valued high school preparation and saw Megan as a bridge between the two. Further, as the middle school and high school were physically connected, two school cultures existed simultaneously; therefore, one strong school culture wasn’t present. While Megan’s colleagues and administration valued Megan, the culture did not push Megan to become highly effective. Therefore, the school environment was categorized as “neutral.”

**Navigation of constraints.** Megan didn’t perceive her environment to be very constraining and didn’t feel she had many constraints to navigate⁹. Although Megan expressed she had a great deal of freedom to teach how she wanted, Megan did express a
great deal of frustration in being assigned a remedial Biology course that wasn’t in her content area. Megan’s general approach to this course was to not put much effort into it in the hope she wouldn’t have to teach it again. At times, Megan tried to implement more hands-on activities in the Biology course but lamented that her efforts often resulted in classroom management issues.\textsuperscript{10}

**Order of consciousness.** Megan displayed meaning-making primarily at the third order of consciousness. Megan can hold multiple perspectives in her mind simultaneously (an achievement of the third order); however, she often viewed those perspectives through how they differed from her viewpoint. While Megan can handle many of the complexities of teaching, she feels stuck when she encounters a difficult situation. When she feels stuck, she continues to try to figure out the problem, but if no solution exists, she often resorts to attributing her frustration to external sources.

Megan viewed herself as an intelligent person, which was often framed through her success with engineering. When she struggled in the MAT, Megan tended to attribute those struggles to external circumstances (e.g., Dr. Clark showing favoritism, role of doctoral students in grading, time constraints).

Megan continued to attribute her struggles to her circumstances during her first year of teaching. She did work to understand students’ perspectives, but when she encountered a difficult situation with students, she often felt stuck. For example, Megan felt frustrated when she wasn’t able to reach one of her students because,

\begin{quote}
I feel like I don't know how to get through to this kid so I can teach him. It's not just annoyance, it's frustration, because I can't figure out how to fix the problem, so I keep coming back to the problem from the same viewpoint, and it's the same thing over and over again. It's very frustrating that I can't figure it out, and there's no way for me to figure it out. Now that he's being taken out of my classroom, I'm never going to be given the chance to figure it out (Megan, 3,1).
\end{quote}
Megan also felt stuck when she found out she had to teach Biology, which wasn’t her expertise, to a group of at-risk students. She stated,

I feel like [in] biology… I don’t know what I would do different. Because if I knew what I would do different, I'd do it and I'd try. But with the mix of bad behavior, like, I can't trust them outside to do something. They sit there and complain and complain. But when I take them outside to do a lab…they go through it as quickly as they can… (Megan, 3,7).

These examples indicate that Megan cannot yet reflect upon her role in the difficult situations she faces. That is, Megan had not yet developed the ability to hold her perspective as object, which may have helped her to see other options to the problems she faced. Instead, Megan often decided to accept her circumstances or remain frustrated. Megan’s way of making meaning seems to be fairly equilibrated with few indications of meaning making at the second or fourth order. Therefore, Megan was coded at a solid third order.

Jamie

**Background.** Jamie went to Midwestern University prior to her MAT to study biochemistry as an undergraduate and sustainable agriculture as a graduate student. She worked as a soil scientist for two years and decided to change career directions because she found soil science “incredibly boring and [isolating]” (Jamie, 2, 1). Jamie had considered being a chemistry teacher as an undergraduate and was drawn back to it because she wanted something that was “mentally stimulating.” She continued, “I want something that's different from day to day. I want something where I feel I am making a positive impact for others, something that I really enjoy…” (Jamie 2,1).

Jamie valued the MAT program and thought “it was everything it was promised to be. It was intense, learned a lot” (Jamie, 1,1). Due to Jamie’s previous experience in a
master’s degree\(^1\), Jamie approached the MAT as a social process and valued the support from the other MAT cohort members. She organized social events, study sessions, and worked with a variety of individuals throughout the MAT. Not surprisingly, Jamie liked the cohort model and even wished more interactions occurred between cohorts\(^2\). Jamie earned a B+ in Secondary Science Methods II, which indicated she had a very good understanding of teaching and learning and articulated research-based teaching throughout her coursework (Appendix E).

During the study, Jamie was a first-year teacher who taught chemistry and environmental science in a small town. She was the only teacher in her school who taught either of those subjects.

**Understanding of research-based teacher decision-making.** Jamie understood and valued many aspects of research-based science teaching, including starting with concrete experiences, using formative assessments to guide decisions, getting students to work together in small groups, ensuring the content is relevant, and working to develop relationships with students.

Although Jamie did articulate some aspects of research-based science teaching practices, she often neglected others. For example, Jamie often framed her understanding through the lens of developmental learning theory\(^3\) (e.g., concrete experiences before abstractions), but she didn’t articulate the implications of other learning theories (e.g., constructivist, social, behavioral) or student goals on her decision-making. Jamie agreed with a great deal of what the MAT promoted and she seemed to greatly value aspects of the research-based science teaching practices that appeared to work in her classroom. However, she eschewed other aspects that had not been immediately successful.
Implementation of science teaching practices. Jamie had an average LSC-COP capsule rating of 2.33 (Figure 4.5), which indicated elements of effective instruction were present, but the lesson is very limited in its likelihood to enhance students' understanding of the content (Horizon Research, Inc., 2005, p.11). Jamie’s SATIC pattern was 1, 2, 3b, 4, 10 (Figure 4.6). Jamie spent the majority of time lecturing and making statements (SATIC 1,2, respectively); however, Jamie’s interactions also included asking questions (SATIC 3,4), answering student questions (SATIC 10), and engaging with students’ ideas (SATIC 11,12).

Jamie often began class on time and gave students a task to work on. The researcher didn’t see students ever engaged in laboratory activities, although evidence existed in the discussions that labs were done. Instead, lessons often involved discussions of prompts provided by the teacher, discussions of readings, or short activities followed by group discussions. Jamie’s lessons were often negatively impacted by her classroom management strategies. For example, she often used perfunctory tactics to manage the class such as frequent, random seating arrangements and pausing until students stop talking rather than privately working with students engaged in off-task behavior. Many of her strategies were modified from strategies she saw her cooperating teacher employ rather than research-based practices. These classroom management issues were exacerbated by the structure of the classroom, as the room was very large and echoed a great deal.

Jamie’s implementation was inconsistent between the chemistry and ecology courses she taught. For example, Jamie’s LSC-COP average capsule score for chemistry was 3.0 (beginning stages of effective teaching), whereas her capsule score for ecology
was 1.67 (ineffective teaching). Likewise, Jamie averaged 13 thought-provoking questions (SATIC 3c/4) in chemistry but only 1.67 thought-provoking questions in ecology. Jamie also engaged with student ideas (SATIC 11/12) more in chemistry (4.0 average) compared to ecology (1.33). Jamie was aware of differences in her teaching, and attributed her differential success to her experiences teaching chemistry with her cooperating teacher. Interestingly, Jamie admitted her content expertise more closely aligned to the ecology course.

* Maximum capsule rating is 7; maximum rating for other categories is 5.

*Figure 4.5.* Average LSC-COP scores of Jamie’s teaching during classroom observations.
Perceived constraints. Jamie did not feel her school was very constraining; on the contrary, Jamie expressed that her administration treated her as a professional and she felt supported. She stated, “[The administration told me] ‘If we hired you, we think you'd know what you're doing.’ And so, they're very supportive.” Jamie also felt her colleagues were supportive of her efforts to have high expectations and teach effectively. As Jamie was the only chemistry and ecology teacher, she did not feel pressure to conform to what others were doing. One area Jamie did feel a great deal of constraint was with her students. Specifically, Jamie was frustrated with the off-task behavior in the class and her difficulties in managing them.

School environment- constraints and their pervasiveness. Jamie’s school environment seemed to be fairly supportive of her efforts to enact research-based science teaching practices. Both Jamie’s principal and mentor seemed to be supportive of Jamie’s efforts while encouraging her to improve. For example, Jamie’s principal
seemed to value and look for many similar practices as those promoted by the MU-STEP when he stated,

[Lessons] need to be to be student-centered, and things I look for are just engagement and working well from bell to bell. There are learning and partnerships and meaning being created. It's based on real world stuff…You're looking for collaboration, connecting prior knowledge and that. And then also there's a component that when I walk through I look for teacher understanding [students’ thinking] … If they give them yes or no questions, or open-ended questions. Those are the things I'm looking for. (Jamie’s Principal, 6,2).

Jamie seemed to have earned the respect of her principal and mentor. For example, Jamie’s mentor believed Jamie worked hard to get better at teaching, was open-minded, and processed decisions before reacting. Jamie’s principal and mentor also noted she was working on her classroom management strategies and relationship building with students, and they supported her in this area by providing suggestions.

While Jamie’s mentor and principal seemed to support Jamie, with particular regard to classroom management, this support most often took the form of encouragement rather than scaffolding Jamie to improve her teaching. In many ways, Jamie was left to figure out many of the details on her own. For example, Jamie’s mentor stated, “I feel bad for her a little bit because she's isolated. She's the only one who teaches the ecology…and chemistry class” (Jamie’s mentor, 7,1). Jamie’s environment could be described as one of encouragement, but not one of mentoring Jamie towards enacted research-based science teaching practices.

**Navigation of constraints.** Jamie didn’t find her school environment constraining and therefore didn’t feel she needed to actively navigate constraints from her colleagues and administration. However, Jamie did feel constrained by the behavior of some of her students in the classroom. Jamie’s typical approach to dealing with this
constraint was to feel frustrated and try to deal with the off-task behavior by tinkering with the classroom environment structure (e.g., types of assignments, seating arrangements). While Jamie did also work to build relationships with students and occasionally dealt with off-task behaviors directly, these strategies were secondary to tinkering with the classroom environment.

**Order of consciousness.** Jamie demonstrated meaning-making between third and fourth order consciousness. Jamie’s subject-object boundaries were most apparent when she discussed classroom management. Jamie often felt frustrated when her classroom became difficult to manage and chose strategies to make quick changes to the classroom environment to deal with that frustration. For example, Jamie stated,

> You know what? I don't like what I'm doing. We're just going to start having a new seating chart every day. And if they don't like it, my answer is going to be “You can deal with it for a day. If you can't, we have other skills we need to work on (Jamie, 5,3).

When Jamie felt frustrated, she did act to make a change, but this seemed to be born out of her feelings rather than thoughtfully considering students’ perspectives. However, Jamie could understand the perspective of her students and did often reflect on students’ perspectives when thinking about her classroom. Jamie reflected,

> Maybe if [the students are] frustrated, is it a point where I expect them to be frustrated? Is it frustration that I want to use to make them dissatisfied with one idea so that they will move to another idea, or are they frustrated for some other reason? If I try to identify that other reason, then it's easier to try something new, "Let's try this. Why don't you do something else different?" If they're frustrated and it's hard for me to tell what the source of the frustration is, I often get frustrated (Jamie, 3,4).

The above quote illustrates that Jamie could take on her students’ perspectives, but still struggled to make decisions if the source of students’ frustrations wasn’t clear to
her. Jamie’s frustration seemed to be grounded in her expectation for how students should behave and how they actually behaved in her classroom. Jamie stated that she originally saw the classroom teacher as “the absolute foremost authority” and students shouldn’t “talk when the teacher is in the front of the room” (Jamie, 4,3). While her views shifted in the MAT program towards students having more ownership in the conversation, when the students started to get off-track, Jamie often felt torn between her initial conceptions of student behavior and what she learned in the MAT program. This tension between sets of beliefs is indicative of third order consciousness. That said, Jamie’s ability to reflect upon her own thinking and take a perspective on her perspectives indicated fourth order consciousness. While Jamie did demonstrate fourth order meaning-making, Jamie most resorted to third order consciousness. Therefore, Jamie’s order of consciousness was coded 3/4.

Kevin

**Background.** Kevin earned a master’s degree in electrical engineering at Midwestern University and spent over ten years as an electrical engineer for a company in a small town. He wasn’t really satisfied with his job or the company; Kevin found aspects of his job exciting, but he started to lose interest in the job overall\(^1\). Kevin began looking for another career path and decided to pursue teaching because he wanted to do something with more purpose, so he decided to return to MU to join the STEP.

Kevin was very satisfied with the MAT program overall, but thought it was tough\(^2\). One difficulty Kevin had was trying to balance the rigors of the program with his commitments to his family. Kevin spoke at length about the amount of time and effort he devoted to the program, but he remained positive about what he was learning\(^2\). Kevin
valued the cohort model of the MU-STEP because he felt comfortable sharing what was happening in the classroom with his cohort members. Although other members in his cohort expressed a division between the cohort members, Kevin felt he got along with everyone well but admitted he was more detached from the cohort and the group dynamics—in part due to his family commitments. Additionally, Kevin spoke very highly of his cooperating teachers. One cooperating teacher effectively modeled research-based practices that the program promoted, and the other cooperating teacher helped Kevin with the day-to-day work of being a teacher. Kevin earned a B+ in Secondary Science Methods II, which indicated he had a very good understanding of teaching and learning and articulated research-based teaching throughout his coursework (Appendix E).

During the study, Kevin was a first-year teacher in a rural school district who taught four courses in the fall semester and five courses in the spring semester. Kevin taught two courses that were part of an engineering curriculum called Project Lead the Way. Kevin also taught a course in astronomy and three levels of physics courses.

**Understanding of research-based teacher decision-making.** Kevin deeply understood, believed in, and attempted to promote student goals. For example, Kevin saw the purpose of being a teacher as helping students become informed “decision-makers and understand that everything that they do is a choice” (Kevin, 2,10). Additionally, Kevin understood the importance of experience in helping students understand science, focusing on concepts over facts, creating a logic flow so students understand the connections between concepts, asking open-ended questions, and teaching the nature of science.
Beyond student goals, Kevin could articulate aspects of research-based practices; however, Kevin’s understanding could be described as a collection of ideas without deep connections between the ideas. Interestingly, Kevin’s understanding as a pre-service teacher, as demonstrated in the MAT assignments, was much more developed and interconnected than his understanding appeared to be in his first-year of teaching.

**Implementation of science teaching practices.** Kevin’s teaching seems to be fairly in line with his understanding and his reflections on his teaching. Kevin had an average LSC-COP capsule rating of 3.3 for his lessons (Figure 4.7), which indicates the lessons had quite a few elements of effective practice, but are somewhat limited in the likelihood the lessons would enhance students’ understanding (Horizon Research, Inc., 2005, p.11). Kevin’s SATIC pattern was coded as a 1, 2, 3b, 3c, 11, 12 (Figure 4.8). Kevin spent a quite a bit of time making statements and lecturing, although he did occasionally ask students questions (SATIC 3,4) and engaged with students’ ideas (SATIC 11,12).

Throughout all of Kevin’s courses, he most often began his lessons with a concrete experience, and his students were often engaged in the activity. However, when the activity was complete, Kevin often told students the connections between the activity and the content rather than carefully scaffolding them (Figure 4.8). At other times, Kevin asked questions that were too difficult for students. For example, in Kevin’s astronomy class, he asked, “If the brightness and size of a star both change with distance, how can we know the size of the star and the distance from Earth?” (Kevin 8, 50). While Kevin could have scaffolded students to consider how parallax might be useful—which was the point of the lesson—students ended up struggling with the question and in turn classroom
management issues arose. Kevin frequently noticed the level of engagement of his students; however, he had not yet developed strategies for adjusting his lessons according to his students’ background knowledge.

Kevin’s lessons were inconsistent across the different courses he taught. In the Biotechnology and Engineering courses, which are part of the Project Lead the Way (PLTW) curriculum, Kevin asked far fewer questions (8.5 average) than the science courses (23.6 average). Kevin also asked students to clarify their thinking or used their ideas (SATIC 11 and 12, respectively) about half as often in PLTW (5.5 average) compared to the science courses (11.4 average). Kevin’s average LSC-COP capsule rating between the PLTW and science lessons were also discrepant. The PLTW lessons averaged 2.25, which indicated elements of effective instruction were present, but the lesson is very limited in its likelihood to enhance students' understanding of the content. In contrast, Kevin’s science lessons averaged 4.2, which indicated beginning stages of effective instruction where students were engaged at times, but the lesson had weaknesses that somewhat limit the likelihood of enhancing students’ understanding of the content (Horizon Research, Inc., 2005, p. 11).

Kevin explained that part of the reason for the discrepancy between the PLTW and science courses was that he relied more on the PLTW curriculum due to the time constraints he faced with the multiple courses. Indeed, Kevin relied much more on worksheets, PowerPoints, and one-on-one interactions with students in the PLTW courses than in the science courses. Additionally, the lessons observed in the PLTW courses seemed to be focused more on learning about careers rather than learning about science and/or engineering content.
* Maximum capsule rating is 7; maximum rating for other categories is 5.

*Figure 4.7.* Average LSC-COP scores of Kevin’s teaching during classroom observations.

*Figure 4.8.* Average occurrences of Kevin’s verbal interactions during classroom observations.
**Perceived constraints.** Kevin didn’t perceive his school environment to be very constraining as he stated, “Here? There's not really [any constraints], I don't have any specific accountability, nobody is really checking up on me too much” (Kevin, 5, 29). While Kevin didn’t perceive his colleagues or administration to be constraining, he frequently mentioned the number of courses he had was extremely difficult. Additionally, Kevin perceived more constraints from his students that seemed to stem from how the culture of the school tended to impact students’ efficacy, understanding of math and science content, and students’ overall beliefs about teaching and learning. For example, Kevin expressed his frustration with students’ lack of math understanding when he stated, “I'm here trying to teach science, but now at the same time, I feel like I'm also having to be the math teacher, because I feel like it's not been done the way it needs to be done in their other classes” (Kevin, 3,12).

**School environment--constraints and their pervasiveness.** Through interviews with Kevin’s principal and mentor, the school environment did not seem to be constraining or have pervasive constraints. Kevin’s principal valued student engagement and real-world application over memorization. As Kevin had about ten years of experience in engineering prior to becoming a teacher, Kevin’s principal saw his experience as a strong asset. Kevin’s principal also stated he valued student-to-student collaboration and remarked that Kevin was striving to get students to work together and go beyond memorization.

Although the principal valued Kevin and seemed to support Kevin’s efforts, he did express concerns about Kevin’s high expectations and how they might not match the students and the broader community the school served. The culture of the school, which
the principal accepted as a reality, wasn’t focused on high academic expectations or an expectation that students should rarely miss school. The principal summarized his position when he stated,

    [Kevin’s] very intelligent and... like it or not and I don't like it, but it's a reality situation. Because it's a double edge sword, he needs to ratchet [down the expectations] a little bit because he has such high expectations for kids. Which is what we want, I don't want to set the bar low, I want to set it high, but the problem is... as a society, I have to be careful about how I say this… [Kevin’s high expectations isn’t] something he needs to improve, that's just the reality of the situation is where, not everybody is college bound (Kevin’s principal, 6, 7).

Kevin’s mentor was studying to become an administrator and therefore was interested in promoting the district’s professional development initiatives. In particular, Kevin’s mentor mentioned numerous times that technology should be integrated into classrooms as much as possible. As Kevin had done some work with coding in his Physics courses, his mentor thought he was integrating technology effectively.

Kevin’s mentor expressed his ideal science classroom would be:

    …a blend of constructivist learning and have traditional learning as well. Questioning is important in science to make kids think and try to understand what's going on. But, in an ideal classroom, students…need to be focused, you need to have standards posted on the walls, or you need to specifically tell students what they should be learning as well (Kevin’s Mentor, 7, 3).

Related to this thinking, the mentor believed Kevin should do more summarizing and telling in his lessons than what he had observed.

**Navigation of constraints.** Although Kevin was striving to enact research-based science teaching practices, his mentor and principal didn’t fully support Kevin’s efforts. Fortunately for Kevin, he rarely interacted with his mentor and principal. When Kevin
did interact with his mentor, he pushed the conversation towards common ground and
safe topics, rather than focusing on the areas in which he and his mentor disagree
towards common ground and
safe topics, rather than focusing on the areas in which he and his mentor disagree.

Kevin often tried to address students’ inaccurate beliefs about learning “head-on”
when they seem frustrated. For example, he stated,

We didn’t get to any of [my lesson that day] because there was frustration and we
just kind of addressed that head on. [A student stated] ‘We haven't learned
anything; you haven't told us anything.’ It's like, how do you know that energy,
the transfer of energy can change matter? [When students knew the answer, I
said] you know it because… [it] makes sense and…you can do these things
(Kevin, 5, 31).

While Kevin did take an active role in navigating some of the constraints he
faced, he frequently felt frustrated regarding the constraints on his time and his students’
attitudes and beliefs. Kevin often spoke about his frustrations regarding not having
enough time to plan lessons. Instead, Kevin usually planned the activity and had some
rough ideas for the discussion, which seemed to negatively impact student learning.
Kevin mentioned his students often expressed being frustrated, which Kevin attributed to
his lack of planning, trying to understand students’ capabilities, and battling many of his
students’ views of teaching and learning. Kevin could understand and express why he
and his students felt frustrated, yet he struggled to articulate how he might reduce these
frustrations.

Order of consciousness. In many ways, Kevin operated from the fourth order.
First, Kevin seemed to have internalized many research-based practices and evaluated
himself based upon those standards, which is indicative of fourth order thinking. Second,
while Kevin often felt frustrated, he didn’t hold others responsible for that frustration.
Third, Kevin often used his understanding of his mentor and his students’ perspectives to
actively navigate constraints.
Although Kevin was fourth order in many circumstances, he also displayed third order meaning-making. For example, he seemed to feel torn between his family and professional commitments. Kevin couldn’t see a way out of the frustration and this tension between two areas he valued seemed to result in Kevin feeling “burnt out” (Kevin 5,3), paradoxically increasing his frustration.

In summary, Kevin displayed meaning-making between third and fourth order of consciousness. Kevin seemed to operate in fourth order most often, but the demands of first year teaching and his ability to manage those demands resulted in him slipping into third order meaning-making. As a result, Kevin’s order was 4/3.

**Rachel**

**Background.** Before the MAT program, Rachel was a graduate student in Physics at Midwestern University. Rachel had felt that she wanted to teach in some capacity for quite some time but was thinking about doing so at the college level. While Rachel hadn’t ruled out teaching at the college level at some point, she decided to switch to K-12 teaching in part due to her confidence in teaching at the college level and in part because she enjoyed working with children.

Rachel greatly valued the MAT program and found the program to be “life-changing” (Rachel,1,1). When asked what Rachel found life changing, she said, “It really helped me articulate my passions better than anything I ever did before.” (Rachel,1,1). Rachel acknowledged the MAT involved a great deal of hard work but she was able to “knit everything together” (Rachel, 1,2) and felt she saw the effort she put into the program resulted in a visible change in her teaching that benefitted the students she taught. Much like others in Rachel’s cohort, Rachel acknowledged that her cohort
seemed to be divided, but instead of attributing that division in terms of “favorites”, she saw a division between those who had not bought in to research-based teaching and those who were actively trying to enact it into their practicum and student teaching experiences. Rachel earned an A in Secondary Science Methods II, which indicated Rachel had a deep understanding of learning, teaching, and could communicate the synergistic relationships of effective science teaching (Appendix E). During the time of the study, Rachel was a first-year teacher in a suburban school district with one course during the time of the study. Rachel taught Integrated Science to 8th grade students in a 7-8 junior high school.

**Understanding of research-based teacher decision-making.** When Rachel was interviewed about her thoughts regarding teaching and learning, she often espoused science teaching practices that highly aligned to the MU-STEP. For example, when asked what types of things influence her decisions as a teacher, Rachel referred to the research she had read during the MAT and how the decisions she made promote or don’t promote her goals for students. Rachel saw teaching as a way to better students and society as a whole, as she wanted to, “influence what [students] do, influence how they think about science, about the world around them, and have an impact on who they are as people” (Rachel, 2, 1).

Rachel seemed to have an integrated understanding of effective teaching, as she could accurately express what she was doing in her classes and how that aligned or didn’t align to science education research. For example, when Rachel was asked how she would describe an effective teacher, she discussed teacher interactions, structure of lessons (teaching models and strategies), and how to help students make sense of
activities by starting with concrete representations and scaffolding the language and concepts using the experience as a foundation for later learning\(^4\). Rachel could articulate multiple aspects of effective teaching readily and in a synergistic way in the sense she used student goals and knowledge about how people learn to inform her decision-making.

**Implementation of science teaching practices.** Rachel’s teaching seemed to align well with her understanding of research-based science teaching practices. For example, Rachel’s average capsule score for the observed lessons was 5.4 (Figure 4.9), which indicates her instruction was purposeful and engaging for most students (Horizon Research Inc., 2005, p. 11). Rachel’s lessons tended to be fairly consistent, with three lessons out of five characterized as accomplished, effective instruction and “highly likely to enhance students’ understanding of science” (Appendix C). Two lessons were characterized as having “quite a few elements of effective instruction.” The lessons were effectively planned, and the content was robust and appropriate but received capsule ratings of 4 and 5 mostly due to classroom management concerns. Specifically, the students observed in the class were quick to get off-topic, and Rachel, at times, had difficulty keeping the students focused.

Rachel’s interaction pattern usually consisted of telling students some information and asking some questions regarding the set-up of an activity they were going to engage with, giving students time to engage with the activity, and asking students questions afterwards\(^4\). Put differently, Rachel exhibited a SATIC pattern of 1, 2, 3b, 3c, 4, 10, 11 (Figure 4.10). The activities were typically engaging and developmentally appropriate for 8\(^{th}\) grade students, and the nature of science was consistently interwoven into her lessons, assignments, and assessments\(^5\).
The questions Rachel asked were often thought-provoking and open-ended (SATIC 3c/4), and Rachel also asked students to clarify their thinking and drive the conversation forward (SATIC 11/12). While Rachel exhibited many interactions that aligned to research-based science teaching practices, Rachel sometimes struggled to scaffold students’ thinking and, as a result, tended to make statements (SATIC 1), lecture (SATIC 2), or ask recall questions (SATIC 3b) to help students see the connections (Figure 4.10).

* Maximum capsule rating is 7; maximum rating for other categories is 5.

*Figure 4.9. Average LSC-COP scores of Rachel’s teaching during classroom observations.*
Perceived constraints. Rachel perceived a great deal of institutional constraints during her first year of teaching. Before the school year, when asked what she was most concerned about as she prepared for her first year, Rachel noted she was most worried about how to structure the lessons so students clearly understand how the concepts connect together⁶. One of the greatest constraints Rachel perceived in her first year was the lack of her ability to structure units, and to some extent lessons, that made sense for her students. She felt pressure from the district to give the same pre- and post-tests and pressure from her mentor, who is also one of her science teammates, to structure lessons in a way that made sense to him. For example, Rachel’s mentor told her that he didn’t care what she thought about her ideas, despite the fact that Rachel had the most science content background of her teammates.

Rachel also felt pressure to keep up with the other science teachers and spend the same amount of time they agreed upon for particular units⁷. Rachel felt like she didn’t have a good idea of the time it would take to help her students deeply understand the
content, and, therefore, she had a hard time advocating for the appropriate time before the unit began.

Rachel was assigned all of the special education students in the 8th grade. When she was asked why this was the case, she stated that she didn’t really know the reasons that went into that decision, but she was surprised a new teacher would have all of the special education students rather than a teacher that had more experience.

School environment--constraints and their pervasiveness. The researcher interviewed Rachel’s mentor and assistant principal to better understand the school environment and to assess the pervasiveness of the constraints Rachel perceived. As a result of these conversations, Rachel’s environment did have a number of considerable constraints, including teaching all of the special education students in the 8th grade, and having limited freedom to decide in which order to teach content, teaching the content in a certain amount of time, and assessing the content in the same way as her peers. The administration required teachers to have a common pre- and post-assessment of all of the units; however, Rachel could and did assess students in an additional way of her choosing. Rachel’s day-to-day teaching seemed to be completely under Rachel’s purview.

Rachel’s mentor had been teaching in another content area for a number of years and recently switched to teaching science. Despite the recent transition to science teaching, he saw himself as resistant to change. For example, when asked how school initiatives relate to his teaching, he stated,

Well, I'm old school, so I like doing demos. I like organizing things and stuff like that. I'm probably a little more resistant. So is [inaudible 03:55]. Us older teachers are probably a little more resistant to implementing some of these because we're
more set in our ways, whereas younger teachers are probably more open… (Rachel’s mentor, 7, 2).

Although Rachel’s mentor believed he was more traditional, he did consistently stress the importance of mixing up his approach so his students had hands-on experiences. However, when asked what he meant by “mixing up teaching,” he stated Mondays were typically video clips or pretests, Tuesdays were demos, Wednesdays were a mix because of the shortened periods, Thursdays were “traditional days” with note taking, and Fridays were lab days\(^8\). The decision to place certain activities on certain days indicated he didn’t understand the necessity of a logical flow of ideas from day to day and unit to unit.

Rachel’s mentor didn’t seem to understand the complexities of teaching and learning, which played out in the conversations between Rachel, the mentor, and the other 8\(^\text{th}\) grade science teacher. When asked how well Rachel implements effective science teaching in his view, he stated,

> Rachel and I have different philosophies. I won't lie to you. She's more theory-oriented and things like that, and I'm more fact-oriented. Every once in a while I'll read what she has and things like that…The fact of the matter is I take it seriously because our science scores went up last year. For instance, this is hers. I'm interested in some of the things and stuff like that too (Rachel’s Mentor, 7,9).

Rachel’s assistant principal seemed to be supportive of effective science teaching. He viewed an effective science classroom as student-centered, inquiry-based with the students doing a lot of labs and experiments\(^9\). Additionally, the assistant principal thought Rachel embodied a lot of these attributes and said,

> She's doing a great job. We could tell from when we interviewed her that she was going to be a good fit for our building. The ideas that she was sharing that she wanted to implement in her classroom and the experiences that she's shared with us that she's had so far; she's brought a lot of new fresh ideas to our science
department... Her labs are always engaging and hands-on, so she's doing a nice job there (Rachel’s Assistant Principal, 6,3).

Although the administration seemed supportive overall, the assessment protocols seemed to undermine many of their espoused beliefs about effective science teaching. The administration required teachers to use a computer system to track students’ progress. Teachers had to give a common pre- and post-assessment to their students that consisted of 18 to 20 multiple-choice questions. As a result of the common assessment requirements, a common timeframe to teach the units also seemed like an expectation. As Rachel and her team didn’t always view science teaching in similar ways and the structure of the test was limited to multiple choice, these pressures seemed to impact Rachel’s ability to make decisions. In summary, school culture seemed neutral towards reforms-based teaching in some regards but unsupportive in many others.

**Navigating constraints.** Often, Rachel’s first reaction to a constraint was to feel frustrated. When she couldn’t deal with that frustration, she would often reach out to a community of like-minded science teachers and science education faculty outside of the school for support. As Rachel progressed through the school year, she developed, often with counsel from her support group, more sophisticated strategies for dealing with the constraints she faced. For example, when she felt pressure to keep up with the other teachers, she often said that she had all of the special education students and the timeline they were working on would not work for her students. This strategy, while true, also indicated that she was using a constraint, which both her teammates readily admitted to be an issue, to battle another constraint.

**Order of consciousness.** Rachel displayed meaning-making between the third order and fourth order of consciousness. Rachel can hold multiple perspectives in her
mind simultaneously and can view difficult situations through the lens of another person.

When Rachel faced a difficult situation, she often initially felt frustrated and had a difficult time getting past her feelings. For example, some of her students had been misusing materials throughout the year, and Rachel was visibly upset when talking about it. When the researcher asked why she felt so upset, she responded,

> Because it's my stuff. Because I feel like they should know better, and maybe they shouldn't, but I'm frustrated that I have to keep... like week one, someone stole my NOS tube and someone cracked one of my white boards in half...And then I see this, later, where have they not figured out that they should respect my stuff? I respect their stuff. You know, and this isn't mine, but like, the yogurt cups, I spend time assembling the materials, I spent time eating that yogurt and saving the cup, you know, it's my stuff and so it's... I don't know. It hurts my feelings (Rachel, 4,5).

While Rachel often initially was stuck feeling frustrated, but, through reflecting with others, she was able to revisit the situation through a different lens. For example, Rachel demonstrated she could view the material misusage from the students’ perspective by stating,

> I don't know to what extent it is, just because they're kids. There's something pointy in front of me, I'm going to poke a hole in the cup with it. They probably don't recognize that I spend time putting the materials together. They probably don't realize that this costs the department money so I can't get everything I want to get because we have to replace broken materials. I think they just don't. Either they don't think about it, or it's just not on their radar that this could influence me (Rachel, 4,5).

These examples indicate that Rachel is capable of fourth order thinking. However, to help herself achieve a different vantage point, she often would seek out others’ perspectives that she trusted. In this sense, her support group served as an external moderator to help Rachel reframe the event she was experiencing. While Rachel didn’t initially make meaning at the fourth order, she could, with assistance from others,
reflect on her experience through a more dispassionate, fourth order lens. When Rachel felt stuck, she would often use her support group to help her achieve a perspective she could not yet accomplish alone. As a result, Rachel displayed meaning-making coded as 3/4.

Grace

**Background.** Prior to joining the MU-STEP, Grace was an undergraduate in geology. She started her undergraduate experience as a chemistry major in part because of the influence of her chemistry teacher in high school who served as her mentor. However, Grace didn’t find her chemistry major as interesting as she had hoped, so she switched to geology. Grace had considered teaching during her undergraduate experience but decided not to pursue it due to how far she was in her program. When she graduated, she found herself still interested in teaching and decided to enroll in the MAT at Midwestern University.

Grace thought the MAT was a good experience but found it to be hard and time-consuming. She admitted she didn’t value it as much as she should have, especially early on, but she did enjoy the program. Grace related well to her cohort members and often interacted with them socially outside of the program. In particular, Grace interacted with Maddie a great deal because they both were placed with the same cooperating teacher. Maddie and Grace’s cooperating teacher seemed to implement aspects of research-based teaching practices, but at other times would explicitly tell Maddie and Grace how her practice differs from practices promoted by MU-STEP. These interactions, perhaps, influenced how Grace came to frame the MAT program. For example, while Grace valued and worked to implement aspects of what she learned, she
thought the practices Dr. Clark promoted were “very different from, sometimes, what happens in actual classrooms” (Grace, 5, 4). Grace explained further,

[The MAT promotes teaching] bell to bell. Sometimes, you can't do that. Sometimes there are other pressing matters... So, to find the right balance between what they call book work, and then discussions, which they've told me they like, but then they also tell me, "I want you to tell me." [I am trying to find] the right balance between what they think they want to learn and how I know that they should be learning things… (Grace, 5, 4).

Grace earned a B+ in Secondary Science Methods II, which indicated she had a very good understanding of teaching and learning and articulated research-based teaching throughout her coursework (Appendix E).

During the study, Grace was a second-year teacher in a suburban school district who taught one course. Grace taught a one semester earth science course twice a year, so at the time of the study, she had been through the course three times and was starting her fourth. Grace split the 9th grade course with another teacher who taught the physical science components of the course; Grace and the other 9th grade teacher traded students at the semester.

**Understanding of research-based teacher decision-making.** Grace’s understanding of effective science teaching practices seemed to be focused primarily on finding engaging activities for students based on the standards and their interests. Throughout all of the interviews, Grace clearly thought and cared a great deal about what students were interested in learning. Additionally, Grace understood the importance of formative assessments and demonstrated this understanding when she mentioned using exit tickets, homework, graphic organizers, pre-tests and other strategies to learn more about her students’ understanding of science content.
Grace, even when pressed by the researcher, did not articulate the role of the teacher in learning beyond “being a facilitator” (Grace, 2, 2). Grace viewed effective teachers as those who, “are armed with the tools necessary to make sure their students are learning in the most effective way based on research” (Grace, 2, 9). Grace seemed to view effective teaching as a collection of engaging activities and assessments. However, Grace didn’t articulate how an effective teacher would ask effective questions to scaffold students’ thinking towards accurate science concepts. Further, goals and how people learn were not evident in Grace’s responses. Overall, Grace’s responses indicated she had a limited understanding of effective science teaching practices.

**Implementation of science teaching practices.** Grace’s understanding was consistent with her teaching practices. Grace’s lessons were also consistent in terms of structure and effectiveness across the researcher’s observations. She would often start class by either presenting some information or providing instructions for an activity. Although the activities Grace used were relatively engaging and developmentally appropriate, they were often over-structured with step-by-step directions and an emphasis on terminology. For example, a worksheet on solar and lunar eclipses had students define “umbra” and “penumbra” (Grace, 12, 1). Further, Grace often explained the activity rather than using the activity to help students build a conceptual understanding through scaffolding students’ thinking (Grace, 8, 84).

Grace’s lessons had an average LSC-COP capsule rating of 2.33, which indicated she had elements of effective instruction, but the lessons were very limited in their likelihood to enhance students’ understanding of science (Horizon Research Inc., 2005, p.11). In regards to Grace’s interaction pattern, she lectured or made statements at a rate
almost double all of her other interactions combined (Figure 4.12). Grace’s SATIC pattern was coded as 1, 2, 10, which does not reflect best practice (e.g., 3c, 4, 6, 11, 12 pattern).

* Maximum capsule rating is 7; maximum rating for other categories is 5.

*Figure 4.11. Average LSC-COP scores of Grace’s teaching during classroom observations.*

*Figure 4.12. Average occurrences of Grace’s verbal interactions during classroom observations.*
Perceived constraints. Grace didn’t believe her school environment placed many constraints on her teaching. She stated,

I have quite a bit of freedom [to teach how I want], I think, because I don’t have anyone else who teaches it with me, so I can try and do things, which is really nice, but I would also like someone else to be there. That would be nice as well. There's not really any [institutional constraints]. I thought there might be more… (Grace, 2, 21).

Grace viewed her administration as supportive of her decisions, especially if she could articulate her reasons for making her decisions. She noted, “[The principal] likes to know why you're doing things. So, you have mini conversations with him, and as long as you know it makes sense, you can for the most part do it” (Grace 2, 16). Grace’s relationship with her colleagues didn’t seem to constrain Grace much either, which she attributed, in part, to her not teaching the same subject as the rest of her department.

Although Grace seemed to have quite a bit of freedom to teach how she wanted, she did often note that she felt frustrated because the other 9th grade science teacher was more “book-centered” and didn’t seem to value student relationships as much as Grace (Grace 2, 14). The differences between Grace and her colleague seemed to create some resistance from her students. In particular, Grace noticed students complained about different grading practices between Grace and her colleague, and she also noticed that her students weren’t always willing to contribute to the class conversations.

School environment--constraints and their pervasiveness. Based on interviews with her mentor and principal, Grace’s environment did not appear to have high levels of constraints. Although Grace’s mentor and principal’s views of effective science teaching departed in many ways from the research base in science education, the pressure for Grace to conform didn’t seem to be too prevalent. Rather, as long as Grace
worked to engage, manage, and know the students, she could avoid pressure from her mentor and principal. 

Grace’s mentor framed effective science teaching differently than the research base in science education. Grace’s mentor saw an effective teacher as one who is knowledgeable about content, organized, and knows how to differentiate for different learning styles\(^6\). Further, Grace’s mentor expressed that the ideal science classroom would have a computer for every child. These responses indicate Grace’s mentor didn’t deeply understand learning theory and viewed an effective teacher as one who has the right knowledge and tools. That said, Grace’s mentor seemed to serve the role as an advice-giver for Grace and wasn’t too engaged with Grace’s teaching on a daily basis.

Grace’s principal wanted to ensure all students knew what they were learning and expected teachers to post learning requirements on the wall. He also valued data-driven instruction with common formative assessments between teachers who taught the same subject. Although Grace’s principal espoused such practices, which often artificially reduce the complexities of teaching and learning, he also recognized the importance of student-centered experiences. Additionally, Grace’s principal believed the teacher should work to understand his or her students’ thinking and avoid rote memorization. Grace’s principal valued Grace a great deal and said, “She is really awesome. She’s really good” (Grace’s Principal, 6, 1).

**Navigation of constraints.** Grace didn’t perceive her environment to be constraining and therefore didn’t actively work to navigate constraints. When Grace did feel constrained—often in a science department meeting or working with her 9th grade colleague—she often dealt with the constraint by remaining silent. She stated,
A lot of [my approach to navigating issues] is keeping quiet. That's one thing I took to heart. Basically, just be quiet, let people talk. If they really do want to know, then you can tell them. I guess before you do that, you have to listen long enough to know how they're going to respond. I do know [that grading practices is] a huge point of contention. [My science colleagues] don't like how we have late work. We will accept it. They think, "Nope. We have to have it. The student should be getting a zero, never can replace it. You're teaching them responsibility!" I think, well no. I'm still teaching them responsibility. I'm teaching them that they can't get out of it. They don't agree with that (Grace, 5,11).

Grace was cautious regarding confrontations with her colleagues on areas in which they differed. Interestingly, while Grace differed from her colleagues in regards to book work and grading practices, she didn’t resist other issues that departed from research-based science teaching practices (e.g., common assessments, posting learning objectives). On the contrary, Grace accepted and participated in these practices.

**Order of consciousness.** Grace meaning-making reflected a third-order consciousness. She didn’t show evidence of self-authoring science teaching practices, but instead followed practices supported by her school or the MAT program. Grace’s choice regarding her practice seemed to be governed by which ideology—the school or the MAT program—seemed to make the most sense to her, which indicated Grace had a “board of directors” to help guide her meaning-making. When Grace felt stuck, she often sided with the strongest influence on her decision-making. For example, when considering activities or grading practices, she often was influenced by her experiences in the MAT program. However, Grace accepted norms of her school, such as classroom management practices and posting learning objectives, which sometimes ran counter to research-based practices promoted by the MAT program.

While Grace could hold multiple perspectives in her mind simultaneously (e.g., her colleagues’ thoughts and her own thoughts), she often viewed other’s perspectives in
regards to the extent to which they were oppositional to her own perspective. Grace seemed to be worried about what her colleagues would think of her if she didn’t contribute in positive ways to the conversations.

These examples indicate that Grace had not yet developed the ability to self-author, which may have helped her to develop a transcendent view of teaching that went beyond specific practices. Grace’s way of making meaning seems to be fairly equilibrated with few indications of meaning-making at the second or fourth order. Therefore, Grace was coded at a solid third order.

**Maddie**

**Background.** Maddie started her undergraduate degree at Midwestern University in elementary education; however, as she began to take science courses, she decided she would switch her major to geology and pursue secondary science teaching\(^1\). Once she graduated with her undergraduate degree, she immediately enrolled in the MU-STEP.

Maddie greatly valued the MU-STEP and thought the program impacted how she thought about teaching. Maddie summarized her experience as follows,

I loved [the MAT]. I just felt, like, a strong sense of…ambition. And I just loved the people I was with. And I was really inspired by you guys, how much work you guys put in. It just was really… especially Dr. Clark, how much dedication and passion he has for the profession. And it made me think of [science teaching] more as a professional endeavor [rather] than an easy one (Maddie, 5, 3-4).

Maddie earned an A in Secondary Science Methods II, which indicated she was an “excellent preservice secondary science teacher” who “conveyed a robust understanding of learning, teaching, and synergistic relationship”, and “exhibit[ed] a passion for teaching” (Appendix E). At the time of the study, Maddie was a second-year
teacher in an urban district. She was one of two teachers who taught 6th grade integrated science throughout the day.

**Understanding of research-based teacher decision-making.** Maddie demonstrated that she deeply understood the importance of having concrete experiences precede the introduction of abstract concepts, which she found especially relevant as she was teaching younger children. Maddie described numerous strategies she used alongside concrete experiences to engage students (e.g., think-pair-share, flexible groupings and seating, writing prompts).

Maddie’s understanding of research-based science teaching practices during her second year of teaching lacked the depth and synergy she exhibited during the MAT. Instead, Maddie often focused on managing the classroom and ensuring the students were on task. For example, Maddie spoke about how she tried to maximize her students’ learning:

> Just having them work right away when we get into class. Having them redo assignments that I don’t think are appropriately done for homework… I'm really energetic and really fast-paced… [I] don't let them sit and talk most of the time. Pretty urgent, sense of urgency (Maddie, 5, 1).

Maddie’s understanding, and subsequently her decision-making, seem to be influenced by the culture of the school. Maddie noted on numerous occasions that the administration cared deeply about a well-managed classroom and “where we lie on the [state] assessment” (Maddie, 5, 8).

**Implementation of science teaching practices.** Maddie’s teaching practices were consistent with her understanding of research-based science teaching practices and were also consistent across the researcher’s observations. Maddie typically started
immediately by explaining how students were to answer the question of the day. Students were on task throughout the lessons; however, they were not often deeply engaged with one another or the content they were studying. Instead, students often independently completed the task they were assigned. Occasionally, students did work in groups; however, even the group time was highly structured with Maddie explaining the steps students should take (Maddie, 8, 82).

Maddie’s lessons had an average LSC-COP capsule rating of 2.75 (Figure, 4.13), which indicated her lessons had some elements of effective instruction but had significant issues that limited the likelihood the children would enhance their understanding of science (Horizon Research, Inc., 2005, p.11). Maddie’s interaction pattern could best be described as a 1,2,7,10 pattern where Maddie most often lectured, made statements, confirmed/praised student answer, and answered students’ questions (Figure 4.14). Maddie did occasionally engage students with thought-provoking questions, ask students to clarify their thinking, or use students’ ideas; however, these interactions made up only 7 percent of her total interaction pattern. In contrast, lecture/making statements made up 56 percent of Maddie’s total interactions.
* Maximum capsule rating is 7; maximum rating for other categories is 5.

**Figure 4.13.** Average LSC-COP scores of Maddie’s teaching during classroom observations.

**Figure 4.14.** Average occurrences of Maddie’s verbal interactions during classroom observations.

**Perceived constraints.** Maddie didn’t find the stakeholders (e.g., teachers, parents, administration, students) to be constraining but did often referred to the ways that curriculum and testing policies at the district level negatively impacted her ability to
make decisions. Specifically, Maddie expressed frustration that she was given a curriculum pacing-guide that outlined the topics, sequence, and time allowed to teach the topics.

Maddie didn’t perceive her administration to be too constraining even though the principal seemingly valued student compliance and improved test scores above all other aspects of teaching. Maddie summarized the principal’s focus as follows:

[The administration] focuses a lot more on classroom management than anything. If you're good at classroom management, then they don't really pay attention to you. They kind of view that more so as good teaching than anything else. And where we lie on the Iowa assessments is a huge deal for us. (Maddie, 5, 8).

Maddie’s perspective of the principal was consistent with the researcher’s interaction with the principal; when the researcher spoke to the principal, she noted the test scores had improved and showed the researcher the large posters where the test scores were displayed in the front office.

The researcher was surprised Maddie didn’t find the principal too constraining, especially after Maddie told a story about how the principal yelled at her for not being in the hallway during passing time even though Maddie was working with a colleague.

Maddie explained the discrepancy between the researcher’s observations and her belief that the administrator wasn’t too constraining when she stated,

Yeah, even though [the principal is constraining], like not really. I think if you're on her bad side, she is. She has sides; if you're on her good side, then it's fine. If you're on her bad side, then it's just a nightmare, which is kind of the way it's happening [with my colleague who also went through the MAT] (Maddie, 5, 23).

Maddie really liked working with her 6th grade colleague, the students, and parents. Beyond the district requirements and Maddie’s efforts to stay on her principal’s
good side, she felt she had quite a bit of autonomy to make decisions in her classroom and didn’t believe she was constrained.

**School environment- constraints and their pervasiveness.** Maddie’s school environment had several constraints—both at the school level and the district level—that are in opposition to research-based science teaching practices. In particular, the district pacing-guide along with common assessments limit teachers’ ability to flexibly make decisions based on the needs of their students. Further, the pacing guide lacked a logical progression as Maddie noted,

> And that's the frustrating part [of the pacing guide], is the order. Because we'll go from scientific inquiry to Newton's laws of motion, which is one week…Yeah, I was like, um, no. To solar system, which makes sense. To cells, for two and a half weeks. To water cycle. To food web. And then ovaries to the Richter Scale (Maddie, 2,9)

At the school level, constraints to effective teaching were also documented by the researcher. The administration expected a well-managed classroom, learning objectives to be posted, and teachers to tell students the purpose of the lesson multiple times throughout the class period. Additionally, teachers were assigned to data teams to make, give, and analyze multiple-choice exams. A well-managed classroom, the use of data, and students knowing the purpose of the lesson doesn’t necessarily constrain research-based science teaching practices. However, the implementation of these policies clearly indicated a culture of student compliance and valuing test scores over an environment based on meaningful relationships and deep, conceptual learning.

**Navigation of constraints.** When Maddie faced constraints, she tended to either accept them, downplay them, or avoid dealing with them. Maddie’s administration expected her to have a highly structured learning environment including explicitly telling students when, how, and why to do classroom tasks. Maddie conformed to these
expectations—they were pervasive in her teaching and interviews—and didn’t seem to see the discrepancy between her actions and research-based science teaching practices. Maddie explained how she dealt with her administrator, thus conforming to the school culture, when she stated,

They focus a lot more on classroom management than anything. If you're good at classroom management, then they don't really pay attention to you. (Maddie, 5, 8)...And so, since I have kind of managed the classroom management side of things, and I like hooking the kids in whenever they come and see me... But they don't ever look at really effective teaching all that much (Maddie, 5, 14).

At other times, Maddie was able to navigate constraints by downplaying their significance and not investing much time or mental energy into them. For example, when her administration came in to observe her, Maddie explicitly told students the learning objectives for the day just as the administration expected. Further, Maddie recognized the teachers in the school didn’t take data teams seriously. Therefore, Maddie said the data team process was “not really on her priority list” (Maddie, 5,12). In this case, Maddie seemed to take cues from other teachers regarding how to handle the data team constraint.

Maddie expressed concerns regarding the district pacing guide of the content and efforts to further standardize teaching practices across the district. Maddie didn’t really navigate these constraints. Instead, she mentioned if the district kept going down the path towards more standardization, she wasn’t sure she would stay.

**Order of consciousness.** Maddie displayed a third order consciousness and didn’t exhibit meaning-making at the second or fourth order. Maddie, in many ways, conformed to the school’s expectations, which was the strongest culture.

One example of Maddie’s third-order thinking can be seen in the way that her emotions are subject. Maddie says that she is ‘pretty emotional,’ and she holds herself
responsible for others opinions\textsuperscript{7} and holds others responsible for influencing her emotions. For example, when asked what are the greatest influences on her decision-making, she responded,

Unfortunately, I'd say some of the greatest influences [on my decision-making], and I try not to be this way, but some of the greatest influences are my mood. Like my mood influences how I decide things sometimes...The students obviously influence my decisions quite a bit. What mood they're in and what they decide to do and what is going inside the classroom...like, for instance, if they decide to just... be really really loud and talkative and things like that, that will kind of like influence my mood, again, going back to how [my] mood will influence how I do things. (Maddie, 2,2).

Maddie did internalize others’ perspectives, an achievement of third order, but she could not hold others’ perspectives and moods as object. Therefore, Maddie was deeply influenced by how others perceived her, thus making her more susceptible to conforming to the traditional culture of her school. In summary, Maddie had not yet developed the ability to self-author and was coded at a solid third order.

Greta

\textbf{Background.} Prior to the MAT program, Greta graduated with her undergraduate degree in Materials Engineering from Midwestern University. Throughout her experience in engineering, Greta was drawn towards interacting with high school students as a part of the outreach program through MU\textsuperscript{1}. She often went to high schools, or participated in experiences where students came to MU, and she engaged them in engineering activities. This experience, along with her desire to “help other people become successful and to help them figure stuff out” (Greta, 2,1) was part of her decision-making process to ultimately become a high school science teacher.

Greta thought the MU-STEP was a valuable experience and, she came to view teaching differently than she previously had. Greta noted some of the strengths of the
program were the interconnections she saw between her methods courses and her student teaching experience and working with members of the cohort. Greta earned a B+ in Secondary Science Methods II, which indicated she had a very good understanding of teaching and learning and articulated research-based teaching throughout her coursework (Appendix E).

During the study, Greta was a second-year teacher in a rural school district. She taught five courses throughout the year including: Engineering/Materials Science, Chemistry, Physical Science, and Physics. Materials Science and Engineering were alternating semester courses resulting in Greta having four different courses per semester.

**Understanding of research-based teacher decision-making.** Greta’s understanding of research-based science teaching practices did, in many ways, align with her understanding while she was at MU-STEP. Greta deeply believed in helping her students become life-long learners and understand the natural world. For Greta, an implication of those student goals was to focus on developing students’ conceptual understanding rather than rote memorization, note-taking, and plugging numbers into a formula. Greta mentioned how she often started with a concrete experience and then used that experience to develop a conceptual understanding. Greta understood the role of formative assessment in gaining insight into student thinking, which she used to guide her decisions. She used pre-assessments, whiteboards, her students’ facial expressions, and how students interacted with each other to guide her teaching practices.

Although Greta could articulate numerous aspects of research-based practices, her understanding of the teacher’s role was less clear. For example, Greta rarely spoke about how she scaffolded students’ thinking, the role of questions, or how she made
changes during the lesson to adjust to student thinking. Greta did express research-based practices with the same specificity she did in the MAT; however, much of what she did articulate was aligned.

**Implementation of science teaching practices.** Greta often began with a concrete experience and then helped her students make sense of that experience. The lessons were often logically structured and focused on developing a fundamental science concept. However, the labs and lessons themselves were often over-structured, which negatively impacted students’ ability to make decisions.

Greta’s lesson had an average LSC-COP capsule rating of 3.17 (Figure 4.15) which indicated “quite a few elements of effective practice”; however, weaknesses in the lesson impacted the likelihood that students would enhance their understanding of the discipline (Horizon Research, Inc., 2005, p.11). Greta’s interaction pattern was 1,2, 3b, 7, 8, where Greta often resorted to lecture, making statements, asking recall questions, and confirming and repeating student answers (Figure 4.16). Further, Greta’s voice intonation often seemed strict rather than encouraging (Greta, 8, 77). As a result, the student participation was often limited to a few students per class period, and students rarely interacted with each other during large group discussions (Greta 8, 29).
Maximum capsule rating is 7; maximum rating for other categories is 5.

Figure 4.15. Average LSC-COP scores of Greta’s teaching during classroom observations.

Figure 4.16. Average occurrences of Greta’s verbal interactions during classroom observations.

Perceived constraints. Greta didn’t perceive many constraints from her administration or her colleagues. She was told by her administration to follow national science education standards, but she felt that afforded her a great deal of flexibility and
freedom to make decisions. Even though Greta had four different courses each semester, she felt the freedom to make decisions outweighed the constraint of the number of courses.

Although Greta perceived few constraints to her teaching overall, Greta often expressed frustration that her students didn’t take as much ownership in their education as she believed they ought. She stated,

[The students are] resistant to a different type of teaching or form of learning. They don't like not handing them the answers. They don't like not having 20 million examples that they can just memorize the process for...some students have come to the realization that... to understand, they have to think. And the students who like to think enjoy my class... But I've kind of learned to deal with that not all of the students are going to like me... And I will help them, and I will provide guidance, and I will ask them lots and lots of questions. But in the end, they're going to have to put in some effort. (Greta, 5, 18).

Related to students’ views on learning, Greta felt she was forced to give her students multiple chances to make up missing work due to the emphasis on improving the graduation rate at the school. She believed the school policies were responsible, in part, for the lack of responsibility many students showed regarding their school work.

Greta perceived the school policies regarding iPad integration and the forced integration of specific teaching strategies were a constraint on her teaching. The expectation from the school district was to use the iPads as much as possible for instructional purposes; however, Greta didn’t believe they were “always appropriate for what we’re learning” (Greta, 5, 13). Similarly, Greta was expected to integrate specific strategies into her teaching during the week. Greta and the teachers in her school were mandated to integrate specific strategies into their teaching; however, Greta believed using a strategy for the sake of using a strategy is a poor way to implement research into practice⁵.
School environment--constraints and their pervasiveness. Greta’s school environment was not overly constraining nor did it have pervasive constraints. During an interview with the principal, she stated the major initiatives for the school are to improve test scores, improve the graduation rate, and incorporate iPads into the classroom. These initiatives did seem to detract from Greta’s ability to implement research-based science teaching practices; however, these initiatives also seemed to be balanced with the principal desiring to have meaningful instruction take place in the classroom. When describing her ideal classroom, the principal stated,

I like to see very active classrooms. I don't like chairs and rows. I like to see engagement amongst the students. I have a constructivism view. I really like to have that big picture and that they're teaching the kids how to figure out what that big-picture looks like instead of facts. If they can Google it on their iPad, there's no reason to do it. So, I really like where they're using their heads to think and that there's sometimes no right or wrong answer. In science, that kind of goes, they discover what it is. But that's the kind of classroom that I like, very active… Make sure, walking around the room. Kids up in front, kids not up in front. Sometimes, projects…That would be my ideal kind of classroom (Greta’s Principal, 6, 5).

Greta worked with her mentor on a daily basis as they both taught Physical Science. Both Greta and her mentor mentioned how they were trying to teach the same thing on the same day. Typically, this sort of language is often accompanied by implicit or explicit restrictions placed on the decision-making abilities for the new teacher. However, in Greta and her mentor’s case, this seemed to be a true collaboration where the mentor listened to Greta’s ideas and opinions. For example, Greta’s mentor said, “I'm her mentor, but there are days when she's my mentor...She has so many good ideas; lots of hands-on type ways to get physical science to the students, and that's good (Greta’s Mentor, 7, 5).
In summary, Greta’s school environment was not constraining; however, the environment was not supporting Greta in improving her science teaching either. Therefore, the school environment might best be described as “neutral.”

**Navigation of constraints.** Greta’s main approach to dealing with constraints was to feel frustrated. Her major source of frustration was the lack of value the stakeholders placed in a quality education. Greta, in explaining her frustration regarding the school culture stated,

> It's frustrating to me because we seem to have this...we have a bunch of rules that we do not enforce, and that's the primary one in that we say, “Well, if you're not doing well academically, you can't participate in extracurricular activities,” but when push comes to shove, whoever pushes harder wins, whether or not that's the rules in the book. I'm more frustrated with the getting around the rules [regarding late work and holding students to expectations] and rules not being enforced, but I also think there is an aspect of we don't take academics seriously enough, and we don't honestly prepare students for life after high school (Greta, 3, 1).

When the researcher probed Greta on how she dealt with this frustration, Greta mentioned she tried to have conversations with students regarding the importance of academics.

Greta also expressed frustration with some of the administration’s expectations to include iPads and specific teaching strategies into her instruction despite their alignment with the current content she was teaching. Greta dealt with this frustration by implementing the strategies when they made sense, but she also recognized the administration wasn’t checking up on these mandates and therefore Greta did what she was told when she believed made sense for her classroom.

Greta often felt unappreciated at her school because she invested so much of herself into her job. Greta navigated feeling unappreciated by making a “more concerted effort to let other teachers know they are appreciated” (Greta, 3,4), which, in turn, made
her feel better about the school culture. In this sense, Greta took an active role in confronting her negative emotions, which were born, in part, out of the constraints she faced, and turning them into positive experiences.

In summary, Greta seemed to initially feel frustrated by the constraints she did face, but she recognized that, overall, she didn’t face too many. At times, Greta actively used strategies to combat her feelings of frustration and feeling unappreciated. However, when the frustration seemed to be born of the school culture, such as the case of valuing academics, she tended to remain frustrated.

**Order of consciousness.** Greta exhibited both third order and fourth order consciousness; however, Greta most often operated with third-order consciousness. When Greta faced issues that didn’t have an immediate solution, such as the value students place in academics, Greta often felt frustrated and struggled to articulate how she might address those frustrations. Similarly, Greta seemed to hold others accountable for her feelings of frustration about the school culture.

Yet, at other times, Greta exhibited fourth order thinking. She seemed to have internalized and self-authored her purpose for being a teacher and the importance of having goals for her students. However, since these instances of fourth-order thinking were not as prevalent or as evident, Greta’s order could best be described as 3/4.

**Hannah**

**Background.** Prior to joining the MAT, Hannah completed her undergraduate degree in chemistry and environmental science from a small liberal arts institution in the Midwest. She then came to graduate school at Midwestern University in environmental
science and had completed her third year before deciding to switch to the MAT. Hannah explained why she changed career paths when she stated,

I was not satisfied with research. Also, there were a lot of political moves going on where there weren't a lot of jobs in environmental science. But then I started coaching softball and that was kind of my, "Oh my goodness, I love working with kids a lot." Found myself being more focused on the kids, not even softball, just the kids. So then it took a whole year before I got the courage to drop the other degree. But I eventually dropped the other degree and switched to the MAT (Hannah, 2, 1).

Hannah loved the MAT because she felt she had a great appreciation for the modeling of the professors and doctoral students and the support she received in understanding and implementing research-based science teaching practices. She found the program to be “rigorous, and life changing, in a good way, and extremely beneficial” (Hannah, 1,1). She believed the cohort model was beneficial because she felt she had a group of people going through similar experiences, which helped her to feel supported. Hannah earned a B+ in Secondary Science Methods II, which indicated she had a very good understanding of teaching and learning and articulated research-based teaching throughout her coursework (Appendix E).

During the time of the study, Hannah was a second-year teacher in a suburban school district with two courses to teach. She taught a general science class to freshman with a team of other teachers that worked to do the same thing as one another each day. Hannah also taught Chemistry with one other teacher and had a great deal more freedom in that course.

**Understanding of research-based teacher decision-making.** Hannah deeply understood research-based science teaching practices, and she demonstrated this understanding pervasively throughout the interviews. In particular, Hannah deeply
believed in goals for students and understood many important aspects of how people learn. She used these understandings as a foundation to make decisions in her classroom. For example, Hannah summarized some important aspects of a teacher’s decision-making when she stated,

[Effective science teachers are] excited about what they're teaching. They're not lecturing…They're excited about the ideas. They're using the kids’ ideas to get from where they are to where they want to be by asking questions and scaffolding correctly. They're letting the kids take control of their learning, to a certain extent, being not just whatever you want, but by valuing the kids’ ideas (Hannah, 5, 8).

Although Hannah deeply believed and understood many important aspects of research-based science teaching practices, she admitted she felt a great deal more pressure to cover content than what research suggests. Hannah felt like she needed to balance her understanding of effective teaching with the practical realities of the classroom.

**Implementation of science teaching practices.** Hannah often began her classes by giving directions to students. Students then often engaged in an activity or a worksheet related to the science concept they were studying. The students were most always engaged in the task and Hannah monitored their work and paid close attention to their conversations. Hannah exuded confidence and excitement for her students and for the science content; however, she struggled to scaffold students’ thinking from the activity towards the fundamental science concept (Hannah, 8, 22). Instead, Hannah asked short-answer questions and made statements rather than helping the students deeply mentally engage by using their ideas to drive the conversation forward.

Hannah’s observed lessons had an average LSC-COP capsule rating of 3.80 (Figure 4.17), which indicated her lessons had “quite a few elements of effective
practice” but were somewhat limited in their “likelihood to enhance students' understanding” of science (Horizon Research Inc., 2005, p. 11). Hannah’s interaction pattern was a 1, 2, 3a, 3b, 6, 8 pattern, which indicated Hannah tended to lecture, make statements, ask dichotomous or short-answer questions, acknowledge student responses, or repeat student responses. Although Hannah’s interaction pattern is not reflective of research-based science teaching practices, she did ask questions, use student ideas, or ask students to clarify or elaborate 31 percent of the time.

* Maximum capsule rating is 7; maximum rating for other categories is 5.

*Figure 4.17.* Average LSC-COP scores of Hannah’s teaching during classroom observations.
Figure 4.18. Average occurrences of Hannah’s verbal interactions during classroom observations.

**Perceived constraints.** Hannah perceived a number of constraints at her school. First, she taught a general science course with a number of other teachers where the expectation was to teach the same content the same day. Second, Hannah taught in an affluent school district and often felt pressure from parents to ensure students are ready for college. Third, the school district had established content standards for each course, and teachers were expected to login to a website at the end of the year and verify that they had taught the standards. Combined, these constraints made Hannah feel like she was in a “time crunch” and felt torn between teaching content deeply, which required time, and covering all the content (Hannah, 2, 5).

**School environment--constraints and their pervasiveness.** As a result of interviews with Hannah’s mentor, Hannah’s environment seemed to have considerable constraints, including teaching the same thing on the same day as her colleagues, assessing students in similar ways as her colleagues, communicating the rigor of the coursework to parents, and navigating some of her colleagues’ opinions that she
overstepped her place as a new teacher in suggesting changes to the curriculum. The school culture seemed to be unsupportive of reforms-based teaching.

Hannah’s mentor corroborated Hannah’s perceptions of constraints, including the value parents and teachers place in covering a great deal of content, the negative perception of Hannah by her colleagues because she resisted the status quo, and the expectation of covering the same content on the same day. Hannah’s mentor didn’t provide a great deal of support to Hannah in the face of these constraints because the mentor didn’t seem to understand the complexities of teaching and learning. For example, on numerous occasions during the interview, Hannah’s mentor kept stating the importance of doing a variety of tasks in the science classroom such as using models, games, and packets that have fill-in-the-blank notes. This seemed to be founded in her naïve view that “different people learn in different ways” (Hannah’s Mentor, 7, 3). Hannah’s mentor had misconceptions regarding teaching science through inquiry and believed inquiry wasn’t effective because “you [can’t] just say you know, figure it out” (Hannah’s Mentor 7, 6). Despite those views, Hannah’s mentor thought she was a really good teacher, engaged students, and asked students a lot of questions.

**Navigation of constraints.** Hannah felt like she could be better aligned to research-based science teaching practices if she didn’t have as many constraints. In particular, having a prescribed amount of time for the content limited her ability to help students deeply understand the content. While constraints Hannah faced were a frustration for Hannah to some degree, she dealt with the constraints by working to find areas where her thinking and the thinking of her stakeholders in her school were aligned. For example, Hannah is strategic about the types of teaching decisions she discusses with
her colleagues who also teach general science by discussing ideas regarding the content, activities, materials, safety, and classroom management considerations. She didn’t engage in conversations with those colleagues in areas they would likely disagree, such as teacher interactions, structuring lessons, and assessment strategies. Additionally, she often questioned decisions by others in a politically savvy and non-threatening way by prefacing her question with “I’m a new teacher that’s learning. Why did you decide to do it this way?” (Hannah, 5, 33). In this sense, Hannah proactively found areas she could work to change while recognizing systematic change of the colleagues will take time. Hannah also worked to make small changes to the curriculum that she believed her colleagues wouldn’t notice in an effort to speed up the change. An additional strategy she used was to get her office moved into the chemistry wing, which was away from her colleagues who provided the most constraints. Overall, Hannah’s strategies to navigate constraints were to resist ineffective practices privately and actively navigate constraints publicly.

**Order of consciousness.** Hannah exhibited aspects of fourth order thinking throughout her interviews. For example, Hannah didn’t seem to be threatened when her views of teaching and learning were different than those around her. Instead, she was able to hold her view and her colleagues’ views in her mind and see the merit of both. Hannah could then use areas where she and her colleagues agreed to gently push them towards that goal by framing her questions from the lens of a new teacher trying to learn. Hannah saw the small changes she made as steps that would add up to make bigger changes in the course and in the school.
Hannah did, on occasion, also exhibit third order consciousness. She often felt frustrated and stuck when she thought about how dissimilar her school environment was to research-based science teaching. Hannah felt guilty for feeling stuck because she knew the school environment had impacted her ability to grow in her teaching. For example, Hannah noted that she didn’t ask as effective questions as she would like because she often felt rushed to cover the content. Hannah summarized her frustrations when she stated,

Once you learn about how people learn, and how to effectively teach, you can't ignore it. And especially if you want to teach well, it gnaws at you inside, like, “I want to do better. I want to do better. I want to do better”…However, I'm on my guard [with my colleagues]. My term for [their approach to teaching] is handout-centered. I feel like handouts misdirect the students' attention. I feel like they're so worried about completion of activities and filling in the blanks and having something written down than really looking at what's in front of them. So, here's what I'm wrestling with in my mind, when a teacher says that we have to give students this structure… and [the students are] going to get buried in a pile of paperwork that they have to fill out. (Hannah, 3, 4-9)

While Hannah exhibited both third and fourth order consciousness, fourth order was much more prevalent in her interview. She tended to self-author and frame the problems she experienced through a fourth order lens, but occasionally admitted she had troubles maintaining that perspective and often felt torn between the school culture and research-based science teaching practices. In summary, Hannah’s order of consciousness was 4/3.

Jennifer

**Background.** Jennifer joined the MAT program directly after she finished her undergraduate degree in Biology with a minor in Psychology at Midwestern University. Jennifer knew she wanted to be a teacher during her undergraduate experience, and the
MAT program made sense to her. Jennifer found the MAT program to be “rigorous, very challenging, but a supportive environment” (Jennifer, 5, 3). She found the program incredibly valuable from the perspective from of a preservice teacher, but she also transferred what she was learning in the MAT to her personal life.

Jennifer valued the MAT program because she saw her practicum teacher use the same strategies and approaches promoted in the MAT program and in the science education literature. When Jennifer taught, she experienced how research-based science teaching practices helped her students learn, which continued to strengthen her commitment to the research-based practices promoted by the MAT program. Jennifer also enjoyed the intellectual rigor of the MAT and being part of a cohort with like-minded others where she engaged them in conversations about teaching and learning. Jennifer worked to develop relationships between herself and other cohort members because and she saw “how valuable each person [was] for different things…” (Jennifer, 1, 3) and believed interacting with other cohort members was mutually beneficial.

Jennifer earned a B+ in Secondary Science Methods II, which indicated she had a very good understanding of teaching and learning and articulated research-based teaching throughout her coursework (Appendix E).

During the study, Jennifer was a second-year teacher in a small school district near a Midwestern city. She was in her second year of teaching Biology in the same school district she student taught. She taught Biology along with two other like-minded teachers, one of which was her mentor and former cooperating teacher. She was in her first year of teaching Environmental Science.
Understanding of research-based teacher decision-making. Jennifer deeply valued research-based science teaching practices, understood them as highly interconnected to each other, and grounded them in her goals for students. For example, Jennifer worked to improve student understanding by considering the following:

how to develop lessons where students are forced to make connections, reflect and built upon their understanding. I'm trying to figure out what... right now, it's been a lot of, what do they know, and how can I move them forward...I think that, for me, an effective science teacher looks or teaches in a way that has goals for students that can be applied to a variety of situations, but uses science as a conduit to do... to teach those goals. And then also through teaching science, making sure that they're accurately reflecting the nature of science (Jennifer, 5, 2-3).

For Jennifer, promoting goals for her students was central to effective teaching. For example, she stated, “[I consider how I can] make kids problem-solvers. Not just in science, but in their everyday life.... How can you get kids to think and to apply what they are learning to new situations?” (Jennifer, 2, 3). While Jennifer did deeply understand science teaching practices, she admitted that her knowledge continued to grow and deepen because she was in a school environment that expected her to use research-based science practices and talk about them intelligibly with her science colleagues.

Implementation of science teaching practices. As soon as students began walking in the room, Jennifer interacted with them and had discussions about their lives. As soon as the bell rang, Jennifer got started with the lesson. She often began with a concrete experience or a question to guide the lesson. Students were most always engaged; however, Jennifer had a bit more difficulty managing her Environmental Science class—a course designed for students that often struggle in science—and as a result, Jennifer’s interaction patterns weren’t as strong as they were in Biology. Despite
minor classroom management issues, Jennifer knew what she wanted her students to learn and guided them towards that understanding.

Jennifer’s observed lessons had an LSC-COP capsule rating of 4.75 (Figure 4.19), which indicated she had “quite a few elements of effective practice” and “students were often engaged in meaningful work”; however, the lesson “had a few weaknesses” that may have impacted students, but the lessons weren’t often adapted in response to students’ needs in the moment (Horizon Research Inc., 2005, p. 11). Jennifer’s average interaction pattern was 1, 2, 3b, 3c, 6, which indicated she often lectured, made statements, and asked questions with neutral responses. Often, Jennifer would ask a question, have students discuss it, and then make a statement or lecture rather than use students’ ideas to push the lesson forward. Although Jennifer’s interaction pattern is not completely reflective of research-based science teaching practices, she did ask questions, use student ideas, or ask students to clarify or elaborate 45 percent of the time.

* Maximum capsule rating is 7; maximum rating for other categories is 5.

Figure 4.19. Average LSC-COP scores of Jennifer’s teaching during classroom observations.
Figure 4.20. Average occurrences of Jennifer’s verbal interactions during classroom observations.

**Perceived constraints.** Jennifer did not perceive her school environment to be constraining. Instead, she perceived her principal and colleagues to be very supportive in promoting research-based science teaching practices. As Jennifer co-planned lessons with her mentor/former cooperating teacher, who also used research-based science teaching practices, Jennifer was expected to develop high-level lessons that would promote her student goals and align to learning theory.

Despite a supportive school environment, Jennifer did feel constrained by some classroom management issues in the Environmental Science course. Jennifer has had to adjust some of her approaches to research-based strategies she used in Biology. For example, when Jennifer had students use a whiteboard to discuss and record ideas in groups, she noticed she would have to reduce the amount of time she gave them to complete the task to avoid classroom management issues. Additionally, Jennifer noticed
her questioning patterns weren’t as strong in the Environmental Science course as they were in Biology.

**School environment- constraints and their pervasiveness.** The researcher interviewed Jennifer’s mentor and principal and found both the mentor and the principal deeply understood research-based teaching practices, articulated a deep understanding of Jennifer’s level of implementation of research-based science teaching practices, knew where Jennifer needed to be supported, and actively encouraged Jennifer to improve her practice.

Jennifer’s mentor stated that she actively coached Jennifer to develop effective strategies and teacher behaviors along with different classroom management strategies; however, she stated that continuing to coach Jennifer on teaching and learning was more important than classroom management. The researcher asked her to clarify why she believed classroom management strategies weren’t as important as developing research-based science teaching practice. The mentor replied,

> Well, I think it's been my experience initially that if your kids are engaged and they're actively participating, and they want to be a participant in creating that collective understanding, you have less classroom management problems. That doesn't mean that you don't have the few jackalopes that you need to wrangle and point in the right direction. But my job is not to babysit. My job is to help kids make meaning and make sense of the world around them. So I feel like if those strategies and my behavior is already in place, I have less classroom management problems.

While many mentors seem to emphasize gimmicks for classroom management, Jennifer’s mentor seems to view effective teaching as inextricably linked to classroom management. Jennifer’s mentor seemed to deeply understand and implement research-based science teaching practices and encouraged Jennifer daily to continue to work to improve.
Jennifer’s principal thought very highly of Jennifer and supported her individually and through school professional development initiatives. Instead of seeing professional development as a disconnected set of initiatives, Jennifer’s principal believed that all professional development should be interconnected, build off of each other, be supported by teachers and aligned to research. He summarized this position when he stated,

So it is not like you have just one initiative out over here and one over here. They are pillars that support learning. I think that is what has been helpful to the staff. We really don’t do anything in isolation. If it doesn't relate or support what we are already doing, we are really reluctant to do it. For example [Professional Learning Communities] they are a big deal. There's value to PLC’s. Several of the buildings in the district have gone with PLC’s. Our contention is that [Authentic Intellectual Work] accomplishes the same thing. We chose... we are not going to do PLC’s and just like it is one more initiative. Let's do AIW well (Jennifer’s Principal, 6, 6).

The culture of the school was very aligned to research-based science teaching practices. Jennifer’s principal summarized the school’s approach to research-based practices when he stated, “If you can’t support [your claims with research], don’t say it. Don’t bring an opinion you can’t support” (Jennifer’s Principal, 6, 2). Even when parents questioned teachers’ practices, the principal supported the teachers. Overall, the school culture was a place where Jennifer could thrive in implementing research-based science teaching practices.

Navigation of constraints. Jennifer did not face any constraints with her colleagues or the administration and therefore didn’t have to actively navigate the environment. However, Jennifer did teach an Environmental Science course with students who weren’t interested in science and tended to have more discipline problems in school. Therefore, Jennifer had to more actively manage those students than the
students in her Biology course. Jennifer felt frustrated with the course because she felt like she isn’t “getting kids to think as hard as they could, sometimes having no other option than to tell them information. Just knowing that there are better ways to do it, but not knowing how to get there” (Jennifer, 3, 1). However, she actively worked to improve the situation by reaching out to other environmental science teacher, meeting with coworkers to discuss strategies, and doing research to improve her practice. Jennifer also worked with the administration to get a part-time associate teacher, which Jennifer believed was helping the classroom environment a great deal. In short, when Jennifer faced a constraint, she worked diligently to overcome it while still striving to enact research-based science teaching practices.

**Order of Consciousness.** Jennifer exhibited elements of fourth order consciousness throughout her interviews. She was able to consider both her students’ perspectives and her own at the same time, didn’t hold others responsible for her feelings, and was able to self-author research-based science teaching practices. Additionally, when the students didn’t respond to her teaching practices the way she expected, she would seek more knowledgeable others to assist her thinking.

Jennifer was also able to hold contradictory thinking at the same time. For example, she discussed how she sometimes felt the desire to have someone validate her feelings while at the same time recognizing she didn’t necessarily need that validation. She stated,

> Well, all of a sudden, you go into teaching and really the only feedback that you get is from the kids. You can't really take the kids’ perspective all the time. Once in a while you have an observation, and I've always gotten positive feedback from them when they come through. With just my interactions with them, I feel they're positive. But you don't have, not that I need it, but someone saying, "You know, you're working hard. You're doing a good job." You know? I'm not saying that I
need that all the time, but just this idea that I'm on the right track… (Jennifer, 3, 3).

While Jennifer seemed to self-author, she still maintained elements of third order consciousness. Jennifer realized her experience in a supportive environment had pushed her to develop faster than she would have in a different environment. The experiences and support Jennifer had seemed to push her to self-author and move towards fourth-order consciousness. In summary, Jennifer’s order of consciousness was coded as 4/3.

**Cross-Case Analysis**

A cross-case analysis was conducted to determine general themes across the participants for each research question. Using the constant-comparative method, data was coded and analyzed concurrently to generate explanations across participants (Glaser & Strauss, 1967). Specifically, emergent explanations were compared to the data across participants and ultimately reduced to the findings described below.

**Teaching practices**

**Research question 1: To what degree do participants understand research-based teacher decision-making?** Participants’ understanding of research-based teacher decision-making at the end of the preservice program were derived from the final grade in Secondary Science Methods II. Grade definitions used in Secondary Science Methods II (see Appendix E) were used to generate categories of understanding. The researcher then used participants’ preservice artifacts (e.g., research-based framework paper, lesson plan, SATIC analysis) to categorize participants’ preservice understanding of research-based decision-making (Table 4.5). Participants’ understanding of research-based teacher decision-making during their first or second year of teaching was derived from
the analysis of participant interviews (see Appendix B) using the procedure described below.

The Teacher Belief Interview (TBI) (Luft & Roehrig, 2007) was used to ascertain participants’ views on learning and teaching in the science classroom (See Appendix B). Participants’ beliefs were analyzed, using the pre-established codes described in the TBI, to categorize participants’ beliefs (Table 4.2). The TBI has five categories—traditional, instructive, transitional, responsive, and reforms-based—that range from views of teaching as transmission of knowledge (traditional) toward views of teaching that focus on student sense-making (reform-based). Participants’ teacher belief categories are summarized in Table 4.3.

**Table 4.2. Teacher Belief Interview Category Description (Modified from Luft & Roehrig, 2007, p. 54).**

<table>
<thead>
<tr>
<th>Category</th>
<th>Generic Example</th>
<th>Example from Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional: Focus on information,</td>
<td>I am an all-knowing sage. My role is to deliver information.</td>
<td>N/A</td>
</tr>
<tr>
<td>transmission, structure, or sources.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructive: Focus on providing</td>
<td>I want to maintain a student focus to minimize disruptions.</td>
<td>Just having them work right away when we get into class. Having them redo assignments that I don't think are appropriately done for homework. I have really... like, I'm really energetic and really fast-paced. I don't let them sit and talk most of the time. Pretty urgent, sense of urgency (Maddie, 5, 1-2).</td>
</tr>
<tr>
<td>experiences, teacher-focus, or</td>
<td>I want to provide students with experiences in laboratory science (no elaboration).</td>
<td></td>
</tr>
<tr>
<td>teacher decision.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transitional: Focus on teacher/student relationships, subjective decisions, or affective response.</td>
<td>I want a good rapport with my students, so I do what they like in science.</td>
<td>A guide, I guess. Especially in the very beginning, I'm pointed in the right direction and then try to keep them on track as best I can. I also like the idea, I can't make good choices for them. I can give them the opportunity to make their good choices (Jamie, 2, 7).</td>
</tr>
<tr>
<td></td>
<td>I am responsible to guide students in their development.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2. continued

Responsive: Focus on collaboration, feedback, or knowledge development.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Teaching Year</th>
<th>TBI Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>First</td>
<td>Instructive</td>
</tr>
<tr>
<td>Megan</td>
<td>First</td>
<td>Instructive</td>
</tr>
<tr>
<td>Grace</td>
<td>Second</td>
<td>Instructive</td>
</tr>
<tr>
<td>Maddie</td>
<td>Second</td>
<td>Instructive</td>
</tr>
<tr>
<td>Jamie</td>
<td>First</td>
<td>Transitional</td>
</tr>
<tr>
<td>Kevin</td>
<td>First</td>
<td>Responsive</td>
</tr>
<tr>
<td>Greta</td>
<td>Second</td>
<td>Responsive</td>
</tr>
<tr>
<td>Rachel</td>
<td>First</td>
<td>Reform-based</td>
</tr>
<tr>
<td>Hannah</td>
<td>Second</td>
<td>Reform-based</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Second</td>
<td>Reform-based</td>
</tr>
</tbody>
</table>

Table 4.3. Participants’ Beliefs of Teaching using the Teacher Belief Interview.

As teacher understanding of research-based science teaching practices includes, but goes beyond, beliefs regarding teaching and learning, the researcher used various data sources (e.g., semi-structured interviews, field notes, assignments from the MU-STEP) to generate data-derived categories of participants’ understanding of effective science teaching practices (e.g., superficial, emergent, informed, and synergistic) (Table 4.4). These data were then triangulated with the TBI categories to generate an overall
understanding of participants’ understanding of research-based decision-making (Table 4.5).

**Superficial.** Participants’ understandings were coded as superficial if they could articulate some aspects of research-based decision-making but left out constructs and failed to connect to a broader framework for teaching decisions. For example, a participant might make a declarative statement such as “I start with concrete experience when teaching”; however, the participant didn’t elaborate or connect this statement to other constructs.

**Emergent.** Participants’ understandings were coded as emergent if they articulated aspects of research-based science teaching practices. Participants who were coded as emergent could explain research-based practices beyond declarative knowledge but often didn’t express connections between constructs or articulate a deep understanding of the practices.

**Informed.** Participants’ understandings were coded as informed if they often articulated a deep understanding of research-based science teaching practices. However, connections to a broader framework (e.g., goals and learning theory) or connections between numerous science teaching practices weren’t always apparent. Instead, participants may have framed their pedagogical decisions based on one or two learning theories or broad generalizations of student goals (e.g., “I want kids to think critically”) rather than articulating an interconnectedness between student goals, learning theory, and teacher decisions.

**Synergistic.** Participants were coded as synergistic if they could articulate the interconnectedness of student goals, learning theory, and science teaching practices.
Additionally, participants used specific examples from their classroom that demonstrated they could apply their understanding to their practice.

Table 4.4 Understanding of Decision-Making Framework Category Description.

<table>
<thead>
<tr>
<th>Category</th>
<th>Example from Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td><em>I try and start with a concrete experience, and I get them engaged in the content...And then sometimes I'll do another activity, or I'll do a reading</em> (Taylor 5, 2).</td>
</tr>
<tr>
<td>Emergent</td>
<td><em>I try to give them opportunities to work in the lab, do things with whiteboards, talk to their groups. And I try to pose questions or ask them to write things, direct them towards things that once they start working through it, will spark some sort of discussion...So, first, the concrete experience. And then, some way to mentally manipulate that concrete experience to organize it</em> (Jamie, 2,10).</td>
</tr>
<tr>
<td>Informed</td>
<td><em>The kids would actually be doing things and trying to...put together evidence to understand something, not just answering a bunch of questions about stuff. Not [rote-memorizing things] like, &quot;Here's the life cycle of stars.&quot; It's, &quot;Yellow dwarf that turns into a red giant, and then white dwarf.&quot; You know, [working towards answering questions] like, &quot;Why does a [star have a life cycle]?&quot;</em> (Kevin, 5,4).</td>
</tr>
<tr>
<td>Synergistic</td>
<td><em>I try to reflect those research-based teaching practices...promoting those goals that I have for students. So I'm responsible for making sure the content is in a logical order and that there are meaningful experiences associated with the content. I'm there to help students put the pieces together, but I try to make sure that they're doing as much of that as possible. And I help by asking questions and making students think deeply about the experiences that they've had in the classroom</em> (Rachel, 2,5).</td>
</tr>
</tbody>
</table>

Table 4.5. Teacher understanding of research-based teaching practices at the end of the MU-STEP and during their first or second year of teaching.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Teaching Year</th>
<th>MU-STEP</th>
<th>During Study</th>
<th>Difference in Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>First</td>
<td>Emergent</td>
<td>Superficial</td>
<td>-1 level</td>
</tr>
<tr>
<td>Megan</td>
<td>First</td>
<td>Emergent</td>
<td>Superficial</td>
<td>-1 level</td>
</tr>
<tr>
<td>Jamie</td>
<td>First</td>
<td>Informed</td>
<td>Emergent</td>
<td>-1 level</td>
</tr>
<tr>
<td>Kevin</td>
<td>First</td>
<td>Informed</td>
<td>Informed</td>
<td>Same</td>
</tr>
<tr>
<td>Grace</td>
<td>Second</td>
<td>Informed</td>
<td>Superficial</td>
<td>-2 levels</td>
</tr>
<tr>
<td>Greta</td>
<td>Second</td>
<td>Informed</td>
<td>Informed</td>
<td>Same</td>
</tr>
<tr>
<td>Hannah</td>
<td>Second</td>
<td>Informed</td>
<td>Synergistic</td>
<td>+1 level</td>
</tr>
<tr>
<td>Rachel</td>
<td>First</td>
<td>Synergistic</td>
<td>Synergistic</td>
<td>Same</td>
</tr>
<tr>
<td>Maddie</td>
<td>Second</td>
<td>Synergistic</td>
<td>Superficial</td>
<td>-3 levels</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Second</td>
<td>Synergistic</td>
<td>Synergistic</td>
<td>Same</td>
</tr>
</tbody>
</table>
Research question 2: To what extent do participants implement research-based science teacher decisions? The Local System Change Classroom Observation Protocol (LSC-COP) (Horizon Research Inc., 2005) and the Schlitt/Abraham Teacher Interaction Coefficient (SATIC) (Abraham & Schlitt, 1973) were used to analyze participants’ implementation of research-based science teaching decisions. The LSC-COP divides a lesson into four broad categories (i.e., lesson design, lesson implementation, science content, and classroom climate) to generate an overall capsule score that includes 7 levels, which, for the purposes of this study, have been numbered from 1 (ineffective instruction) to 7 (exemplary instruction) (Appendix C).

The SATIC is a fine-grained analysis of the participants’ verbal interactions, which is a small consideration within the lesson implementation category on the LSC-COP. However, the verbal interaction patterns can greatly impact the extent to which the content was understood by the students and the classroom climate. A teacher’s verbal interactions with a student can impact all aspects of a lesson—including each domain measured by the LSC-COP. For example, if the design of the lesson may have taken into account students’ developmental level and prior knowledge, be carefully planned, and incorporated effective activities; however, if the teacher lectures throughout the lesson, the design of the lesson will be negatively impacted. Similarly, the teacher might be personable, but the chances of an effective dialogue—aspects of classroom culture—are minimal if a teacher lectures. Conversely, effective verbal and non-verbal interactions can enhance all aspects of a lesson. The teacher education program completed by study participants placed substantial emphasis on interaction patterns, and participants were required to record their teaching and conduct a SATIC analysis at least four times, documenting their current state and efforts to improve. To analyze SATIC patterns, three levels were defined by the researcher based on commonly-occurring interaction patterns and their relative effectiveness as documented in the extensive literature base on teacher interaction patterns (e.g., Blosser, 1978). The SATIC pattern scores are described below.
SATIC Level 1: The teacher’s interaction pattern is not consistent with research-based science teaching practices. The teacher often lectures with few questions and student interactions. When the teacher asks questions, they tend to be dichotomous or short-answer rather than thought-provoking. The teacher often responds to students by answering their questions. The teachers’ interaction pattern does not reflect a 3c/4/6/11/12 pattern.

SATIC Level 2: The teacher’s interaction pattern is somewhat consistent with research-based science teaching practices. While the teacher may still lecture, questions were a prominent part of the interaction pattern. Teachers at this level may ask dichotomous or short-answer questions, but also ask thought-provoking questions. The teacher responds to students in a variety of ways, which include using their ideas and asking students to clarify; however, those may not be prevalent. The teacher’s interaction pattern somewhat reflects a 3c/4/6/11/12 pattern.

SATIC Level 3: The teacher’s interaction pattern is consistent with research-based science teaching practices. The teacher often asks open-ended, thought-provoking questions and rarely asks dichotomous or short answer questions. Lecture and making statements are not prevalent in the interaction pattern. The teacher responds to students most often by using their idea or asking the students to clarify their thinking. The teacher’s interaction pattern reflects a 3c/4/6/11/12 pattern.

LSC-COP and SATIC were combined to generate an overall implementation score. Implementation scores that ranged from 2-3.99 were categorized as a low, scores from 4.00-5.99 were categorized as medium, and scores from 6.00-10.00 were categorized as high. Methodological issues arise with the addition of scores from two separately-validated instruments, portions of which may overlap. To mitigate concerns regarding potential over-weighting of teacher interaction patterns, participant scores were arranged from high to low for both the LSC-COP and SATIC analyses, and participant order remained the same—that is, teachers with the highest LSC-COP scores were also
highest on SATIC, and teachers with the lowest LSC-COP scores were lowest on SATIC. Thus, adding these scores did not change the order of participants from high to low implementation. Further, these data were compared to the original LSC-COP data and field notes to ensure that the relative order of the participants from high to low implementation was supported by observational records. Therefore, the SATIC analysis was added to the LSC-COP score to produce a final implementation score for each teacher (Table 4.6), with acknowledgement that the final score is a compilation of three data sources that are triangulated.

Table 4.6. Summary of Implementation Levels of Participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>LSC-COP Capsule Score</th>
<th>SATIC Pattern Score</th>
<th>Composite Implementation Score</th>
<th>Implementation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Megan</td>
<td>2.33</td>
<td>1</td>
<td>3.33</td>
<td>Low</td>
</tr>
<tr>
<td>Jamie</td>
<td>2.33</td>
<td>1</td>
<td>3.33</td>
<td>Low</td>
</tr>
<tr>
<td>Grace</td>
<td>2.33</td>
<td>1</td>
<td>3.33</td>
<td>Low</td>
</tr>
<tr>
<td>Taylor</td>
<td>1.5</td>
<td>2</td>
<td>3.5</td>
<td>Low</td>
</tr>
<tr>
<td>Maddie</td>
<td>2.75</td>
<td>1</td>
<td>3.75</td>
<td>Low</td>
</tr>
<tr>
<td>Greta</td>
<td>3.17</td>
<td>2</td>
<td>5.17</td>
<td>Medium</td>
</tr>
<tr>
<td>Kevin</td>
<td>3.33</td>
<td>2</td>
<td>5.33</td>
<td>Medium</td>
</tr>
<tr>
<td>Hannah</td>
<td>3.8</td>
<td>2</td>
<td>5.8</td>
<td>Medium</td>
</tr>
<tr>
<td>Rachel</td>
<td>5.4</td>
<td>2</td>
<td>6.4</td>
<td>High</td>
</tr>
<tr>
<td>Jennifer</td>
<td>4.75</td>
<td>2</td>
<td>6.75</td>
<td>High</td>
</tr>
</tbody>
</table>

Institutional constraints

**Research question 3: To what extent do participants perceive institutional constraints impact their teaching decisions?** To understand the perceived institutional constraints across all of the participants, data analyses were conducted to generate common themes of constraint. Magnitude coding (Miles & Huberman, 1994; Saldana, 2005; Weston et al., 2001) was used to categorize the perceived intensity of institutional constraints by ranking each theme from 0 (no constraint) to 3 (intense constraints) (Table 4.8). Quotations are included below to describe each level of constraint.
Level 0- No perceived constraint. The participant did not see the stakeholder as constraining his or her decisions.

I can do whatever I want in my classroom. From both principals, because it’s been stated “you can do whatever you want in your classroom”…They really don’t understand the science standards. I know one of the principals doesn’t understand the science standards at all. So we could tell them whatever we want and they would believe us. So that’s kind of been nice because the science department kind of just designed our own curriculum and we really haven’t had influence…So I can do whatever I want, however I want, as long as kids aren’t getting physically or emotionally abused (Megan, 2, 15).

Level 1- Minimal constraints. The participant perceived some constraints, but believed the constraint minimally impacted his or her teaching decisions.

My mentor [and I] don't meet a lot, we don't have a scheduled time during the day to meet, so any time we meet, it has to be outside of school. So we've met a few times, and some of the things he helps with are okay, but his ideas of what to do and mine don't align in some ways (Kevin, 2,1). I try to steer [the conversations with my mentor] in certain directions. [I avoid talking about] certain things that he'll try to say that I should be doing that I don't want to be doing (Kevin, 5, 29).

Level 2- Moderate constraints. The participant perceived constraints and may have believed the constraints impacted his or her teaching, but he or she believed the constraints were manageable.

I got caught up with [the speech specialist] in a discussion about a student in the teacher's lounge…and I was like three minutes late to passing time…I was talking to the lady and then [the principal] came into the conference room and she was like, yelled at me a little bit, like, "You get in the hallway," and I'm like, "Okay." (Maddie, 5, 21). Yeah, even though [my principal is constraining], like not really. I think if you're on her bad side, she is. She has sides; if you're on her good side, then it's fine. If you're on her bad side, then it's just a nightmare, which is kind of the way it's happening (Maddie, 5, 23).

Level 3- Intense constraints. The participant perceives the constraint to greatly impact his or her ability to make teaching decisions.

The institutional constraints are very, very real. Not that I doubted that, or anything, but I thought maybe I'd be better prepared for it, or better able to handle it. That was a little surprising. But I see the teachers who are doing the things that the MAT program espouses are being successful, that I can see while I'm teaching
here. This idea of making sure our curriculum lines up between all three science teachers, that restricted me from the get-go. I wasn't able to organize. Like we're doing next generation science standards... And, for some reason, we all have to do [the same thing] at the same time. That I do not like. That's restricting me a lot. (Rachel, 2, 7).

The analysis described above took into account the participants’ perceived constraints and the intensity of constraints from the stakeholders of the school environment. However, one constraint may influence the participant’s perception of school environment. For example, if the principal demanded the teacher teach a particular way, that one constraint could lead the teacher to perceive a highly constraining environment. Therefore, a second analysis was conducted, using the initial magnitude codes as a guide, to determine if individual constraints (e.g., workload, colleagues, administration) impacted the overall perception of constraints by the participants. The perceived constraints of the participants are displayed in Table 4.7 below.

Table 4.7. Magnitude Codes of Participants’ Perceived Institutional Constraints.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Setting</th>
<th>Workload</th>
<th>Student/Parent</th>
<th>Colleagues</th>
<th>Mentors</th>
<th>Admin/District</th>
<th>Total</th>
<th>Overall Category#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>Rural</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Rural</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Megan</td>
<td>Rural</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>Medium</td>
</tr>
<tr>
<td>Grace</td>
<td>Suburb</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>Medium</td>
</tr>
<tr>
<td>Jamie</td>
<td>Rural</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>Medium</td>
</tr>
<tr>
<td>Maddie</td>
<td>Urban</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>Medium</td>
</tr>
<tr>
<td>Greta</td>
<td>Rural</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>Medium</td>
</tr>
<tr>
<td>Kevin</td>
<td>Rural</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>Medium</td>
</tr>
<tr>
<td>Rachel</td>
<td>Suburb</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>High</td>
</tr>
<tr>
<td>Hannah</td>
<td>Suburb</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>High</td>
</tr>
</tbody>
</table>

^ Workload was categorized by number of courses taught. #Overall category was determined by total points and a second analysis of individual constraints.
Research question 4: How constraining and pervasive are participants’ perceived institutional constraints? Interviews with participants’ mentors and administration were coded—using magnitude coding (Miles & Huberman, 1994; Saldana, 2005; Weston et al., 2001)—to determine how constraining and pervasive the institutional constraints were in the school. Put differently, the interviews were used to analyze the level of support participants received in the school environment. The school environment was ranked as unsupportive, neutral, or supportive (Table 4.8). Descriptions of levels of support and quotations to support those levels are included below.

**Unsupportive.** The school environment was coded as unsupportive if stakeholders (e.g., colleagues, administration, mentors) held views of teaching that conflicted with research-based science teaching practices and those stakeholders exerted pressure of the participant to conform to traditional practices.

Well, I'm old school, so I like doing demos. I like organizing things and stuff like that. I'm probably a little more resistant (Rachel’s Mentor 7, 2). Rachel and I have different philosophies. I won't lie to you. She's more theory oriented and things like that, and I'm more fact oriented. Every once in a while, I'll read what she has and things like that. I don't have a problem at all with her theory things and stuff like that. I think I need to learn a little more her way and she needs to learn a little more my way. The fact of the matter is I take [my way] seriously because our science scores went up last year. Well, I'm a brand-new [science] teacher. I studied. I told the boss at the interview, "That's my goal." So science scores went up. (Rachel’s Mentor, 7, 9).

**Superficial.** The school environment was coded as superficial if the stakeholders did not pressure the participant to conform to traditional practices, but provided suggestions—often in an effort to be helpful—that, if implemented, would undermine research-based science teaching practices. For example, a mentor, colleague, or administrator might suggest implementing “quick fix” classroom management strategies
such as putting students’ desks in rows, calling on students randomly, or giving kids more worksheets to keep them busy.

An ideal science classroom to me has to have a blend of constructivist learning, and it has to have traditional learning as well. Questioning is important in science to make kids think and try to understand what’s going on. But, in an ideal classroom, students also need to be given that wrap-up at the end so that they know what it is they're learning. They need to be focused, you need to have standards posted on the walls, or you need to specifically tell students what they should be learning as well. I think [Kevin] does a great job of questioning kids and not giving students the exact answer all the time, leading them where he wants them to go. But at the same time, when working with Kevin we need to make sure we close the lesson and give students the, 'OK, so this is what you saw, this is what it should be,' kind of recap and bring the lesson back together. Because, sometimes, I see students lost when they leave because he asks questions and answers their questions with questions and that frustrates a lot of kids that aren't used to that. So, you got to have kind of a blended style, more traditional, I would think (Kevin’s Mentor, 7, 3).

Neutral. The school environment was coded as neutral if the stakeholders did not pressure the participant to conform to traditional practices. The lack of pressure to conform could be because the stakeholders didn’t interact with the participant in significant ways, treated the participant as a professional who is capable of making his or her own decisions, or encouraged the participant in superficial ways (e.g., “quick fix” classroom management strategies).

Well, you would hope that what they would do as teachers is they would practice what we had done and then carry that into the classroom (Jamie’s Principal, 6, 1). So for me an effective teacher has to have certain traits. They have to know their curriculum, they have to be grounded in common sense, they have to understand that relationships are the backbone of everything that is done in this school district, and they have to be a team player, and I have to see authentic uses of that when we visit an interview. When they’re hired, how they become effective teachers is... are they team players? Do they realize that our hallways and our sidewalks intermingle in our school and our community? It's one and the same. Do they understand that they're not defined by a master contract but by effort and attitude. And that's it. If I get that, I'm going forward (Jamie’s Principal, 6, 3).

Supportive. The school environment was coded as supportive if the stakeholders actively encouraged the participant to enact research-based science teaching practices.
The mentor and/or principal understood the struggles and successes of the participant and actively worked to mentor the participant to improve his or her practice.

Well, in terms of trying to coach and help Jennifer develop strategies and behaviors, we would talk about different classroom management strategies. But more importantly, what kinds of questions could be posed. Behaviors like position in the classroom, diversity of small groups, large group discussions, a sequence to a lesson where kids can pose questions or questions are posed to them, and what strategies or resources are available to try to coach and guide kids towards making a coherent collective understanding. (Jennifer’s Mentor, 7, 1).

Table 4.8. Participants’ School Climate.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Setting</th>
<th>School Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rachel</td>
<td>Suburb</td>
<td>Unsupportive</td>
</tr>
<tr>
<td>Maddie</td>
<td>Urban</td>
<td>Unsupportive</td>
</tr>
<tr>
<td>Hannah</td>
<td>Suburb</td>
<td>Unsupportive</td>
</tr>
<tr>
<td>Kevin</td>
<td>Rural</td>
<td>Superficial</td>
</tr>
<tr>
<td>Taylor</td>
<td>Rural</td>
<td>Neutral</td>
</tr>
<tr>
<td>Jamie</td>
<td>Rural</td>
<td>Neutral</td>
</tr>
<tr>
<td>Grace</td>
<td>Suburb</td>
<td>Neutral</td>
</tr>
<tr>
<td>Megan</td>
<td>Rural</td>
<td>Neutral</td>
</tr>
<tr>
<td>Greta</td>
<td>Rural</td>
<td>Neutral</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Rural</td>
<td>Supportive</td>
</tr>
</tbody>
</table>

Research question 5: How do participants navigate perceived institutional constraints? Process coding (Bodgan & Biklen, 2007; Charmaz, 2002; Corbin & Strauss, 2008; Saldaña, 2013) was used to generate five themes of how participants navigate institutional constraints. Below, each theme is supported with a description and an exemplar quotation from a participant. Participants sometimes exhibited more than one approach to dealing with constraints; however, the final coding (Table 4.9) was generated by considering what strategy the participant used most frequently.

External Cues. Each participant’s response to constraints was coded as using external cues when he or she used what she heard from stakeholders to determine how to best proceed and to judge his or her teaching efficacy.
I'm far exceeding the person that was here before. Which also makes me feel better, because anything I do is better than what he did, from what I've been told. So I can mess up on a lesson plan, or a lab won't go just right, and it's still okay, because we did something rather than just multiple choice quizzes out of the book. So that's helpful too… I think [thinking about my practice compared to the person here before] affects it quite a bit. Because even if I fall flat on my face on a lesson, it's still better than what they had. Everybody has told me that (Taylor, 3, 3).

Accept. Participants that accepted the school environment and didn’t work to actively change it were coded as “accept.” These participants more often adapted to the culture of the school rather than navigating the culture.

Yeah, even though [my principal is constraining], like not really. I think if you're on her bad side, she is. She has sides; if you're on her good side, then it's fine. If you're on her bad side, then it's just a nightmare, which is kind of the way it's happening [with my colleague that also came from MU-STEP] (Megan, 5, 23).

Frustrated. Participants were coded as “frustrated” when they didn’t accept the constraints of the school but didn’t know how to proceed in actively navigating the constraints either. Participants with this navigational approach most often described feeling frustrated when they discussed constraints.

Whenever I reflect on the things I know I should be doing, I usually feel like I'm not doing them. I even feel like I have reverted to where I was at the start of student teaching (or worse sometimes). I struggle, I don't see a payoff, I get little support from colleagues, and I get student attitudes up the wazoo. The negative students right now overshadow the positive ones. I find myself giving notes, not pushing hard enough to get deep thinking, and not sticking to my policies (particularly leaving the room to use the restroom or get a drink). I feel wishy-washy and ineffective so frequently (Rachel, 12, 1).

Resist/Negotiate. Participants that actively negotiated their institutional constraints in public and resisted conforming to the constraints in private were coded as resist/negotiate. In this sense, participants had to be politically savvy to navigate the constraints they faced.
I actually talk about what I'm doing with classes [with my mentor]. I don't try and steer [the conversations] in certain direction[s] [where we would disagree]… [I stay away from] certain things because he'll try to say that I should be doing things I don't want to be doing. (Kevin, 5, 30).

*Thrive.* Participants coded as thriving didn’t have to have a pretense for discussing their successes or struggles. Instead, they worked in a functioning and effective professional learning community where others in the community would assist them in strategies to improve their teaching practices and the school culture at large.

I don't think I would be having near the intellectual conversations that I have [if I were in a different school]. I'm in a situation that I'm with highly experienced teachers who have a lot of experience implementing a lot of [research-based] strategies and getting kids to think. Because they're more experienced, they have a deeper understanding of the science content (Jennifer, 5, 11).

Table 4.9. *Participants’ Navigational Strategies to Constraints.*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Setting</th>
<th>Navigation of Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>Rural</td>
<td>External Cues</td>
</tr>
<tr>
<td>Megan</td>
<td>Rural</td>
<td>Accept</td>
</tr>
<tr>
<td>Grace</td>
<td>Suburb</td>
<td>Accept</td>
</tr>
<tr>
<td>Maddie</td>
<td>Urban</td>
<td>Accept</td>
</tr>
<tr>
<td>Jamie</td>
<td>Rural</td>
<td>Frustration</td>
</tr>
<tr>
<td>Rachel</td>
<td>Suburb</td>
<td>Frustration</td>
</tr>
<tr>
<td>Greta</td>
<td>Rural</td>
<td>Frustration</td>
</tr>
<tr>
<td>Kevin</td>
<td>Rural</td>
<td>Resist/Negotiate</td>
</tr>
<tr>
<td>Hannah</td>
<td>Suburb</td>
<td>Resist/Negotiate</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Rural</td>
<td>Thrive</td>
</tr>
</tbody>
</table>

**Orders of Consciousness**

**Research question 6: What are the participants’ orders of consciousness?**

Participants’ interviews were analyzed using the Subject-Object Interview Protocol (Lahey, Souvaine, Kegan, Goodman, & Felix, 2011) to determine the order of consciousness for each participant. Below, the orders of the participants in the study are described, and an exemplar quotation is provided.
2(3) Order of Consciousness. Individuals with a second order of consciousness understand that others have different perspectives from themselves, but often view the perspectives of others through the lens of how others’ views impact the individual (Lahey, et al., 2011). An individual with a 2(3) order of consciousness has begun to internalize someone else’s perspective, but still often resorts to how others’ views impact him or her. Participants coded at this level often derive their thoughts and feelings as a consequence to others’ perspectives—an external validation (Lahey et al., 2011).

If the students came into the classroom and they asked him to watch a movie, he would put in a movie, any movie, and just let them sit and sleep, watch the movie. That was it. They didn't have to take notes on the movie. The movie didn't pertain to science necessarily. He never got up from his desk. He never had them do any sort of project work, homework. If it wasn't a movie, then they would come and open their books to the next section. Read the section, do the questions at the end. So it was one or the other. It’s either reading a book or watching. [When I came,] the faculty was like, “Thank God we have a real science teacher now.” So that's been good. And almost everybody has said that. They're happy that I'm here. That includes the superintendent. That includes the principal. I don't get to work with the other science teachers all that often, but I haven't heard any bad things (Taylor, 2, 14).

3 Order of Consciousness. Individuals with a third order of consciousness have internalized more than one way of making meaning and therefore can internalize other points of view. However, if conflict occurs between these points of view, there is no sense of what the individual wants outside of the societal expectations and norms (Berger, 2002).

People's opinions [is one of the greatest influences on my decision-making]. Like, other teachers and parents and students. Because they're the people I'm working for. But also, decision-making, what I learned in college, there are points where I say, "Okay, I'm not going to do that, because I know it's wrong." And so that influences my decision-making. But most of the time, I really care a lot about what other people think. (Maddie, 5, 2-3).
3/4 Order of Consciousness. Participants who were coded as 3/4 have internalized others’ points of view, but can additionally begin to differentiate between themselves and the points of views they have internalized, yet participants in this stage often still feel frustrated when a solution isn’t clear.

[I feel frustrated] because it's my stuff [students are breaking]. Because I feel like [the students] should know better, and maybe they shouldn't, but I'm frustrated that I have to keep... like week one, someone stole my NOS tube and someone cracked one of my white boards in half... And then I see this, later, why have they not figured out that they should respect my stuff? I respect their stuff. You know, and this isn't mine, but like, the yogurt cups, I spend time assembling the materials, I spent time eating that yogurt and saving the cup, you know, it's my stuff and so it's... I don't know. It hurts my feelings. I don't know to what extent it is, just because they're kids. There's something pointy in front of me, I'm going to poke a hole in the cup with it. They probably don't recognize that I spend time putting the materials together. They probably don't realize that this costs the department money so I can't get everything I want to get because we have to replace broken materials. I think they just don't. Either they don't think about it, or it's just not on their radar that this could influence me (Rachel, 4,5).

4/3 Order of Consciousness. Just as participants that were coded as 3/4, participants at this order have internalized points of view and can differentiate themselves from those points of view. A difference between 3/4 and 4/3 is the individuals can now self-author their point of view. However, as the participants are not yet a full fourth order, elements of third order consciousness are still present.

Well, all of a sudden, you go into teaching and really the only feedback that you get is from the kids. You can't really take the kids’ perspective all the time. Once a while you have an observation, and I've always gotten positive feedback from them when they come through. With just my interactions with them, I feel they're positive. But you don't have, not that I need it, but someone saying, "You know, you're working hard. You're doing a good job." You know? I'm not saying that I need that all the time, but just this idea that I'm on the right track… (Jennifer, 3, 3).
Table 4.10. *Order of Consciousness of the Participants*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Order of Consciousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>2/3</td>
</tr>
<tr>
<td>Megan</td>
<td>3</td>
</tr>
<tr>
<td>Grace</td>
<td>3</td>
</tr>
<tr>
<td>Maddie</td>
<td>3</td>
</tr>
<tr>
<td>Jamie</td>
<td>3/4</td>
</tr>
<tr>
<td>Rachel</td>
<td>3/4</td>
</tr>
<tr>
<td>Greta</td>
<td>3/4</td>
</tr>
<tr>
<td>Kevin</td>
<td>4/3</td>
</tr>
<tr>
<td>Hannah</td>
<td>4/3</td>
</tr>
<tr>
<td>Jennifer</td>
<td>4/3</td>
</tr>
</tbody>
</table>

Research question 7: To what extent do teachers’ orders of consciousness relate to their perception and navigation of institutional constraints and teaching practices? The qualitative data from research questions 1-6 was reduced and displayed in Table 4.11. These data include the year of teaching, order of consciousness (research question 6), understanding of research-based science teaching practices (research question 1), implementation of research-based science teaching practices (research question 2), perceived institutional constraints (research question 3), pervasiveness of institutional constraints (school climate) (research question 4), and participants’ response to institutional constraints (research question 5). From these data, participants that have higher orders of consciousness also tend to have higher levels of understanding and implementation of research-based science teaching practices and also have more sophisticated strategies for navigating institutional constraints than participants with lower orders of consciousness.
### Table 4.11. *Overview of Findings.*

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Year</th>
<th>Order of Consciousness</th>
<th>Understanding</th>
<th>Implementation</th>
<th>Perceived Level of Institutional Constraints</th>
<th>School Climate</th>
<th>Response to Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor</td>
<td>1</td>
<td>2/3</td>
<td>Superficial</td>
<td>Low</td>
<td>Low</td>
<td>Neutral</td>
<td>External Cues</td>
</tr>
<tr>
<td>Megan</td>
<td>1</td>
<td>3</td>
<td>Superficial</td>
<td>Low</td>
<td>Medium</td>
<td>Neutral</td>
<td>Accept</td>
</tr>
<tr>
<td>Grace</td>
<td>2</td>
<td>3</td>
<td>Superficial</td>
<td>Low</td>
<td>Medium</td>
<td>Neutral</td>
<td>Accept</td>
</tr>
<tr>
<td>Maddie</td>
<td>2</td>
<td>3</td>
<td>Superficial</td>
<td>Low</td>
<td>Medium</td>
<td>Unsupportive</td>
<td>Accept</td>
</tr>
<tr>
<td>Jamie</td>
<td>1</td>
<td>3/4</td>
<td>Emergent</td>
<td>Low</td>
<td>Medium</td>
<td>Neutral</td>
<td>Frustration</td>
</tr>
<tr>
<td>Greta</td>
<td>2</td>
<td>3/4</td>
<td>Informed</td>
<td>Medium</td>
<td>Medium</td>
<td>Neutral</td>
<td>Accept</td>
</tr>
<tr>
<td>Kevin</td>
<td>1</td>
<td>4/3</td>
<td>Informed</td>
<td>Medium</td>
<td>Medium</td>
<td>Superficial</td>
<td>Resist/Negotiate</td>
</tr>
<tr>
<td>Hannah</td>
<td>2</td>
<td>4/3</td>
<td>Synergistic</td>
<td>Medium</td>
<td>High</td>
<td>Unsupportive</td>
<td>Resist/Negotiate</td>
</tr>
<tr>
<td>Rachel</td>
<td>1</td>
<td>3/4</td>
<td>Synergistic</td>
<td>High</td>
<td>High</td>
<td>Unsupportive</td>
<td>Frustration</td>
</tr>
<tr>
<td>Jennifer</td>
<td>2</td>
<td>4/3</td>
<td>Synergistic</td>
<td>High</td>
<td>Low</td>
<td>Supportive</td>
<td>Thrive</td>
</tr>
</tbody>
</table>

Participants’ understandings of research-based science teaching practice, implementation of research-based science teaching practices, responses to institutional constraints, and orders of consciousness were plotted on to a radar graph (Figures 4.21 and 4.22). These graphs are a graphical representation of the results generated for each of the four categories described above. The purpose of the radar graph, therefore, is to compare across categories to gain insight into relationships between the categories (e.g., understanding, implementation, response to constraints, and order of consciousness). Just as in Table 4.12, the radar graph indicates that people with higher orders of consciousness also tend to have higher understanding and implementation of research-based science.
teaching practices and more sophisticated responses to constraints compared to those participants with lower orders of consciousness.

Figure 4.21. Relationship between order of consciousness, response to institutional constraints, understanding, and implementation of research-based science teaching practices of participants in their first year of teaching.
Summary of Findings

Teaching practices

Research question 1: To what degree do participants understand research-based teacher decision-making?

- At the end of the MAT program at MU-STEP, zero participants demonstrated a superficial understanding, two participants demonstrated an emergent understanding, five participants demonstrated an informed understanding, and three participants demonstrated a synergetic understanding.

- At the end of the participants’ first or second year of teaching, four teachers demonstrated a superficial understanding, one participant...
demonstrated an emergent understanding, two teachers demonstrated an informed understanding, and three teachers demonstrated a synergistic understanding.

- Between the end of the MAT program and the end of the first or second year of teaching, participants’ understanding of research-based teacher decision-making dropped by three levels with one participant, dropped by two levels with one participant, and dropped by one level with three participants. Four participants maintained their level of understanding, and one participant improved her understanding by one level.

**Research question 2: To what extent do participants implement research-based science teacher decisions?**

- In the participants’ first or second year of teaching, five participants implemented research-based science practices at a low level, three participants implemented at a medium level, and two participants implemented at a high level.

- In the participants’ first or second year of teaching, four participants had a verbal interaction pattern that was not aligned with research-based science teaching practices (SATIC level 1), six teachers had a verbal interaction pattern that was somewhat aligned (SATIC level 2), and zero participants had a verbal interaction pattern that was highly aligned (SATIC level 3).

- In the participants’ first or second year of teaching, one participant had an average LSC-COP capsule rating of ineffective instruction, four teachers
had a rating of elements of effective instruction, and five teachers had a rating of beginning stages of effective instruction.

**Institutional constraints**

**Research question 3: To what extent do participants perceive institutional constraints impact their teaching decisions?**

- At the end of the study, two participants perceived a low level of institutional constraints, six participants perceived a medium level of institutional constraints, and two participants perceived a high level of institutional constraints.

- Participants in the rural school districts tended to have greater numbers of different courses to teach and therefore constraints on their time. Participants in the suburban school districts tended to have greater constraints with stakeholders in the school.

- The most ubiquitous constraint teachers perceived were their students in their classrooms; however, this constraint wasn’t always perceived as the most intense.

**Research question 4: How constraining and pervasive are participants’ perceived institutional constraints?**

- The school climate for three participants was characterized as unsupportive, the school climate for one participant was superficial, for five participants was neutral, and for one participant was supportive.

- All unsupportive environments occurred in suburban and urban schools, one superficial environment occurred in a rural school, one neutral
environment occurred in a suburban school, four neutral environments occurred in rural schools, and one supportive environment occurred in a rural school.

- Although the environment of only one participant (Kevin) was identified as providing superficial support, all participants except for Jennifer had elements of superficial support.

**Research question 5: How do participants navigate perceived institutional constraints?**

- One participant used external cues to decide how to navigate constraints, three participants accepted the constraints of the school environment, three participants felt frustrated by the constraints, two participants resisted and negotiated the constraints, and one participant thrived.

**Orders of Consciousness**

**Research question 6: What are the participants’ orders of consciousness?**

- One participant had an order of consciousness of 2/3, three participants had an order of 3, three participants had an order of 3/4, and three participants had an order of 4/3.

- All participants exhibited some third order consciousness.

**Research question 7: To what extent do teachers’ orders of consciousness relate to their perception and navigation of institutional constraints and teaching practices?**
Participants with lower orders of consciousness tended to:

- Articulate superficial understandings of research-based science teaching practices at the end of their first or second year of teaching.
- Drop in their level of understanding of research-based science teaching practice from the end of the MU-STEP to the end of their first or second year of teaching.
- Implement research-based science teaching practices at low levels.
- Perceive their school environment to not have many institutional constraints.
- Not actively work to navigate the constraints they did perceive.
- Adapt to the pedagogical practices and attitudes supported by the school regardless of their alignment to research-based science teaching practices.

Participants with higher orders of consciousness tended to:

- Articulate informed or synergistic understanding of research-based science teaching practices.
- Maintain or improve their level of understanding of research-based science teaching practices.
- Implement research-based teaching practices at medium or high levels.
- Identify institutional constraints that acted as a barrier to research-based science teaching practices.
- Actively work to navigate the constraints they faced.
- Resist conforming to traditional practices.
CHAPTER 5: DISCUSSION AND IMPLICATIONS

This study investigated beginning science teacher effectiveness through the framework of adult development. Specifically, this study sought to understand relationships between beginning science teachers’ meaning-making systems and their abilities to reflect upon their circumstances, respond to constraints, and implement research-based science teaching practices. A discussion of the findings and the implications of these findings will be discussed below.

Discussion

Understanding and Implementing Research-based Science Teaching Practices

1. Teachers not possessing both a deep understanding of research-based science teaching practices and at least a 3/4 order of consciousness at the end of the MU-STEP are unlikely to implement research-based science teaching practices in the first years of teaching.

    Fletcher & Luft (2011) found that teachers’ beliefs tended to revert from research-based toward more traditional during the induction phase of teaching. This reversion often occurs without teachers awareness because they begin to see teaching and learning through the lens that their school promotes rather than the research-based lens promoted in their pre-service program (Featherstone, Gregorich, Niesz, & Young, 1995). This study supports the findings of Fletcher & Luft (2011) and Feathermore et al., (1995) as five of the ten participants (Taylor, Megan, Jamie, Grace, and Maddie) dropped in their understanding of research-based science teaching from the end of the MU-STEP to the
end of their first or second year of teaching. Just as in the Feathermore et al. (1995) study, most of these teachers were unaware their views had become more traditional.

Contrary to these prior studies, four participants in the study reported here (Kevin, Rachel, Greta, and Jennifer) maintained their understanding and use of research-based decision-making, and one participant (Hannah) improved her understanding. These five also tended to have the highest orders of consciousness, or more complex meaning making systems that allow them to deal with more demands and uncertainties in life (Kegan, 1994). Perhaps these teachers maintain or improved their understanding because they better handle the complexities of research-based science teaching decision-making and practice. As stated in the literature review, understanding the complexities of teaching requires teachers to see synergistic relationships amongst a number of variables and to be okay with a type of “deep uncertainty” (Mitchell, 2009, p. 3) in the face of a “relatively ill-structured, dynamic environment” (Leinhardt & Greeno, 1986, p. 75). Orders of consciousness, therefore, adds an explanatory framework lacking in the literature as to why some teachers “slip” in their understanding and implementation of research-based science teaching practices while others do not.

2. Effectively implementing research-based science teaching is possible, but not predominant, in the participants’ first years of science teaching.

Considering the demands of highly effective teaching, many researchers have questioned whether implementing research-based science teaching practices is possible in the first years of teaching (Meyer, 2004; Simmons et al., 1999). Haberman (1992) goes one step further by claiming, “there is no stage of human development less appropriate to the work of building self-esteem in others than the typical ages of late adolescence and
young adulthood” (p. 31). For this reason, he asserts, college-aged students are ill-suited for teacher preparation.

However, the study reported here challenges simplistic notions of age as a determinant of whether or not teachers will implement research-based decision-making and practices. Three of the ten participants’ implementation was a medium level, and two participants’ implementation was at a high level. While Kevin was in his thirties at the time of the study, the other high and medium implementers were in their early to mid-twenties. These results provide evidence that effective teacher decision-making and practice is possible in early adulthood, but that an individual’s order of consciousness may be an important salient factor in whether or not they do. Consistent with the findings of Herman, Clough, & Olson (2013) and Madsen & Olson (2005), a relationship appears to exist between orders of consciousness and teaching effectiveness. The results of this study do lend support to the claims of Haberman (1992), Meyer (2004), and Simmons et al. (1999) in the sense that participants in this study who had lower orders of consciousness did struggle to implement research-based science teaching practices. Specifically, teachers who had less than a 3/4 order of consciousness tended to implement research-based science teaching at low levels, whereas teachers at 3/4 or above tended to implement research-based science teaching at medium or high levels.

**Institutional Constraints**

3. **All teachers in this study struggled to acclimate to their new environment; however, the types of struggles teachers experienced related to their orders of consciousness.**
Studies of teacher development have made clear the transition from pre-service to in-service can be a difficult one. Studies note beginning teachers experience “reality shock” (Veenman, 1984, p.144) that foster survival mode thinking (Huberman, 1989) that leads to teaching practices at odds with well-established research regarding teaching and learning. The literature has attributed the difficulties of this transition to a reluctance to assume the classroom leadership role (Ryan, 1970), inadequate pre-service preparation (Feiman-Nemser, 1983), institutional constraints and lack of teacher autonomy (Brickhouse & Bodner, 1992; Ingersoll & May, 2011), lack of support beginning teachers, or personality factors (McDonald, 1982).

Regardless of the cause of induction troubles, how a teacher survives the first years of teaching has a lasting impact on the teacher he or she will become (Feiman-Nemser, 1983). The coping mechanisms and habits a teacher develops in the first years can result in a pattern that endures throughout a teacher’s career (McDonald & Elias, 1980). As reported in this study’s findings, how a teacher processes the struggles in the first years of teaching seems to be indicative of his or her implementation of research-based science teaching practices. Teachers below ¾ order of consciousness used external cues, accepted their constraints, or stayed in frustration that resulted in their being less likely to implement research-based science teaching practices than their ¾ or higher counterparts who actively resisted and negotiated constraints. Related to this, participants with a higher order of consciousness were typically more adept at identifying and successfully navigating constraints so they could create the space necessary to enact research-based science teaching practices.
4. **The school context matters, but it matters more for some than for others.**

For all participants, the school climate had an impact on how they viewed teaching and learning and implemented research-based decision-making and practices. However, participants with a third order consciousness or below seemed to be greatly impacted by the culture of the school, whereas those who had an order of consciousness higher than third order were less impacted. Specifically, participants with a third order or lower order of consciousness tended to accept their school culture or, at the very least, used external cues to make their decisions. Participants exhibiting 3/4 order of consciousness tended to feel frustrated by the school culture and felt stuck in that frustration, whereas those with 4/3 order of consciousness tended to actively resist or negotiate their constraints or sought out a supportive environment that aligned to research-based science teaching practices. Considering the transition from third to fourth order involves a movement towards self-authorship and feeling less constrained by one particular culture or ideology, these findings align well with Kegan’s (1982; 1994) orders of consciousness.

Berger (2002) used an analogy of a river to explain the relationship between context and orders of consciousness that seems to work well to also explain how teachers navigate the school culture. The culture of the school is like a river. If the current is flowing in a traditional direction and the teacher has a second or third order consciousness, he or she will likely be swept along with the current. If a teacher is transitioning between third and fourth order, he or she may be fighting against the current; however, the net result is often no gain or modest gains. A teacher that is close to or at fourth order will be able to navigate the waters to make some progress. If the
current is flowing in a research-based direction, third order teachers will also likely be swept along with the current. A teacher approaching fourth order consciousness will likely be able to swim faster and farther than he or she could have done otherwise. In summary, the school culture makes a difference in the success (or lack thereof) of all teachers in this study. However, a research-based school culture seems particularly important for teachers at a 3/4 order of consciousness or below because it can greatly influence the teacher they will become. Unfortunately, only one school out of ten in this study was a supportive environment.

5. **Advice new teachers receive regarding classroom management is a key school experience that washes out teacher education.**

Zeichner & Tabachnick (1981) noted that teacher education is often “washed-out” by school experiences. This study determined that a key cause of wash-out among study participants seemed to be related to advice they receive from mentors and administrators who advocate traditional quick-fix classroom management strategies such as putting students in rows, calling on students randomly, and using lecture and highly directive activities to maintain order. For example, Rachel’s mentor discussed his view of students in rows when he stated,

If you notice when you come in here, my desks are in rows. But if you go in the other two their desks are in squares. Well, they never put their desk in rows…So I want their focus up here…I think when I walk into an effective classroom because, let's be honest, these are junior or middle school kids, and when their tables are facing each other they're going to talk. This is just a classroom management thing I have practiced for years…You don't have near the discipline problems when people are looking forward and focused and not looking at each other (7, 5-6).
These strategies, often aimed at maintaining order and making students more compliant, do reduce the complexity of teaching, but they also promote thinking and action that are at odds with what research makes clear is crucial for promoting desired reforms in science education. Teachers who adopted the simplistic classroom management advice of others in their school tended to also drop in their understanding of research-based science teaching practices and tended to implement those practices at lower levels.

Importantly, the strategies stakeholders in the school suggest (e.g., students in rows) aren’t really the issue. The more subversive message teachers seem to be receiving is that student compliance, however achieved, is the hallmark of successful teaching. However, the ends sought by science education reform documents demands that students critically think, make decisions, and extensively interact with each other and their teacher. In short, effectively managing student behavior is crucial, but must be achieved using strategies and behaviors aligned with goals for science education.

A challenge for new teachers to enact research-based science teaching practices is that they will struggle with the complexities of such practices and can often unwittingly slip into survival mode, and these understandable struggles makes any support from their colleagues, mentors, and administration seem appealing. However, the types of supports new teachers seek and often adopt reflect their understandable craving to reduce the cognitive demands of teaching (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010) rather than working to synergistically implement research-based science teaching practices. Dewey (1929) warned against prescriptive, quick fix strategies when he wrote,
[Teachers] want very largely to find out how to do things with the maximum prospect of success. Put baldly, they want recipes” (p. 15). “There is a pressure for immediate results [of strategies in the classroom], for demonstration of a quick, short-time span of usefulness in school. There is a tendency to convert the results of statistical inquiries and laboratory experiments into directions and rules for the conduct of school administration and instruction” (p. 17-18). “School administration and instruction is a much more complex operation than was the one factor contained in the scientific result. The significance of one factor for educational practice can be determined only as it is balanced with many other factors (p.19).

Luft (2009) explained new teachers often seek out teachers in close proximity to them to survive the first year. However, the teacher next door is often not best suited to provide the type of mentorship required for new teachers to enact research-based science teaching practices. Goodlad (1990) made clear the issues of relying upon experienced teachers to mentor new teachers when he wrote,

Had there been recognition and understanding [of the array of circumstances impinging on teachers’ performance], surely reformers would not have prescribed once again that old bromide: Have today's teachers mentor tomorrow's. Schools and teachers are not very effective, said report after report. Yet according to conventional wisdom, the best way to ensure a competent teaching force is to place neophytes in those same schools with those same teachers. Surely we can come up with better remedies than this (p. xiii).

In order for teachers to avoid the potential wash-out from superficial advice, they need to have strategies for the difficult first years while also navigating the constraints they face.

**Implications**

**Navigating Constraints**

1. Code switching might be an important way new teachers can be “in” the culture of the school, but not “of” the culture of the school.
Code-switching—the alternating use of two or more “codes” within one conversational episode—was initially used by linguists in the 1950’s to explain how bilingual people navigated between two languages and two cultures (Auer, 2013). Since that time, code-switching has gained a broader definition to include the subtle ways an individual changes his or her intonation, word choice, and amplifies different aspects of his or her identity. For example, the way a person would talk to his or her friends is not the same way a person might talk to a child. This second definition of code-switching—situational language—has important implications for a beginning teacher working to navigate the culture of his or her new school.

As the cultures of most schools in this study were not in line with research-based science teaching practices, a beginning science teacher must learn the culture of the new school without becoming part of the culture. In this sense, the teacher may gain strategies to code-switch between the research-based science decision-making culture learned in their teacher education program and the often much more traditional culture of the public school. Just as the education literature points out expertise regarding how to teach a certain culture of children a certain concept (i.e., pedagogical content knowledge) (Shulman, 1986), so too must teachers learn how to enact research-based science teaching decisions in the school environment in which they work—a sort of pedagogical culture knowledge. Of course, prerequisite to code-switching, the beginning teacher must work to understand the culture of the school and the areas of agreement between that culture and research-based science teaching practices. Therefore, beginning science teachers should begin the induction phase by listening to stakeholders in the school to glean insight into their values and decision-making processes. In this sense, beginning teachers
should spend a great deal of time listening and carefully framing their contributions to the larger discussions.

A difficulty in achieving effective code-switching is the ability of the individual to hold his or her perspective, the perspective of others, and compare the similarities and differences between these perspectives simultaneously. Unfortunately, such a task would require a beginning teacher to be, at the very least, transitioning to fourth order consciousness. In this study, only three teachers had fourth order consciousness prevalent in their thinking and therefore would likely require the assistance of someone with a higher order to build up the capacity to code-switch and effectively navigate the school environment.

2. New teachers need to find like-minded individuals in order to find the support they need to implement research-based science teaching practices.

Research on induction has made clear that early career teachers need support; however, participants in the study reported here did not receive support aligned with reforms-based science teaching practices. In order for teachers to thrive in such environments, new teachers – particularly those exhibiting orders of consciousness lower than 3/4—need to seek out like-minded individuals to provide them the emotional support and advice aligned with reforms-based science teaching practices.

Herman, Olson, & Clough (In Press) and Ihrig (2014) found that teachers who have a high understanding of research-based pedagogy and a strong desire to teacher well who built support networks of like-minded individuals tended to practice research-based practices at higher levels than those with equal or lesser understanding who did not engage with a support network. Perhaps one reason for this trend is that teachers who are
closer to fourth order can help third order teachers process the school culture in ways which those third order teachers may not be able to do on their own. Further, communicating with like-minded individuals is a way to maintain the influence of a research-based culture in the face of a more traditional school setting.

### 3. Teachers can begin to change the classroom culture.

This study found the most ubiquitous perceived constraint teachers faced were the students in their classrooms. Students who cause classroom management issues or aren’t interested in learning can be frustrating and draining for any teacher. Kruse & Wilcox (2009) found one reason students may not engage in a research-based science teaching classroom is that students’ naïve views of knowing and learning, often referred to in the literature as epistemological beliefs (e.g., Hofer & Pintrich, 1997), act as an engagement barrier. However, Wilcox, Kruse, & Herman (2013), drawing from nature of science (e.g., Khishfe & Abd-El-Khalick, 2002) and conceptual change literature (e.g., Posner, Strike, Hewson, & Gertzog, 1982), found students’ inaccurate epistemological beliefs can be improved by having students occasionally reflect upon their learning experiences and explicitly drawing students’ attention to the pedagogical practices the teacher is using to achieve the learning. In this sense, students get a chance to “peek behind the curtain” and consider why research-based science teaching practices are used.

An implication of this research is that a new science teacher should actively work to change the epistemological beliefs of his or her students, which could potentially result in higher student engagement and a reduction in student behavior as a constraint to implementing research-based science teaching practices. Indeed, Kevin found some
success with this approach when he dealt with students’ frustrations by talking with them about it. He stated,

Today I spent the entire [day talking about why kids are frustrated]; we didn't get to any of [my plans] because there was frustration and we just kind of addressed that head on. Like here's why I do things, here's what I'm trying to do, here's the things you have learned. But I think, I'll have a discussion like that, I'm guessing, it's probably my second one this semester with them. I'll probably have two or three more before the end of it. For some [students, conversations like this] will help [alleviate frustration] (Kevin, 5, 31-32).

Rather than feeling frustrated with students, a teacher can work to begin by changing the classroom culture by helping students better understand teaching and learning. Importantly, these conversations are done at key moments when students have learned something significant or the teacher senses students’ frustrations. The purpose wouldn’t be to teach a science methods course, but rather to let students receive an invitation to “watch the teachers’ performance from the wings” (Lortie, 1975, p.62). Helping students gain a broader understanding of what learning entails and pedagogical practices that promote learning can potentially help reduce students’ resistance to research-based science teaching practices. While the MU-STEP did address the importance of helping students understand what learning entails and the kind of experiences that promote deep learning, even more attention is needed to help teachers address student misconceptions about learning so students are more open to research-based science teaching practices.
4. Teachers who are not in a supportive environment in their first or second year of teaching already experienced negative effects on their teaching practice.

In this study, teachers in their first or second year in an unsupportive school already suffered negative consequences of either conforming to traditional practices or feeling frustration at having to constantly resist institutional constraints. Teachers in these situations may find more success if they move to a different school. Teacher attrition literature (e.g., Buchanan, 2012; Feiman-Nemser, 2001; Ingersoll, 2001; Ingersoll & May, 2011; Patterson, Roehrig, & Luft, 2003) however, often cites problems due to teachers leaving the field or moving to new jobs. While moving schools has some negative consequences for continuity within a school, such a practice may ultimately result in the teacher implementing research-based science teaching practices because of the supportive environment.

Alternatively, teachers in a more neutral environment might find success in taking on leadership roles to push the school in a more supportive direction for research-based science teaching practices. Having a critical mass of like-minded individuals—such as in the case of Jennifer’s school—greatly impacted the professional development initiatives and quality of the education of the entire school. If a research-based teacher was in a position to help make hiring decisions, support new teachers, and work to retain like-minded individuals, the school culture might begin to change. Of course, changing the system would likely require a teacher to be transitioning towards or already at a fourth-order consciousness to enact a long-term strategy.
Recommendations

Science Teacher Education

- Science teacher education programs should be structured to increase in complexity throughout the program to reflect the complexities of effective science teaching. To achieve this, programs should include multiple methods courses to ensure teachers undergo conceptual change necessary to resist reverting back to more traditional approaches often advocated by the public schools. Even with multiple methods courses, as was present with the MU-STEP, teachers face many challenges that can cause their practices to regress. This raises substantial concerns for science teacher education programs that have a single science methods course, or a general “secondary” methods course. Much time is required for conceptual change, and contact time with a consistent teacher education program is necessary, but insufficient for lasting changes in teachers’ practices.

- Science teacher educators should take an active role in placing pre-service teachers with cooperating teachers that support, understand, and implement research-based science teaching practices. Seeing someone implementing effective practice can help pre-service teachers visualize—in a concrete way—what they are learning in methods courses looks like in real life and reduce barriers for pre-service teachers to understand and implement research-based science teaching practices themselves.

- Science teacher educators should explicitly address navigating institutional constraints. This might include, but may not be limited to, teaching students how to code-switch using scenarios derived from real teachers’ experiences, addressing the importance of being politically savvy and listening a great deal,
inviting current teachers in the induction years and more experienced teachers to
discuss classroom life, teaching the importance of finding like-minded individuals
in their schools and beyond their schools, encouraging pre-service teachers to get
involved in professional organizations for additional support.

- Teacher education programs must support teachers in developing collaborative
  relationships with cohort members. Without support, beginning science teachers,
  particularly those with a 3/4 consciousness or below, are more likely to develop
  understandings and practices to align with the culture of their schools.

- A formalized induction experience developed by the MU-STEP might help to
  mitigate the school cultures that don’t support research-based science teaching
  practices. Through this mentorship, students would have access to fourth-order
  peers to assist beginning teachers in dealing with the constraints of their schools.

School Administration and Education Leadership Programs

- When assigning mentors for new teachers, the administration should honestly and
  carefully consider the practices being enacted and select mentors based on which
  teachers are best aligned to research-based practices. This study found that in
  unsupportive environments, mentors who are also same-subject colleagues of the
  new teacher often created a power dynamic where the new teacher felt pressure to
  conform to traditional practices while concurrently dealing with the reality shock.
  Mentors that aren’t also teaching the same subject may provide new teachers a
  safer space to talk about the frustrations of the induction years, but these
  individuals, if chosen by a school administrator, may still have a powerful role
  over the new teacher which can stifle trust. However, in a supportive
environment, the mentor may assist the new teacher to quickly implement research-based science teaching practices. Therefore, in a supportive environment, the “science teacher next door” might be the person for the mentoring job. In summary, while mentoring decisions are and should be contextual, the decisions should be thoughtful and carefully consider issues of power and trust.

- One strategy to improve schools is to ensure all teachers teach the same content are doing the same activities and assessments. This strategy should be abandoned, as what seems to be happening in reality is a regression to the mean. A more effective approach seems to be working with teachers to develop professional development that made sense and to build an authentic professional learning community that has its foundations in trust, honesty, and a shared goal of teaching as effectively as possible for the students’ sakes.

- Professional development initiatives should support each other, be seen as necessary by a critical mass of teachers, and have solid foundations in research. While all schools in this study had professional development initiatives, the only school that was supportive of research-based science teaching practices approached professional development differently. The principal made clear that a number of conditions had to be satisfied to implement new initiatives. First, the principal of the school made clear that opinions needed to be backed by research in order to eschew intuitive, traditional practices. Second, before any professional development initiative was rolled out, teachers had a voice in the need for the initiative. An initiative was implemented only if a critical mass of teachers found
the initiative worthwhile. Finally, new initiatives had to be seen as interconnected to other initiatives rather than doing something new every year or two.

- One focus of education leadership programs is often to teach future principals how to be the educational leaders in the school. Just as teachers often work to differentiate for learners with different prior knowledge, so too must principals learn to differentiate for the teachers. Teachers with third order consciousness likely have different struggles with the teaching profession than those who are fourth order. For example, a third-order teacher might need more concrete strategies for improvement whereas a fourth-order teacher would likely benefit from being a part of the conversation of how to help all teachers improve their practice and develop strategies that have greater impacts on the system. Therefore, educational leadership programs should help future principals identify, support, and coach teachers with different meaning-making systems.

**Recommendations for Further Study**

- Does the MU-STEP improve pre-service teachers’ orders of consciousness? As the MU-STEP helps teachers develop a more complex understanding of science teaching, the experience with complexity might impact a pre-service teacher’s order of consciousness.

- Do graduate students implement research-based science teaching practices at greater levels than undergraduates? Haberman (1992) noted young adults may struggle with teacher education as they have not yet reached cognitive maturity. Kegan (1982,1994) found older adults are more likely to have higher orders of consciousness than younger adults. Based on this research, graduate students tend
to be older and therefore might have more success understanding and implementing research-based practices than undergraduates.

- What is the relationship between teachers leaving the field and their order of consciousness? Research has made clear teachers leave the field because of working conditions and institutional constraints (e.g., Ingersoll & May, 2011). Perhaps people of different orders of consciousness leave the field for different reasons, or perhaps people with different orders leave the field at different rates.

- What relationship exists between orders of consciousness, institutional constraints, and teaching practices over time? Conducting a longitudinal study that explores if the findings in this study hold as teachers move out the of induction years would help researchers understand if these findings only apply to the induction years or are maintained throughout the teachers’ careers.

- To what extent does support from like-minded individuals impact teachers’ ability to understand and implement research-based science teaching practices? This study found the culture of the school impacted a teacher’s ability to enact research-based science teaching practices. If teachers have support from like-minded individuals, they may be more likely to persist in the face of constraints.

- Does the order of consciousness of the teacher educator impact the structure and teaching of the teacher education program? The science education literature makes clear what is necessary for an effective science teacher education program (e.g., Clough, Olson, & Berg, 2009; Tillotson & Young, 2013); however, few studies deeply explore the teacher educator (Bruxvoort, 2005; Lee, 2010).
What other factors besides orders of consciousness influence teacher implementation of research-based science teaching practices? While this study found orders of consciousness and school culture impact teaching practices, other factors very likely also impact teachers’ practices. A few of these might include: perseverance (Beltman, Mansfield, & Price, 2011), grit (Duckworth, 2016), motivation (Pintrich, Marx, & Boyle, 1993), teacher value of student goals (Clough et al., 2009; Hunter & Markman, 2017; Penick & Harris, 2005), and personal values (Carr, 2006).

Conclusion

Traditional practices are often maintained through a cycle of practices that continue for generations of teachers. Students often believe teaching looks easy; however, they only see teaching through a limited vantage point (Lortie, 1975). Further, the types of teaching they often experience are traditional practices. As some students end up becoming teachers themselves, the views they have carried with them often frame their teacher education programs. Many teachers never experience cognitive dissonance regarding their teaching beliefs, and the cycle continues.

Highly effective science teacher education can change teachers’ beliefs about teaching. Such programs have the following: a methods instructor that models and supports pre-service teachers, a framework that permeates throughout the program, a strong curriculum that spans multiple semesters, and are support through effective field placements (Darling-Hammond, 2006a; Tillotson & Young, 2013).

Despite effective science teacher education, science teachers often find themselves working in the same traditional environments they experienced as students.
When science teachers work to enact research-based science teaching practices, they are often met with institutional constraints, which are often exacerbated by the traditional culture of the schools. As a result, effective science teaching practices are often washed out (Zeichner & Tabachnick, 1981).

At the core, this study sought to find out why some science teachers persist with effective science teaching practices and some science teachers don’t. While a great deal of research has focused on science teacher beliefs and understandings (e.g., Fletcher & Luft, 2011) or what meaning teachers make, this study found how teachers make meaning seems to more adequately explain why some teachers persist. More specifically, this study’s theoretical framework—order of consciousness—provides a basis to explain how people handle complexity as their mind develops throughout their lives. The ability to handle more complexity is a critical, and often overlooked, factor impacting teachers’ abilities to understand and implement research-based science teaching practices.

Navigating the school culture is a necessary skill to avoid and minimize institutional constraints that often impact teachers’ abilities to teach effectively. Effectively navigating a school culture requires teachers to consider multiple points of view and to communicate their own point of view in an appropriate way. This, too, requires teachers to have an order of consciousness high enough to adequately navigate the school culture. This study suggests that greater amounts of support from like-minded and more knowledgeable others can assist teachers during the difficult early years of teaching.
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APPENDIX A: INFORMED CONSENT DOCUMENTS

Teacher Letter

Greetings,

My name is Jesse Wilcox and I am a Ph.D. student at Iowa State University working with Drs. Michael Clough and Joanne Olson. We hope this greeting finds you well and that you have fond memories of the time you spent in the Midwestern University Secondary Science Teacher Education Program (MU-STEP).

Because you completed the MU-STEP within the last two years, we are inviting you to participate in a study we are conducting to investigate how new teachers acclimate to the teaching profession. Understanding MU-STEP graduates’ practices along with their successes and challenges will permit the development of recommendations for improving MU’s secondary science teacher education program and science teacher education programs more widely.

If you agree to participate in this important study of our program, you may decide to take part in as many of the following as you wish during the semester long study:

- Permit us to observe you teaching at least three science classes.
- Permit us to conduct four interviews. Three of the interviews will be relatively short (less than 30 minutes) and will, if possible, occur during the same day as our observations. The fourth interview will occur at the end of the semester and will take approximately an hour.
- Provide us artifacts (e.g. course syllabus, lesson plans, assignments, readings, exams, etc.) that will help us better understand your teaching practices, decision-making, and teaching experience.
- Permit us to collect your correspondences with MU-STEP faculty.
- Permit us to review your archived MAT MU-STEP Exit Interview.
- Permit us to review artifacts from your MU-STEP coursework (e.g. research-based framework paper and oral defense, self-evaluation of teaching behaviors assignments, and lesson plans).

This study is completely voluntary and you can elect to skip portions of the study or withdraw from any or all of the study at any time without penalty. Teachers who elect to participate in the study will, unfortunately, not be compensated for their time spent participating. However, future humankind may benefit from this study through the improvement of science teacher preparation programs.

There are no foreseeable risks at this time from participating in the study. Pseudonyms will be used so participants and their schools will not be identified. If you have any questions, comments, or concerns with this study, they can be directed to:

Jesse Wilcox, jlwilcox@iastate.edu, (515)450-2759
Dr. Michael Clough, mclough@iastate.edu, (515)294-1430, or
Dr. Joanne Olson, jkolson@iastate.edu, (515) 294-3315.

If you choose to participate in this study, please carefully read the enclosed informed consent form. If you decide to participate, please sign and return the consent form to me as soon as possible. Additionally, please let me know who I should contact in your school district to obtain approval for the study. Feel free to contact Dr. Clough, Dr. Olson, or me with any questions you may have about the study. Thank you for your time and consideration!

Sincerely,

Jesse Wilcox, Ph.D. Student
**Administrator Letter**

Greetings,

My name is Jesse Wilcox and I am a Ph.D. student at Iowa State University working with Drs. Michael Clough and Joanne Olson. XXXXXXX, a teacher in your district, has shown interest in participating in a research study I will be conducting. This research will follow graduates of the Midwestern University Secondary Science Teacher Education Program (MU-STEP) to determine how these new teachers acclimate to the teaching profession. Understanding the practices of these beginning teachers along with their successes and challenges will permit the development of recommendations for improving the program at MU-STEP and science teacher education programs more widely.

This study has been approved by the Iowa State University [IRB ID: 13-380], and I am seeking district approval to include XXXXXX in my study. If the district approves XXXXXX to participate in this important study of the MU-STEP program, he/she may decide to take part in as many of the following as he/she wishes:

- Permit us to observe at least three science class.
- Permit us to conduct four interviews. Three of the interviews will be relatively short (less than 30 minutes) and will, if possible, occur during the same day as our observations. The fourth interview will occur at the end of the semester and will take approximately an hour.
- Provide us artifacts (e.g. course syllabus, lesson plans, assignments, readings, exams, etc.) that will help us better understand XXXXX teaching practices and decision-making.
- Additionally, we are seeking permission to conduct an interview (lasting approximately 30 minutes) with XXXXXX principal and/or mentor teacher regarding their perceptions of the pedagogical understandings and practices, successes and challenges of the MU-STEP teacher.

This study is completely voluntary and XXXXXXX and the principal/mentor teacher can elect to skip portions of the study or withdraw from any or all portions of the study at any time. Teachers and administrators who elect to participate in the study will not be compensated for their time participating. However, this study may help improve science teacher preparation programs.

While XXXXXXX participation in this study may include classroom observations, students will not be a part of this study. Pseudonyms for schools, school districts, communities and study participants will be used so participants’ and school district’s identifying information will be kept confidential. If you have any questions, comments, or concerns with this study, they can be directed to: Jesse Wilcox, jlwilcox@iastate.edu, (515)450-2759; Dr. Michael Clough, mclough@iastate.edu, (515)294-1430; or Dr. Joanne Olson, jkolson@iastate.edu, (515) 294-3315.

If you will permit XXXXXXX and his/her principal and/or mentor teacher to participate in this study, please sign complete the information below and return this letter in the self-addressed envelope provided.

Thank you for your time and consideration!
Jesse Wilcox, Iowa State University Ph.D. student

**CONFIRMATION:**

I have read the previous statements in this letter and give my consent for XXXXXXXX to participate in the educational research described above.

Signature: ___________________________ Print: ___________________________
Name: _______________________________
Position: ____________________________ School: __________________________
Teacher Consent Form

CONSENT FORM FOR: UNDERSTANDING THE PRACTICES AND EXPERIENCES OF NEW SCIENCE TEACHERS

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Who is conducting this study?
This study is being conducted by:
Jesse Wilcox, School of Education, Iowa State University
Dr. Michael Clough, School of Education, Iowa State University
Dr. Joanne Olson, School of Education, Iowa State University

Why am I invited to participate in this study?
You are being asked to take part in this study because you graduated from the Midwestern University Science Teacher Education Program between 2011 and 2013 and are a first or second year science teacher.

What is the purpose of this study?
The purpose of this study is to investigate how recent graduates of the Midwestern University Secondary Science Teacher Education Program acclimate to the teaching profession. Understanding MU-STEP graduates’ practices along with their successes and challenges will permit the development of recommendations for improving MU’s secondary science teacher education program and science teacher education programs more widely.

What will I be asked to do?
If you agree to participate, you will be asked to:
• Permit us to observe you teaching at least three science classes.
• Permit us to conduct four audio recorded interviews. Three of the interviews will be relatively short and will, if possible, occur during the same day as our observations. The fourth interview will occur at the end of the semester and will take approximately an hour.
• Provide artifacts (e.g. course syllabus, lesson plans, assignments, readings, exams, etc.) that will help us better understand your teaching practices, decision-making, and teaching experiences.
• Permit us to collect your correspondences with MU-STEP faculty.
• Permit us to review your archived MU-STEP MAT Exit Interview.
• Permit us to review artifacts from your MU-STEP coursework (e.g. research-based framework paper and oral defense, self-evaluation of teaching behaviors assignments, and lesson plans).

What are the possible risks and benefits of my participation?
Risks—District leaders and administrators/mentor teachers will be aware of your participation in this study and therefore could potentially figure out your identity from published works. Further, interviews with the researcher could potentially be overheard by others.

The following measures will also be taken to minimize these risks: 1) you will be interviewed in a private setting, 2) pseudonyms and identification numbers will be used so your identity and your school’s identity will not be disclosed, 3) you can elect to withdraw from any or all portions of the study (including interview questions) at any time without penalty, 4) data will be kept confidential and seen only by the participant and the researchers, 5) results from this study will include pseudonyms for the teacher, the teacher’s school, and the MU-STEP program, 6) the specific year you graduated from the MU-STEP will not be disclosed.

You can choose to refrain from any or all parts of the study at any time without penalty.
Benefits—You may not receive any direct benefit from taking part in this study. We hope that this research will benefit society by helping to inform the instructional practices of teacher education programs.

**How will the information I provide be used?**
The information you provide will be used to help us understand: MU-STEP teachers’ pedagogical practices, their successes and challenges while teaching, and how they are acclimating to the school. This information will be used to develop recommendations for improving MU’s secondary science teacher education program and science teacher education programs more widely.

**What measures will be taken to ensure the confidentiality of the data or to protect my privacy?**
Records identifying participants will be kept confidential to the extent allowed by applicable laws and regulations. Records will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the ISU Institutional Review Board (a committee that reviews and approves research studies with human subjects) may inspect and/or copy your records for quality assurance and analysis. These records may contain private information.

To ensure confidentiality to the extent allowed by law, the following measures will be taken:
Participants’ names and school information will be replaced with pseudonyms on all documents. Electronic files will be secured on a password protected laptop and paper files will be secured in a locked file cabinet. Only the researchers will have access to information collected as a part of this study. After seven years, all files will be destroyed. If the results are published, we will not share your name or the name of your district. However, those familiar with the district and your position within the district may be able to figure out your identity. Because your confidentiality cannot be fully protected, you should be mindful of what you choose to share with the researcher.

**Will I incur any costs from participating or will I be compensated?**
You will not incur any costs from participating in this study. You will not be compensated for participating in this study.

**What are my rights as a human research participant?**
Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer. Your choice of whether or not to participate will have no impact on you in anyway.

**Whom can I call if I have questions or problems?**
You are encouraged to ask questions at any time during this study.
- For further information about the study contact: Jesse Wilcox at 515-450-2759 or jwilcox.23@gmail.com, Dr. Michael Clough at 515-294-1430 or mclough@iastate.edu, or Dr. Joanne Olson at 515-294-3315 or jolson@iastate.edu.
- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

**Consent and Authorization Provisions**
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed) __________________________________________

__________________________________________ (Participant’s Signature)       (Date)
Administrator Consent Form

CONSENT FORM FOR: UNDERSTANDING THE PRACTICES AND EXPERIENCES OF NEW SCIENCE TEACHERS

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Who is conducting this study?
This study is being conducted by:
Jesse Wilcox, School of Education, Iowa State University
Dr. Michael Clough, School of Education, Iowa State University
Dr. Joanne Olson, School of Education, Iowa State University

Why am I invited to participate in this study?
You are being asked to take part in this study because you work with a recent graduate of the Midwestern University Secondary Science Teacher Education Program.

What is the purpose of this study?
The purpose of this study is to investigate how recent graduates of the Midwestern University Secondary Science Teacher Education Program acclimate to the teaching profession. Understanding our graduates’ practices along with their successes and challenges will permit the development of recommendations for improving MU’s secondary science teacher education program and science teacher education programs more widely.

What will I be asked to do?
If you agree to participate, you will be asked to complete an audio recorded interview (lasting approximately 30 minutes) regarding your perceptions of the pedagogical understandings and practices, successes and challenges of the MU-STEP teacher.

What are the possible risks and benefits of my participation?
Risks—While any information you provide in the interview will be kept confidential, the MU-STEP teacher will be aware of your participation in the study. To reduce the risk of your identity being known, your name, school, and any other identifying information will be replaced with pseudonyms. Further, you can choose to refrain from any or all parts of the study at any time without penalty, which includes any questions asked during the interview.

Benefits—You may not receive any direct benefit from taking part in this study. We hope that this research will benefit society by helping to inform the instructional practices of teacher education programs.

How will the information I provide be used?
The information you provide will be used to help us understand: MU-STEP teachers’ pedagogical practices, their successes and challenges while teaching, and how they are acclimating to the school. This information will be used to develop recommendations for improving MU’s secondary science teacher education program and science teacher education programs more widely.

What measures will be taken to ensure the confidentiality of the data or to protect my privacy?
Records identifying participants will be kept confidential to the extent allowed by applicable laws and regulations. Records will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the ISU Institutional Review Board (a committee that reviews and approves research studies with human subjects) may inspect and/or copy your records for quality assurance and analysis. These records may contain any private information that you provide.
To ensure confidentiality to the extent allowed by law, the following measures will be taken:
Participants’ names and school information will be replaced with pseudonyms on all documents. Electronic files will be secured on a password protected laptop and paper files will be secured in a locked file cabinet. Only the researchers will have access to information collected as a part of this study. After seven years, all files will be destroyed. However, those familiar with the district and your position within the district may be able to figure out your identity. Because your confidentiality cannot be fully protected, you should be mindful of what you choose to share with the researcher.

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You will not incur any costs from participating in this study. You will not be compensated for participating in this study.

**What are my rights as a human research participant?**
Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer. Your choice of whether or not to participate will have no impact on you in anyway.

**Whom can I call if I have questions or problems?**
You are encouraged to ask questions at any time during this study.
- For further information about the study contact: Jesse Wilcox at 515-450-2759 or jwilcox.23@gmail.com, Dr. Michael Clough at 515-294-1430 or mclough@iastate.edu, or Dr. Joanne Olson at 515-294-3315 or jkolson@iastate.edu.
- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

**Consent and Authorization Provisions**
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed) ________________________________

(Participant’s Signature) ________________________________ (Date)
APPENDIX B: SEMI-STRUCTURED INTERVIEWS

Post-MAT Program Interview
1. The MAT program follows a cohort model; describe your experiences as a cohort. How well did you feel part of the group?
   a. Who did you work with?
   b. When did that start to happen?
2. Tell me about your experiences with your cooperating teachers.
   a. What was the impact of your cooperating teachers on your understanding of effective science instruction?
3. What were the pros and cons of having a methods course concurrent with student teaching?
4. What are your concerns about teaching as you enter the profession?
5. Here is a visual of the entire MAT program:
   a. What was most beneficial in your development?
   b. What was the least beneficial in your development?
6. What role, if any, did the course “Introduction to the Purposes and Complexities of Science Teaching” play in preparing you for the MU-STEP?
   a. What specific components of the course, if any, were beneficial?
      i. For what reasons were these components meaningful?
   b. What did you take away from this course?
7. What role, if any, did the course “Secondary Science Methods I” play in preparing you to teach science?
   a. What specific components of the course, if any, were beneficial?
      i. For what reasons were these components meaningful?
   b. What did you take away from this course?
8. To what extent, if any, did the course “Nature of Science” help you understand the nature of science?
   a. What impact, if any, did the course “Nature of Science” have on your understanding of how to effectively teach science?
   b. What specific components of the course, if any, were beneficial?
      i. For what reasons were these components meaningful?
   c. What did you take away from this course?
9. What role, if any, did the course “Secondary Science Methods II” play in preparing you to teach science?
   a. What specific components of the course, if any, were beneficial?
      i. For what reasons were these components meaningful?
      ii. If SATIC analyses were not discussed for either Methods I or II, then ask, “For what reasons did you not bring up SATIC analyses?”
   b. What did you take away from this course?
10. What role, if any, did the course “Advanced Pedagogy” play in preparing you to teach science?
    a. What specific components of the course, if any, were beneficial?
       i. For what reasons were these components meaningful?
    b. What did you take away from this course?
    c. What was it like to get your picture and paragraph from your first methods course back during your last methods course?
11. Many policymakers think we should bypass teacher education courses, considering teacher education as irrelevant after having a college degree and a job. How would you respond to a policymaker with this point of view?
12. The MU STEP emphasized the development and implementation of a research-based framework for teaching science. How do you plan to use this framework, if you plan to use it at all, to inform your science teaching?
    a. What parts of the RBF do you think were the most significant in preparing you to teach science?
    b. What aspects of your teaching, if any, do you think will not be informed by your RBF?
    c. To what extent, if any, was the oral defense helpful?
    d. To what extent, if any, was the oral defense a hindrance?
    e. What effect, if any, did the oral defenses have on the effort you put into your understanding of effective science instruction?
13. What assignments or experiences from your MU-STEP (this includes all your education courses) do you feel most prepared you to teach effectively?
   a. For what reasons?
   b. How well prepared do you feel you are for your first teaching position?
      i. What do you feel most prepared to do effectively?
      ii. What concerns you most about teaching?
14. What else would you like me to know about your experiences with the MU-STEP?

Lesson Reflection Questions: Used after each observation
1. What were you hoping students would gain from class today?
2. To what extent was the lesson different than what you had planned?
3. What has this class been doing in science recently?
   a. What unit are you working on?
4. What will be the class be doing next?

Interview 1: Focused History and Teacher Belief Interview
Context Statement for Interview
Thank you for taking the time for this interview today.
There are no right or wrong answers to the interview questions I am about to ask you. I am interested in your personal views concerning each of the topics. Your responses to these questions will be kept confidential. In addition, some of the questions are similar to each other, so you may feel a question is asked twice. If you want to skip anything, let me know.

What questions do you have before we begin?

Part 1: Background of Teacher:
1. Tell me a little about your educational background.
2. Why did you decide to become a teacher?
3. How would you describe yourself?

Part 2: Views on Students/ Teaching/ and Education of Teacher
Teaching
1. How do you describe your role as a teacher?
2. What do you feel are the greatest influences on your decision making as a teacher?
   a. Why do you think ________ influences you?
   b. What factors did you consider when planning this lesson?
   c. What factors did you consider when teaching this lesson?
   d. How do you decide what to teach or what not to teach?
      i. How do you decide when to move on to a new topic in your class?
      ii. How do you decide the order of the content you’re teaching your students? Why?
Student Learning
3. How do you know when student learning is occurring in your classroom?
   a. How do you know when your students understand?
   b. How do you attempt to maximize student learning in your classroom?

MU-STEP Program Influence on Teaching
4. How has your teaching experience compared with what you learned in your science methods courses?

Part 3: Institutional Constraints
1. What has your relationship with your colleagues been like?
   a. To what extent, if any, have the relationships between you and other teachers influenced your views and actions?
2. What has your relationship with your administration been like?
   a. To what extent, if any, has the relationships between you and your administrators influenced your views and actions?
3. To what extent, if any, have the relationships between you and your students influenced your views and actions?
4. What have your interactions with parents been like thus far?
5. What can you tell me about any mentoring you might have received? How has this experience influenced your views and actions in any way?
6. How would you characterize the District’s philosophy toward science education?
7. How much freedom do you have to teach the way you want to?
8. To what extent are you expected to teach like your colleagues?
   a. How do you deal with that?

Interview 2: Subject-Object Interview Protocol
1. The researcher started by stating the purpose of the interview was to understand more about how the participant is acclimating to the school by exploring the participant’s feelings and how they were making sense out of their experiences as a teacher.
2. The researcher described the interview and stated that the participant does not have to answer anything that would make him/her uncomfortable.
3. The participant was handed a number of index cards with words that describe emotions. The interviewer asked participants to select around three cards from the “positive” pile and three cards from the “negative” pile that stuck out to the participant. Participants were then given time to read and select the cards. If a participant had a hard time choosing, the researcher would state the participant is not limited to three from each.

<table>
<thead>
<tr>
<th>“Positive” Emotion Cards</th>
<th>“Negative” Emotion Cards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fulfilled</td>
<td>Frustrated</td>
</tr>
<tr>
<td>Accomplished</td>
<td>Anxious/ Nervous</td>
</tr>
<tr>
<td>Confident</td>
<td>Angry</td>
</tr>
<tr>
<td>Positive</td>
<td>Torn</td>
</tr>
<tr>
<td>Successful</td>
<td>Unappreciated</td>
</tr>
<tr>
<td>Happy</td>
<td>Stressed</td>
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<tr>
<td>Compassionate</td>
<td>Inadequate</td>
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<tr>
<td>Needed</td>
<td>Isolated</td>
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<tr>
<td>Proud</td>
<td>Overwhelmed</td>
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<tr>
<td>Influential</td>
<td>Unsure</td>
</tr>
<tr>
<td>Uplifted</td>
<td>Sad</td>
</tr>
<tr>
<td>Capable</td>
<td>Trapped</td>
</tr>
</tbody>
</table>

4. The researcher asked participants to describe why they selected each card (e.g., “Why did you select____?” “When do you feel _____?”). When the participant was speaking, the researcher looked for key aspects of the participants’ response (e.g., responsibility, conflict, perspective-taking, assumptions) and then asked probing questions (e.g., “What did you mean by ____?”, “Why do you think that made you feel _____?”) to elicit more dialogue surrounding subject/object boundaries.

Further information regarding the Subject-Object Interview Protocol can be found in: *A Guide to the Subject-Object Interview: Its administration and interpretation* (Lahey, Souvaine, Kegan, Goodman, & Felix, 2011).

Interview 3: Self-Reflection Interview
1. How do you determine if the lessons you teacher are effective or not?
2. How do you determine if you are effective teacher?
3. How does your current practice compare to where you want to be?
   a. What is causing you from not reaching the ideal yet?
4. What do you perceive are your strengths and weaknesses in your teaching practices?
   a. How do you deal with areas of weakness?
      i. What kinds of things are you doing to get yourself there?
Interview 4: Final Interview

Part 1: Views on Students/ Teaching/ and Education of Teacher

General Questions
1. When you’re away from the classroom and you think about teaching, what do you find yourself thinking about most?
2. What do you worry about most when it comes to teaching?

Student Learning
3. How do you attempt to maximize student learning in your classroom?
   a. How do you know when student learning is occurring in your classroom?

Teaching
4. How do you describe an effective science teacher?
5. What do you feel are the greatest influences on your decision making as a teacher?
   a. Why do you think ______ influences you?
   b. What factors do you consider when planning a lesson?
   c. What factors do you consider when teaching a lesson?

MU-STEP Program
6. Tell me about the TEP. What did you think of the MAT when you were in it? How has your thinking changed now that you are a teacher?
7. In your view, what do you think the MU-STEP program attempts to teach teachers?
8. Venn Diagrams
   a. I would like you to draw a Venn Diagram to show how much overlap you believe you have between what the MU-STEP promotes and what you believe about effective teaching.
      i. What areas do you believe overlap?
      ii. What areas do you believe don’t overlap?
      iii. How does your MAT experience influence our teaching practice?
   b. I would like you to draw another Venn Diagram to show how much overlap you believe you have been the culture of your school and what you believe about effective teaching.
      i. What areas do you believe overlap?
      ii. What areas do you believe don’t overlap?
   c. How much overlap is there between your school and MAT?
9. When I think about the MAT, I sometimes think about ______________. Why do you think that didn’t come to the forefront of your mind?
10. How would you describe your student teaching experience? In what ways was that experience helpful or not helpful in your development as a teacher?

Part 2: Scenarios to Understand Teacher Decision-making

For the next few questions, I am going to provide you with a few scenarios.
1. Chris is a new teacher at a local high school. During one of the department meetings before the school year begins, her department head (Mrs. Jones), announces that a new textbook just came in. Mrs. Jones continues to explain that the books will make teaching easier because teachers won’t have to piece together a curriculum to meet state standards.

   Chris looks around the room. Many teachers are speaking excitedly to one another, but some teachers are beginning to protest about their autonomy and the curricula they developed for themselves. The department head tells them that the vast majority of instructional time must be devoted to work out of the textbooks, which includes assessments.

   Chris picks up her new book and notices it is a coherent curriculum, but is she is worried about how quickly it moves and that the focus seems to be on facts and terms instead of concepts and all of the assessments are multiple choice. She sees some value Mrs. Jones knocks on Chris’ door and tells her
that her first two weeks of lesson plans (textbook pages) are due tomorrow. If you were in Chris’s situation, what would you do next?
• Where is Chris torn?
• What strategies does she have at her disposal that might help her deal with this situation?
• What is most important about this conflict?
• What is the hardest part?

2. In many schools, principals expect teachers to list the objectives for the lesson on the board for students to see. Yet, with inquiry activities you may not want students to know the exact objective upfront. If your principal expected objectives to be listed on the board and was coming to observe your class during an inquiry activity, how would you go about dealing with this issue?

3. If a parent of one of your students approaches you and says, “My daughter is complaining that when she asks you questions, you respond to her by asking questions. She’s frustrated because she wants you to just answer the question. Why do you do this?” How would you respond?

Part 3: Institutional Constraints

1. What institutional constraints, if any, have you faced since you started?
   a. How have you dealt with ______________?

2. What has your relationship with ___________ been like?
   • colleagues
   • administration
   • students
   • mentor
   • parents

3. In what ways have ___________ been constraining?

Interview Protocol for Administrator and/or Mentor Teacher

Context Statement for Interview
Thank you for taking the time for this interview today. There are no right or wrong answers to the interview questions I am about to ask you. I am interested in your personal views concerning each of the topics. Your responses to these questions will be kept confidential. In addition, some of the questions are similar to each other, so you may feel a question is asked twice. If you want to skip anything, let me know.

What questions do you have before we begin?

1. What professional development initiatives is your school building/district implementing this year?
2. How do you see the professional development impacting classroom instruction?
3. When you observe a teacher, what types of things do you look for?
4. How would you describe what makes a teacher effective?
5. What would your ideal science class look like?
6. How well do you think XXXXXX implements effective science teaching?
7. What do you see are the strengths and areas of improvement for XXXX?
8. What suggestions or advice would you have for teacher education programs?
APPENDIX C: LOCAL SYSTEMIC CHANGE
CLASSROOM OBSERVATION PROTOCOL (LSC-COP)

I. Design

<table>
<thead>
<tr>
<th>D/K</th>
<th>N/A</th>
</tr>
</thead>
</table>

**A. Ratings of Key Indicators**

1. The design of the lesson incorporated tasks, roles, and interactions consistent with investigative mathematics/science.
   - 1 2 3 4 5 6 7
2. The design of the lesson reflected careful planning and organization.
   - 1 2 3 4 5 6 7
3. The instructional strategies and activities used in this lesson reflected attention to students’ experience, preparedness, and/or learning [theories].
   - 1 2 3 4 5 6 7
4. The resources available in this lesson contributed to accomplishing the purposes of the instruction.
   - 1 2 3 4 5 6 7
5. The instructional strategies and activities reflected attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language-appropriate strategies/materials).
   - 1 2 3 4 5 6 7
6. The design of the lesson encouraged a collaborative approach to learning.
   - 1 2 3 4 5 6 7
7. Adequate time and structure were provided for "sense-making."
   - 1 2 3 4 5 6 7
8. Adequate time and structure were provided for wrap-up.
   - 1 2 3 4 5 6 7
9. Formal assessments of students were consistent with investigative mathematics/science.
   - 1 2 3 4 5 6 7
10. Design for future instruction takes into account what transpired in the lesson.
    - 1 2 3 4 5 6 7
11. _____________________
    - 1 2 3 4 5 6 7

**B. Synthesis Rating**

| 1 | 2 | 3 | 4 | 5 |

Implementation of the lesson is not all reflective of best practice in mathematics/science education.

**C. Supporting Evidence for Synthesis Rating**

II. Implementation

<table>
<thead>
<tr>
<th>D/K</th>
<th>N/A</th>
</tr>
</thead>
</table>

**A. Ratings of Key Indicators**

1. The instruction was consistent with the underlying approach of instructional materials designated for use by the LSC.
   - 1 2 3 4 5 6 7
2. The instructional strategies were consistent with investigative mathematics/science.
   - 1 2 3 4 5 6 7
3. The teacher appeared confident in his/her ability to teach mathematics/science.
   - 1 2 3 4 5 6 7
4. The teacher’s classroom management style/strategies enhanced the quality of the lesson.
   - 1 2 3 4 5 6 7
5. The pace of the lesson was appropriate for the development levels/needs of the students and the purposes of the lesson.
   - 1 2 3 4 5 6 7
6. The teacher was able to “read” the students’ level of understanding and adjusted instruction accordingly.
   - 1 2 3 4 5 6 7
7. The teacher's questioning strategies were likely to enhance the development of student conceptual understand/problem solving (e.g., emphasized higher order questions, appropriately used “wait-time,” identified prior conceptions and misconceptions).
   - 1 2 3 4 5 6 7
8. The lesson was modified as needed based on teacher questioning or other student assessments.
   - 1 2 3 4 5 6 7
9. _____________________
   - 1 2 3 4 5 6 7

**B. Synthesis Rating**

| 1 | 2 | 3 | 4 | 5 |

Implementation of the lesson is not all reflective of best practice in mathematics/science education.

**C. Supporting Evidence for Synthesis Rating**
III. Mathematics/Science Content

D/K N/A

A. Ratings of Key Indicators

1. The mathematics/science content was significant and worthwhile.

2. The mathematics/science content was appropriate for the developmental levels of the students in this class.

3. Students were intellectually engaged with important ideas relevant to the focus of the lesson.

4. Teacher-provided content information was accurate.

5. The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).

6. Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigative analysis, and/or proof/justification.

7. Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) were included when it was important to do so.

8. Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.

9. The degree of “sense-making” of mathematics/science content within this lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.

B. Synthesis Rating

1 2 3 4 5

Implementation of the lesson is not all reflective of best practice in mathematics/science education

Implementation of the lesson is highly reflective of best practice in mathematics/science education

C. Supporting Evidence for Synthesis Rating

IV. Classroom Culture

D/K N/A

A. Ratings of Key Indicators

1. Active participation of all was encouraged and valued.

2. There was a climate of respect for students’ ideas, questions, and contributions.

3. Interactions reflected collegial working relationships among students (e.g., students worked together, talked with each other about the lesson).

4. Interactions reflected collaborative working relationships between teacher and students.

5. The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions.

6. Intellectual rigor, constructive criticism, and challenging of ideas were evident.

B. Synthesis Rating

1 2 3 4 5

Implementation of the lesson is not all reflective of best practice in mathematics/science education

Implementation of the lesson is highly reflective of best practice in mathematics/science education

C. Supporting Evidence for Synthesis Rating

A. Likely Impact of Instruction on Students’ Understanding of Mathematics/Science

While the impact of a single lesson may well be limited in scope, it is important to judge whether the lesson is likely to help move students in the desired direction. For this series of ratings, consider all available information (i.e., your previous ratings of design, implementation, content, and classroom culture, and the pre-and post-observation interviews with the teacher) as you assess the likely impact of this lesson. Feel free to elaborate on ratings with comments in the space provided.
Select the response that best describes your overall assessment of the likely effect of this lesson in each of the following areas.

<table>
<thead>
<tr>
<th></th>
<th>Effect:</th>
<th>Negative</th>
<th>Mixed/Neutral</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation.</td>
<td>D/K N/A</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
<td></td>
</tr>
<tr>
<td>2. Students' understanding of important mathematics/science concepts.</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
<td></td>
<td></td>
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<tr>
<td>3. Students' capacity to carry out their own inquiries.</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
<td></td>
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</tr>
<tr>
<td>4. Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations.</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
<td></td>
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<tr>
<td>5. Students' self-confidence in doing mathematics/science.</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
<td></td>
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<tr>
<td>6. Students' interest in and/or appreciation for the discipline.</td>
<td>1 2 3 4 5</td>
<td>6 7</td>
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</tbody>
</table>

**B. Capsule Description of the Quality of the Lesson**

In this final rating of the lesson, consider all available information about the lesson, its context and purpose, and your own judgment of the relative importance of the ratings you have made. Select the capsule description that best characterizes the lesson you observed. Keep in mind that this rating is not intended to be an average of all the previous ratings, but should encapsulate your overall assessment of the quality and likely impact of the lesson. Please provide a brief rationale for your final capsule description of the lesson in the space provided.

**Level 1: Ineffective Instruction**

There is little or no evidence of student thinking or engagement with important ideas of mathematics/science. Instruction is highly unlikely to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science. Lesson was characterized by either (select one below):

- **Passive "Learning"**
  - Instruction is pedantic and uninspiring. Students are passive recipients of information from the teacher or textbook; material is presented in a way that is inaccessible to many of the students.
- **Activity for Activity's Sake**
  - Students are involved in hands-on activities or other individual or group work, but it appears to be activity for activity's sake. Lesson lacks a clear sense of purpose and/or a clear link to conceptual development.

**Level 2: Elements of Effective Instruction**

Instruction contains some elements of effective practice, but there are serious problems in the design, implementation, content, and/or appropriateness for many students in the class. For example, the content may lack importance and/or appropriateness; instruction may not successfully address the difficulties that many students are experiencing, etc. Overall, the lesson is very limited in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.

**Levels 3-5: Beginning Stages of Effective Instruction (Select one below.)**

- **Low 3**
- **Solid 4**
- **High 5**

Instruction is purposeful and characterized by quite a few elements of effective practice. Students are, at times, engaged in meaningful work, but there are weaknesses, ranging from substantial to fairly minor, in the design, implementation, or content of instruction. For example, the teacher may short-circuit a planned exploration by telling students what they "should have found"; instruction may not adequately address the needs of a number of students; or the classroom culture may limit the accessibility or effectiveness of the lesson. Overall, the lesson is somewhat limited in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.

**Level 6: Accomplished, Effective Instruction**

Instruction is purposeful and engaging for most students. Students actively participate in meaningful work (e.g., investigations, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and the teacher implements it well, but adaptation of content or pedagogy in response to student needs and interests is limited. Instruction is quite likely to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

**Level 5: Exemplary Instruction**

Instruction is purposeful and all students are highly engaged most or all of the time in meaningful work (e.g., investigation, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and artfully implemented, with flexibility and responsiveness to students' needs and interests. Instruction is highly likely to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

* The original LSC-COP has five categories with a three low, medium, and high. Scores were changed to a seven point scale for clarity purposes.
APPENDIX D: SCHLITT/ABRAHAM TEACHING INTERACTION CO-EFFICIENT (SATIC*)

Teacher: ___________________________  Course: ___________________________  Date: ____/_____/

Lesson goals: _____________________________________________________________
Lesson objectives: __________________________________________________________

<table>
<thead>
<tr>
<th>Teacher Behaviors</th>
<th>1st five minutes</th>
<th>2nd five minutes</th>
<th>3rd five minutes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiatory (talking)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Lectures or gives directions</td>
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<tr>
<td>2. Makes a statement or asks rhetorical question</td>
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<tr>
<td>Initiatory (questioning)</td>
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<tr>
<td>3. a) dichotomous question (either/or, yes/no)</td>
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<tr>
<td>b) short-answer question</td>
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<tr>
<td>c) thought-provoking short-answer question</td>
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<td>4. Extended-answer question</td>
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<tr>
<td>Responding (does not encourage student mental engagement)</td>
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<tr>
<td>5. Reject student comment</td>
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<td>6. Acknowledge student comment (value neutral)</td>
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<tr>
<td>7. Confirms or praises student comment</td>
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<tr>
<td>8. Repeats student comment</td>
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<tr>
<td>9. Clarifies or interprets what student said</td>
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<tr>
<td>10. Answers student question</td>
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<tr>
<td>Responding (encourages student mental engagement)</td>
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<td>11. Asks student to clarify or elaborate</td>
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<tr>
<td>12. Uses student question or idea</td>
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<tr>
<td>Non-verbals</td>
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<tr>
<td>13. a) Inappropriate wait-time I</td>
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<tr>
<td>b) Inappropriate wait-time II</td>
<td></td>
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<td></td>
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<tr>
<td>14. Passive non-verbals</td>
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<tr>
<td>15. Annoying mannerisms</td>
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</tbody>
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*A teacher behavior assessment devised by Dorothy Schlitt and Michael Abraham (Abraham & Schlitt, 1973) and modified by Michael P. Clough
APPENDIX E: ARCHIVED ARTIFACTS FROM THE MIDWESTERN UNIVERSITY SCIENCE TEACHER EDUCATION PROGRAM

Research-Based Framework for Teaching Science—Written/Oral Defense:
The research-based framework papers were typically 25 to 30 pages long, contain more than 40 relevant references, and included:

- all aspects of the decision-making framework (see below for more details);
- why science should be taught;
- why the pre-service teacher has chosen to teach science;
- how the pre-service teacher will provide evaluation of your program, students, and his or herself;
- and a list of references in correct APA format.

The oral defense was typically 90 minutes long and is structured to understand to what extent students understand the synergistic teaching research literature that brings coherence to teacher decision-making. The first question asked of students during the oral defense is typically, “What did you learn through the process of writing this paper?” Follow-up questions depend upon what the student writes in his or her paper and how they respond to questions in the interview.

Self-evaluation of Teaching Behaviors:
Pre-service teachers submitted three 10-minute audio recordings of their teaching during an associated secondary school teaching experience. For each recording, students submitted quantitative and qualitative assessments of your teaching which provided evidence the pre-service teachers were: (a) implementing research-based teaching behaviors and strategies that reflect how students learn and facilitate student goals consistent with the reform documents in science education; and (b) accurately self-assessing.

For the quantitative component of the assignment, pre-service teachers used the Schlitt-Abraham Teaching Interaction Co-efficient (SATIC) form (see “SATIC Analysis” document for more information) to determine his or her verbal interaction pattern. The qualitative component required pre-service teachers to compare the actual state to the desired state represented in by the decision-making framework (see below for more details) and make appropriate recommendations to move his or her teaching progressively towards the desired state. The self-evaluations were assessed by the quality of the interaction pattern (its congruency with a 3c/4, 6, 11/12 pattern; voice intonation and volume; etc.), the accuracy of the self-assessment, and how well you link your self-evaluation to the research/literature base.

Lesson Plan
Pre-service teachers developed a lesson plan with a classmate for ten 50-minute class periods (the first five days were detailed, the second five days less so).

The lesson plan included:

- a description of how the lesson plan promoted the National Science Education Standards and the Iowa Core Curriculum;
- student goals for the unit;
- a concept map linking together the key concepts/processes relevant to the unit topic;
- the big ideas/understandings the unit will target; unit objectives;
- detailed day-by-day schedule of activities;
- and the rationale for the unit that reflects the research literature for teaching science.
Letter Grade Definitions for Science Methods II*

At the end of your exit interview you must justify a final grade using the following grade definitions and rubric, and provide evidence that unequivocally supports that grade. Your final grade for the course will be determined by how clearly and substantially the evidence you provide aligns with the grade definitions and rubric standards. All criteria under a particular grade definition must be met to defend that grade. Discrepancies demand a minus. Exceeding the grade definitions justify a plus.

“A” This individual is an excellent pre-service secondary science teacher. This person 1) always refers to student goals aligned with science education reform documents, 2) skillfully articulates (both orally and in writing) a thorough, yet concise, research-based framework for teaching science that conveys a robust understanding of learning, teaching, and synergistic relationships, 3) extensively and accurately self-evaluates classroom practice thus showing an understanding of the desired state, discrepancies, and recommendations to move progressively towards the desired state, and (4) clear evidence of 3c/4, 6, 11/12 interaction patterns with students. All assignments are thorough, show great effort and convey a deep understanding of learning and teaching. This person demonstrates excellent and thorough lesson planning, a strong command of subject matter, and discusses issues and research in science education. All of these MUST have been well demonstrated through active participation in class sessions. This person uses research findings to support statements and exhibits a passion for teaching. This individual is a formal operational teacher. Compelling evidence must be provided to justify an “A”.

“B” This individual is a very good pre-service secondary science teacher. This person 1) often refers to student goals aligned with science education reform documents, 2) clearly articulates (both orally and in writing) a thorough research-based framework for teaching science that indicates an understanding of learning, teaching, and several important synergistic relationships, 3) accurately self-evaluates classroom practice thus showing an understanding of the desired state, discrepancies, and recommendations to move progressively towards the desired state, and (4) emerging evidence of 3c/4, 6, 11/12 interaction patterns with students. All assignments are thorough and convey a very good understanding of learning and teaching. This person has a good grasp of subject matter, demonstrates very good lesson planning, and sometimes discusses issues and research in science education. All of these MUST have been demonstrated at times in class discussions. This person uses research findings to support most statements, but misses other appropriate opportunities. A strong commitment to teaching is always exhibited. This individual is in transition between concrete and formal. The “B” student, with effort, shows every sign of one day becoming an “A” teacher.

“C” This individual is a satisfactory pre-service secondary science teacher. This person shows the basic competencies necessary for secondary science teaching, may be quite successful in some areas, but struggles in others. This person 1) conveys declarative knowledge of student goals, learning and teaching, 2) has a research-based framework, but struggles to convey synergistic relationships, 3) self-evaluates classroom practice, but misses important issues that show an understanding of the desired state, discrepancies, and recommendations to move progressively towards the desired state, and (4) lacks evidence of 3c/4, 6, 11/12 interaction patterns with students. Special attention during student teaching/first year teaching will likely be required to ensure effective teaching that matches the desired state. All assignments are turned in, but they sometimes are skeletal or late. This person has a sufficient grasp of subject matter, demonstrates satisfactory lesson planning, but is sometimes cynical towards education research. This individual demonstrates a satisfactory commitment to teaching, but is concrete-operational as a teacher.

“C-” or above students must consistently demonstrate effective communication (i.e. correct grammar, spelling, punctuation, and verbal communication) required of a secondary teacher. This requirement supersedes all other grade criteria.

* While this course is titled “Science Methods II”, it is actually the third methods course in a sequence of four. For more detail, Table 3.2 outlines the science education coursework in the MU-STEP.
APPENDIX F: SUBJECT-OBJECT ANALYSIS SHEET*

Participant Pseudonym _____________________

Range of Orders

<table>
<thead>
<tr>
<th></th>
<th>1(2)</th>
<th>1/2</th>
<th>2/1</th>
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<tr>
<td>2</td>
<td>2(3)</td>
<td>2/3</td>
<td>3/2</td>
<td>3(2)</td>
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<tr>
<td>3</td>
<td>3(4)</td>
<td>3/4</td>
<td>4/3</td>
<td>4(3)</td>
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<tr>
<td>4</td>
<td>4(5)</td>
<td>4/5</td>
<td>5/4</td>
<td>5(4)</td>
</tr>
</tbody>
</table>

1. What subject-object boundaries are present in the interviews?

2. What orders are likely not representative? What are some reasons why?

3. Of the remaining orders, to what degree is the participant exhibiting each?

4. What is the overall order of consciousness of the individual?

* The subject-object analysis sheet was modified from Lahey, Souvaine, Kegan, Goodman, & Felix (2011, p.162-163).
APPENDIX G: IRB APPROVAL FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515-294-4566
Fax 515-294-4287

Date: 9/28/2013
To: Jesse Wilcox
1123 NE 8th Lane
Ankeny, IA 50021

CC: Dr. Michael Clough
N162C Lagomarcino

Dr. Joanne Olson
N131 Lagomarcino

From: Office for Responsible Research

Title: Impact of Institutional Constraints on Research-based Teaching Practices of Novice Secondary Science Teachers

IRB ID: 13-380

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Submission Type: New
Review Type: Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- Use only the approved study materials in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.

- Retain signed informed consent documents for 3 years after the close of the study, when documented consent is required.

- Obtain IRB approval prior to implementing any changes to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.

- Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.

- Stop all research activity if IRB approval lapses, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.

- Complete a new continuing review form at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. Approval from other entities may also be needed. For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. IRB approval in no way implies or guarantees that permission from these other entities will be granted.

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.
Notes

Key

(Participant pseudonym, data source, page number/s)

Data sources

13- Post-MAT Interview
14- Interview 1
15- Interview 2
16- Interview 3
17- Final Interview
18- Administrator Interview
19- Mentor Interview
20- Field notes
21- RBF
22- SATIC
23- Lesson Plan
24- Artifacts

Taylor

1 I mean I have all of the tools, this program was rigorous, it's an exceptional program, content wise. There were some social issues we had, our cohort, but we're all prepared to be in the classroom. It's going to be stressful. Because in my case I'm building an entire curriculum by myself. You know, those are things we didn't have to do student teaching. So it's going to be a new experience. But it's not that we're not prepared (Taylor, 1, 13).

2 I think [the cohort structure of the MAT program] worked out very well. I had some good friends from cohort that I will stay in contact with. That we worked really well together, supported each other. I think that's a good idea (Taylor, 1,1).

3 Oh, Jesse, he has his favorites and that's a problem…Well, for our cohort, two of the kids had already been in class with him, so he already knew them. So it just kind of started out "Oh, I already know your name. I already know where you're from and connect with you on that level" and then he forgot to do that with the other kids…[Dr. Clark] has “good grade people. I think that they will be good teachers eventually. [Two students] didn't student teach last semester. So they had a lot more time to do those assignments, so of course they did well. And nobody in this program got there because they don't work and they're not intelligent people, not at all. But it just, it was really hard. I don't want to say this. It was really hard to watch them succeed and not have to work for it. (Taylor, 1, 10-11)

4 You raise important but broad pedagogical ideas, but do not provide the detail necessary to convey your understanding of those ideas. Thus, your understanding is unclear and I am unable
to provide detailed feedback. See my many comments below that illustrate this. (Taylor feedback from Dr. Clark, 10, 1).

\[\text{5}\] To be able to realize your vision of effective teaching there are portions of your research-based framework that need more attention.
- You did not address the use of materials and strategies in your RBF.
- You will need to better understand how teacher behaviors are informed by how people learn and implemented to understand the learner.
- To better employ your understanding of learning theory when planning, teaching, and reflecting next year, keep working on adding depth to your understanding of learning theory and implications that follow. (Taylor feedback from Marie (Ph.D student), 9, 33)

\[\text{6}\] I do think that the MAT program is trying to prepare them for what they're actually going to face their first year of teaching. I think the stress, though, and the classes that are provided, and the work that we are required to do in the MAT program, all benefits young teachers. And I think that's the honest goal. It's to make them the best teachers that they can be, you know, right out of the bat. (Taylor, 5, 9)

\[\text{7}\] I think a lot about activities that I can get my kids involved with...And what materials I need to do those activities... [I worry most about] if it's going to flop. If the kids aren't going to get as much out of it as I thought... Well, [I know if it's going to flop or not because] you've got a good idea, like, because you know your kids, so you know, oh, they might like this, they might like that. (Taylor, 5, 1).

\[\text{8}\] My cooperating teacher told me that when we were having difficulty getting a lot of kids engaged in the classroom, she's like "Go ahead and call on them". I was like, "Call on them cold? You're not supposed to do that" and she was like "Well, in this case we've tried everything else, just call on them cold". And I had a real issue with that, because it seemed to me that if we were doing things that we should have been doing the whole thing would have come together (Taylor, 5, 3).

\[\text{9}\] I'm far exceeding the person that was here before. Which also makes me feel better, because anything I do is better than what he did, from what I've been told. So I can mess up on a lesson plan, or a lab won't go just right, and it's still okay, because we did something rather than just multiple choice quizzes out of the book. So that's helpful too...I think [thinking about my practice compared to the person here before] affects it quite a bit. Because even if I fall flat on my face on a lesson, it's still better than what they had. Everybody has told me that. Parents, faculty, other teachers, administration, even the students. They're like, "You normally take notes. That's way better than what he did." And we don't take notes all that often, but every once in a while we do, and they're like, "This is still way better than what he did." So that helps.

\[\text{10}\] I think it's a... my idea of a good classroom, a science classroom, would be, you know, engaging kids. I think you've also got to keep the practical. The lecture, the note-taking. You've got to keep that at minimum, because you want to... you know, you've got to do those things. But I think it's also very important that the kids are engaged in some type of experiment or some type of lab activity (Taylor's principal, 6, 6).
That would be great. Just because I didn't even know how to run the copy machine. It's one of those things that I had to go ask the school secretary. Not that she's rude or anything, but she has a lot of other things on her plate. She doesn't need to be teaching the new teacher how to use the copy machine, when her mentor is being paid to spend time with the new teacher. But I've seen her twice (Taylor, 3,4).

It's not like I'm cut off from everything and I don't know about anything. Or like I feel like I'm on my own little island. That's not it at all. But I don't know enough to even ask the questions, because I don't know. That's what I mean by isolated. If my mentor probably came in here and told me, "Hey, such and such has free period this period, and such and such has free period this period." That would be an easy way for me to be like, "Oh, okay. Then I can do this and this during those periods." Da da da da (Taylor, 3,4).

How engaged the students are, I guess. If they're having an off day, then I know that I need to do something different. We don't take notes very often, but every once in a while, you've got to give them information. It's trying to figure out, 'Was this way most effective based on how the students respond to it?' If they don't respond to it, then I have to go back and modify (Taylor, 4,1).

Megan

The boss that I had...the boss that I was blessed with, honestly, at my chemical engineering job, she was really the one who saw that I would be happier doing what I'm doing, just because normally my most favorite part about my job was training the new people. She's like, "You really need to look into teaching." So I did. Here I am (Megan, 2,1).

When I was in the MAT program? MAT program was probably one of the hardest things that I have ever done and that's from somebody that went through an engineering program that I hated every step of the way (Megan, 5,4).

If I wasn't in the classroom with kids I would have quit in December (Megan, 5,4).

So with them, in physics class, I still think like they're my 8th graders. I still have to think, "What can they feel? What can they touch? What can they see?" So I still think very macroscopically with those guys. If I can't see, feel, or touch it, or in some way observe it, I don't teach it because they just can't grasp that yet. They don't have the foundation to be able to grasp that. As I'm flipping through the textbook, I decide if I can't see it, I'm not going to teach it. (Megan 2,3).

Yeah, well sometimes its an exit ticket, sometimes its white boards which have been stolen by every other science teacher… (Megan, 5,2).

They have the clear objective in their mind of where they want their kids understanding to be and they also know where their stretch goal is. So if they get all their kids there, where can we go next, so they have that objective milestone out, I guess. (Megan, 5,3).
7. So I do a lot with white boards, I ask so many questions. I think one of the best things that came out of my last evaluation was my principal said you asked so many questions I couldn't get them all down. (Megan, 5, 2).

8. So at all times, when I'm teaching, I have this spider web going on in my head about, "What's my goal?" I know what my goal is. I know where I want to get. So how do I spider web them to get there? It's been really interesting because we spend a whole week on how to write a lab report, which isn't that exciting, but I tried to make it interactive. "What do you think needs to be in a lab report? What information do you want to know?" Try to make it as much as I can about how to get it there. Then in my bio class, I don't think about anything when I'm teaching. I just think about, "Oh God, oh God, I'm going to die" (Megan, 2, 4).

9. There aren't a lot of constraints at my school in the sense that things that I have to do or things that are in my way. I think there's almost too much freedom at my school (Megan, 5, 17).

10. I feel like biology, if I had to keep that class, I think that's the thing that I mind find the most frustrating. I don't know what I would do different. Because if I knew what I would do different, I'd do it and I'd try. But with the mix of bad behavior, like, I can't trust them outside to do something. They sit there and complain and complain. "We do worksheets all the time, we do worksheets all the time." But when I take them outside to do a lab or do, literally, an exploration activity. And yes, I'm aware that it's "exploration" and not "inquiry." That they take 10 minutes, go through it as quickly as they can and they're like "Okay, we're done. What do we do"? (Megan, 3, 7).

**Jamie**

1. I've done a graduate program before, in the social aspect of it was, I think, more or as rewarding, if not more rewarding than the academic part of it, and the social end of it enhanced the academic stuff. The Sustainable Ed program they have, every Wednesday they have a . . . I took a seminar, but it's a bit looser. You have to attend and it's just an interesting talk, and, after the seminar, they have Colloquium. They call that "Colloquium," and then after Colloquium, they go to [a café] and get drinks and talk about whatever happened in seminar, so whatever the speaker, controversial or not, topic was hashed over at colloquium, and, to me, that was the essence of graduate study. (Jamie, 1, 5-6).

2. If there was some, more connection between a before and after year, then there would be overlap… It would be easier to build a community; whereas, right now, it seems like each cohort is insular. (Jamie, 1, 4).

3. So, first, the concrete experience. And then, some way to mentally manipulate that concrete experience to organize it (Jamie, 2, 10).

4. The amount of time in a day. As the year goes on, the more I'm like... after I got through all the stuff that I worked with Eileen doing, so now most everything is even newer to me as a teacher. So, this is more just kind of like a gathering experience year. I'm just keeping in the back of my mind what I should be and what I shouldn't be doing and maybe I'm not always doing it,
but as long as I remember long enough to try to start shoving some of that stuff into what I do next year, then I'm happy (Jamie, 5, 5).

I think she's very open to learning and becoming better. She's not set in her ways by any means. She takes all suggestions and processes those and makes a decision. I don't think she jumps on or reacts quickly. I think she processes before she reacts, which is a positive. That's both with staff and the students. Jamie’s Mentor, (7, 5).

They were both in that meeting. They were just like "If we hired you, we think you'd know what you're doing." And so, they're very supportive. Along with ecology, but also along with chemistry. They're like "However you want to teach it, that's how it's going to get taught." So, it's great school district for an MAT person to go in to...I had one formal and one informal observation for an extended period of time. And then, at least once a week, someone comes in and just kind of hangs out in the back. Sometimes, they catch me in-between classes. They're like "Oh, I saw this happen." Great. Or "I saw this happen. Maybe you can think about this" (Jamie, 2, 10-11).

Kevin

I guess it was a lot of things. At first there was a lot of family type of things. There was a lot of dissatisfaction with my job, part of it was the company, I'm sure, working for. I was working for Electrolux and it wasn't a great company to work for. And there was a lot of things that we were doing, some things were really interesting and exciting but it just was kind of, I started to lose interest in that (Kevin, 2, 7).

A lot of it was the ones that had high expectations especially the 5-18, 5-19 courses that are really high expectations... I just feel like I have learned so much from the last six months. (Kevin, 1, 1,3).

I think just the perspective of my purpose of being there. I'm there for the kids, I'm not necessarily somebody who's teaching a bunch of science but trying to get more out of it, trying to get them to understand society and their role in society and their significance in life. And why they're there and what they're trying to do and being decision-makers and understanding that everything that they do is a choice. So many kids, this year they've talked to me a lot, I give a homework assignment. They say, "Do we have to do this homework assignment?" I say, "No, of course you don't have to do it; you don't have to do anything in your life. But I recommend doing the homework assignment because it's going to help you understand the stuff; you're going to use it on the test." (Kevin, 2,10).

That was a big thing. Just what are your goals, and what are you trying to do. I think that was probably the biggest focus, for us to figure out what do we actually want from these kids by the end of our teaching (Kevin 5, 10).

I'm here. That's a home run for me. Digital electronics, let's do that. Let's not do biotech with me. If you want new biotech, somebody else has got to do biotech. So I'm going to talk to a guidance counselor this year about if we can switch for next semester. Because I'm not doing any
good with the students in biotech. They're not getting anything out of it, I'm not getting anything out of it (Kevin, 2, 15).

6Starts with a concrete activity… Kevin attempts to connect this worksheet to real life situation, but the [science]content seems lacking… [Kevin’s teaching in the astronomy course] has a much better [interaction] pattern, direction, discussion, routines, management, important science concepts (Kevin, 8, 35).

7Kevin attempts to connect this worksheet to real life situation, but the [science]content seems lacking… (Kevin, 8, 35).

8I did, yeah. I think it's just a microcosm of how they view a lot of the things in school. You can kind of see that, and you can see it come from the kids, too, that they're just throwing around all these phrases, and the expectations of the tests and the quizzes, that, "Why don't you just tell us these answers. I feel like I haven't learned a thing. I'm not learning anything. Just tell me about stuff." It's this idea that we just give more information, and that's how they'll learn, just getting more information. And I've had so many battles with the students, and I tell them that, "You have more access to information than anybody else in the history of the world. Giving you more information is not going to help you, because you have more than I could ever give you. I need to do more than that." .... I mean, part of it is, because of all these other things, I'm not very well prepared most days. So, I'm winging it a lot of times, and as a result, I'm probably not being very effective in doing things, and I'm not very consistent in a lot of my expectations, and routine. There's just so many things, that I'm just kind of falling apart in, and different from day to day, that I think that, I haven't really been able to establish things as well as I wanted to. (Kevin 3, 3-4).

9Interviewee: ...like I actually talk about what I'm doing with classes. I don't try and steer it in a certain direction… certain things that he'll try to say that I should be doing that I don't want to be doing.

Interviewer: I see, so you try to govern the conversation and push it different places, I see. That's how you avoid that, I got it.

Interviewee: Exactly. (Kevin, 5, 30).

10I don't know if it's on things I'm doing, or beyond their capability, or if I'm just missing it and what's happening. It's just been kind of a growing ongoing frustration with everybody throughout the year. And I feel myself being frustrated with them, too, because, I feel like a lot of their . . . you know, obviously, I know I'm not doing everything I need to be doing, but I feel, too, that some of them have kind of tuned out and given up, too. So, I'm just frustrated that they just aren't . . . Because I can't turn around in most of my classes without them just going off, and talking to each other about anything. Even when we're in a discussion. In most kind of things, we'll start a discussion in the class, and somebody will say one thing, and the next person will start talking, and then everybody else will start talking about other things. It's like we can't get through even two minutes of discussion without everybody just starting to go off in their own direction (Kevin, 3,6).
That's my biggest struggle to date, is actually coming up with any kind of lesson plan (Kevin, 2, 10).

Rachel

1 I guess I'm not sure. Maybe part of it is a confidence thing. I know I know this material. Whereas I'm not 100 percent confident on all the stuff I would be teaching if I was teaching college. The fear that my students would be smarter than me, I think that may have motivated some of that (Rachel, 2,1).

2 I really like working with kids. I think that's one; I enjoy it. I also think it's a really important thing to do for the betterment of the world as a whole, the betterment of the people I will be sharing this world with once they graduate. I want to influence what they do, influence how they think about science, about the world around them, and have an impact on who they are as people...I knew I wanted to teach in some capacity, but I had always thought that it would be college, instead of K-12. I guess, I don't know. I would still be happy, I think, if I was teaching college. Maybe I could put this another way: the rigor that you teach at a college level and the depth into the content, I prefer the more simple science concepts and teaching those instead, which would put me more with the younger group of people (Rachel, 2,1).

3 People who have been identified to me as the ones who will succeed [inaudible 35:26]. They're the people who do what he says we should do. So we're the ones who willingly sat [inaudible 35:41], and we're the ones who sign up to give presentations in ISTF [SP]. So maybe it's because what he says does make sense when we try to do it, and we do it, that it was like [inaudible 36:00] (Rachel, 1,11).

4 Class begins with a question of the day. The periodic table activity was unique, engaged students, and seemed to scaffold towards [understanding the structure of] the periodic table (Rachel, 8, 2-3).

5 Excerpt from Rachel’s Quiz
   • Why is atomic theory considered a scientific theory? Provide specific examples…
   • What influence did technology have on the development of atomic theory? Provide at least one specific example. (Rachel, 12, Artifact 1).

6 So I'm worried about how to put this all together. How to make it learnable. What I'm not worried about is the questioning and behaviors, and structuring, day-to-day. (Rachel, 1,5).

7 And so we have this list of stuff that we have to get through and we have no idea how long it's going to take. So, like my colleagues and I have been deciding, a week let's see what happens, two weeks let's see what happens. And somehow they're able to get stuff back [inaudible 00:00:45]. So maybe, they're uncomfortable with it too, I don't think they are…So I want to spend more time on these things than I'm given. But, I'm also afraid that if I were to spend as much time as I wanted, first of all I wouldn't be lying up in my [inaudible 00:00:59] which is a no-no. Also I wouldn't get through all the material that I was supposed to get through (Rachel, 3,1).

8 If I have a demo or similar thing I like to do Tuesday demos if I can. We're coming up on a quiz and some missed days, so today was a little more math, actually. Mondays, you never give
a quiz or something like that on Monday. Monday I like to show them a short video clip or something if I have it, and give them something like a pre quiz or a pretest. Mondays are good for that, to know about that. And then Wednesdays are short days around here because we have professional development, so this Wednesday we took a pretest that started this unit on plate tectonics. They're told to take the journal home. Instead they're going to have a post test on Wednesday because it's short day. Thursdays, tomorrow, I'm going to the computer lab. We're going to do an earthquake simulation where I have made sheet forms, and we have Microsoft publisher here (Rachel’s mentor, 7,7).

My ideal science class to me is inquiry based, hands-on, a lot of the kids discovering their own knowledge, doing labs and experiments. Things like that. Not a lot of direct instruction going on, very student-centered (Rachel’s Assistant Principal, 6, 3).

As I said, we're doing pre and post assessments for every unit. Most classes throughout the year, they'll have six units and a unit could last up to six weeks. In each unit we're covering certain standards, so our lessons are designed around those standards. Before we even start the unit, we give the kids a pretest based on those standards. Each question is linked to a standard. They'll do the typical level sheets, normally anywhere from 18 to 20 questions. Then after that we have a computer that we scan it into, scan the test into, and it reads it (Rachel’s Assistant Principal, 6,4).

Grace

When I went to school, I had a really awesome chemistry teacher, and I also babysat her kids. So, I knew her on a more personal level, and she actually became my mentor. She was the reason why I got really involved in chemistry in high school, and also why I got involved in chemistry later...She was very passionate about everything she did, not just in teaching, but also outside of school. I just liked that. She was just totally passionate, and you could easily pick up on that. You just automatically became excited about whatever you were doing be it chemistry or whatever...In high school, I actually got a service credit for hanging out in class and helping other students, if I could. When I first began with her, I hadn't been in chemistry yet, so I just helped with the lower level classes such as physical science, which she taught. Eventually, I took chemistry and then AP chemistry. I did what I could to help during that service time. Either I would help set up for labs, or I would help other students (Grace, 2, 1-2).

I graduated from Iowa State University with a bachelor's degree in geology, so I spent more than a few years doing that. More than a few. When I did my bachelor's in geology, I did field camp in Wyoming. I got some six weeks of hands on work that you might do in industry, and I also studied abroad in England during that time. Once I finished up my undergraduate degree, I did go into Master of Arts in teaching...I kind of always wanted to be a teacher. Originally, when I went to college, I was a chemistry education major, but I found out I didn't really like chemistry as much as I did. Then, I didn't really know what I wanted to do, so I was undecided for a while. I figured I still wanted to teach, because I had been working at a daycare. I really liked that and I had always kind of wanted to do that. Eventually, I thought that it was kind of late in the game to add on education, so I thought I might as well wait and see if I really want to do it. I had my bachelor's degree. I still did (Grace, 2, 1).
It's hard, and very time consuming. Which was good and bad. It was hard because, I say at the beginning, you think you know teaching, because you've been a part of it. You've learned, administered it, but you actually haven't had the role of teacher. So, changing that kind of mindset. You think you know what it is, and really, there's a lot more to it. That was the biggest thing...The second thing, time consuming. It was time consuming, just like reading, grading. And then writing, especially around Christmas time, I was writing? No, right before then. For the second draft. The second draft I found more difficult than the third one. You have to do it a third time, right? Yes (Grace, 5, 2).

Oh, I guess I enjoyed it. I liked making connections with everyone… (Grace, 1,1).

I also was thinking back to my student teaching, and seeing the difference between what our cooperating teacher did, and then what we were learning about. Trying to find that right balance (Grace, 5, 6-7).

Organized, efficient. Personable. You need to know how to differentiate material, because you're not going to have the same level of student in the class. So knowing how to present material three or four different ways over the same subject, the same topic so that you're getting it to all the kids no matter what their...mode is, whether they like the auditory/visual, or the kinesthetic (Grace’s Mentor, 7, 3).

Maddie

Okay. So I have an undergraduate in geology. And then masters of arts and teaching. I also did as well...Well I started out as elementary education. When I was a freshman…And then I didn't really didn't want to do science, I just did elementary education and then I was going to get emphasis in science. But then I got into some sciences and I thought it was really interesting, and at that time I was getting really into the outdoors and what not. So I decided that since I wanted to teach middle school anyway, that I would get my secondary degree instead, and then I did that in geology. So then I switched to undergrad teaching in geology together with earth science. And then I learned about that at MIT and then I switched to geology (Maddie, 2, 1).

I guess. I'm trying to think of ideas that... there was something I was thinking about today, but I was thinking about, like, concrete to abstract. I use that a lot...And so that's one that I definitely... I definitely, especially in sixth grade plans…Where they're really concrete thinkers (Maddie, 5,6).

And that's the frustrating part, is the order. Because we'll go from scientific inquiry to Newton's laws of motion, which is one week…Yeah, I was like, um, no. To solar system, which makes sense. To cells, for two and a half weeks. To water cycle. To food web. And then ovaries to the Richter Scale…They make you record the scores to the district, but this year I don't have to grade it. But next year they're going to tell us what percentage has to be the district assessment, what percentage has to be quizzes and tests, what percentage .

Researcher: It sounds like the freedom is getting reduced over time.

Maddie: That's why I don't like the direction it's going. And that makes me nervous about staying in the district.
Researcher: Just let me summarize some of the constraints that are happening to you. These quarter tests, and the order in which you teach things. And then next year they're going to dictate how much of your gradebook is what percentage of these things and other things. Okay. Those are the main constraints?

Maddie: Yes. (Maddie, 2, 10).

4 We got an email saying that we had to be out in the hallways obviously during [inaudible 00:04:44] monitor, and that she was going to be checking. I forgot she was going to be checking that day and I got caught up with a discussion about a student in the teacher's lounge. It was like his speech specialist that I never get to see, and we were talking about the student, and I was like three minutes late to passing time…It was supposed to be like ten minutes we were supposed to be in the hallway before school, and I was talking to the lady and then she came into the conference room and she was like, yelled at me a little bit, like, "You get in the hallway," and I'm like, "Okay." (Maddie, 5, 21).

5 I look for lesson rigor, classroom rigor, which is pace, energy, those things that are hard to quantify. I look at learning objectives, whether they're made clear, and addressed and posted (Maddie’s Assistant Principal, 6, 1)

6 I bet you hear this all the time, but I just … it seems like first-year teachers are just never prepared for the crunch on their time and the fast pace of the job. They get a little overwhelmed about the fourth or fifth week in; that feeling ‘I just can’t take this’, because they are always are going to struggle with classroom management. I don’t care what you do in the universities, you cannot teach that until you’re in there. (Maddie’s Assistant Principal, 6, 1)

6 People... sorry. People's opinions. Like, other teachers and parents..and students…Because they're the people I'm working for (Maddie, 5, 2).

Greta

1 I have a Bachelor’s degree in Materials Engineering and after graduating I decided that I liked working with high school kids specifically. So I went back to school and got my Masters of Arts in Teaching … While I was in Materials Engineering I did lots of outreach. And all of it was outreach to teach high school students. Some middle school but mostly high school students about science. …Yeah. So, I would go to schools. I would do, when groups would bring students to [Iowa State] I would do activities with them there…there was a year in between where I was deciding what I want to do. (Greta, 2,1).

2 I thought it was valuable. It definitely was different than what I thought teaching was going to be, in a good way. So I think it was a valuable learning experience and I liked the time I had in the methods class and in the student teaching internship at the same time to see it applied instantly (Greta, 2, 7).

3 I liked it, I think our cohort didn't take as much advantage of it early on as we could of or should of but, I think we became a lot closer during this semester…I think maybe it was more, we feel more in the same boat, like what's going on, I think going to NSTA colleges (Greta, 1,1).
For example, my students don't like if there is not a text book. My students don't like that. They can't just make notes and memorize. My students don't like that they can't just use formula and [plug in] numbers. So, teaching them that they have to understand and have a conceptual understanding of what's happening is a big part of the teaching that I do (Greta, 2, 3).

Yes. They are valuable strategies, and I agree with a lot of them, but the mandated, "You just use this strategy sometime this week," is a poor implementation of them (Greta, 5, 7).

Hannah

But let's just say that I loved MAT probably, I feel, more than the average person would. Like, had a greater appreciation because I was coming from a [different graduate] program where one: I felt ignored. Two: I was taken for granted. Three: I wasn't getting any support that I needed, even though I was practically crying for help. I mean, you guys modeled really well, taking our ideas and valuing them. But you also took us very seriously. Coming from a program where I didn't feel like I was taken seriously, and I knew I was doing my part, asking for help and asking questions and things like that...You guys valued the fact that I was taking this seriously, and that's appreciated (Hannah, 5, 9-10).

The cohort model was fantastic…because I think we were all in the same boat, and so we were all experiencing the same things, and because we had those familiar faces along the way. And obviously, a program that I think kind of made you vulnerable because you had to acknowledge your weaknesses. And I think a lot of us, being good students, weren't used to, you know, publicly displaying some of our, I don't want to say faults, but weaker points. That was really nice to have other people that were, like, a support system, but then also, like, people who, I guess, as a graduate school, just kind of, like, rewiring your brain to think differently. And so since that was a little bit hard sometimes, it was nice to have people who were, like, going through the same rewiring process and could relate to you (Hannah, 1, 3-4).

[I feel pressure from parents] mostly from parent night. A lot of them say, "Is this stuff that they're going to do? My kid's going to college." A lot of them are science bound so they're going to get this again, are they going to be prepared, things like that. I have a lot of kids who come from parents who are chemistry people and so I haven't received any complaints about what I'm teaching but I haven't also tested the waters on how much I'm teaching if that makes sense. (Hannah, 2, 6).

And also, our district standards are a lot. So what I have to cover is just enormous…At the end of the year, we have to go online and basically check if we've done it. Now, it's a little bit daunting because it's a legal thing. It's in writing that I've done it so if anybody asks, I have to prove this evidence to say I have. So, yeah, some things I could get away with, just on a random worksheet but there's also this, it's looming over your head (Hannah, 2, 5).

Not with me, but I know she's had some issues with working with other teachers. I guess, we have the chemistry part and then we have the foundations part that she does, but I've never done before. So, I'm not exactly sure how that works, but I think she's been having some problems with them. I don't know how to . . . sometimes in teaching there's like a pecking order
and sometimes when new teachers come they want to do everything their way and the older
teachers you know like, maybe that's not okay with them. To me, I don't care because I do things
my way and she can do things her way and as long as people are learning, I don't care what
happens, but I think there's some pecking going on (Hannah’s Mentor, 7, 9).

Yeah or like, yeah. I always give my kids packets and it has kind of the outline of the
notes we're going to be taking so they know what they need to have. She's more free quelling
which works for her. It wouldn't work for me, but it works really well for her. I just feel like some
kids . . . I don't know, I like kids to know exactly what I expect them to know (Hannah’s Mentor,
7, 8).

I think that it would require small changes over time that weren't as noticeable, that I
would just do, like the saying better to ask forgiveness than permission kind of thing. To a point
also, if I could physically relocate myself over here completely instead of never having to go over
there. That could be pulled off well, which I'm actually working on. I think it could. I think there
would be a lot of time and work involved in that (Hannah, 3, 13).

Jennifer

Incredibly valuable. Not only as a teacher. But just as, like my personal life, of think
about things. Like why am I doing what I do? (Jennifer, 1,1).

Because I started to, I started realizing that the program was coming to an end, and how
valuable each person is for different things. And like, the stronger that I could make, I only had,
really a limited amount of time where a relationship can be easily established. So I decided that
branching out now would be greatly beneficial to both of us (Jennifer, 1, 3).

You know, excellent. [Jennifer] is unbelievable. In fact we just sat down and had our
the end of our two year portfolio interview yesterday. I could not ask her do to any better or
anymore. A lot of that is that student teaching here gave her a little up on that. But she has good
colleagues that she has good rapport with and I think that has helped. Honestly, I couldn't ask her
to do any better or any better at this point. I watch her in action and she has great rapport with
kids. And everything it is amazing, her mastery of the content at this point. Oh, very, very solid.
So if you want this on a scale of one to ten, I would have to give her a ten. She went to an
institute last year with Sarah and so here she is with one year out and she is already going to an
institute to improve her skills.

And we had some bloody moments, with kids and parents. My first bloody nose came at
a board meeting and one the board president's kids was in [the physics teacher’s] class. He said
“He's not teaching.” [I responded] “What he is not doing, that you and your kid don't like, is that
he is not being handed the answer. And we are not going to do that. We are not going to spoon
feed our kids. We are going to make them think and solve the problems themselves. With the
assistance of the teachers, but spoon feeding is no longer going to take place.” My superintendent
afterwards said, “you might not want to [inaudible 00:24:42] in their lunch quite like that”. Thank
goodness the superintendent was very supportive of all that we were doing (Jennifer’s Principal,
6, 11).
I tried to do a lot of reaching out like you and I have met, or I’ve met with other people who teach the course, or I’ll meet with my coworkers, I do research. I was the only teacher with 27 kids and it was just a lot. And we knew it was going to be an issue actually, where I usually have a co-lab, and we talked to the other deans or whatever and they said that they pretty much could have been more helpful. So they got a part-time co-lab in there on Tuesdays and Thursdays, helping me, which helps the other kids so much. I think I knew my roster was going to be difficult, so I went around to the different deans, asking about the kids I didn’t know, in the interaction between the kids. When they would look at my roster, I wasn’t upset about it, they were joyfully laughing, like “Man, we did give you get a doozy”, or “there aren’t enough corners of the room”, I kind of thing. And I don’t even have help in here. Then kept adding kids. So it started off with like 13 kids, and now I’m up to 27. And so I stayed in constant contact, with kids getting in trouble, I would talk to the Dean (Jennifer, 3, 1-2).