A GROUNDED THEORY STUDY ON THE ROLE OF DIFFERENTIATED INSTRUCTION IN EFFECTIVE MIDDLE SCHOOL SCIENCE TEACHING

by

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A Dissertation Presented in Partial Fulfillment Of the Requirements for the Degree Doctor of Education

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ABSTRACT

The purpose of this grounded theory study was to develop a model explaining the role of differentiated instruction (DI) in effective middle school science teaching. The study examined the best teaching practices and differentiated elements from eight general education middle school science teachers, all scoring at the highest level of a teaching effectiveness measure on their evaluations, through a collection of observational, interview, survey, and teaching artifact data. The data were analyzed through the methodology of a systematic grounded theory qualitative approach using open, axial, and selective coding to develop a model describing how and to what degree effective middle school science teachers differentiated their best teaching practices. The model that emerged from the data shows instruction as a four-phase process and highlights the major elements of best practices and DI represented at each phase. The model also depicts how teachers narrowed the scope of their differentiating strategies as instruction progressed. The participants incorporated DI into their pedagogies, though in different degrees at each phase, and primarily by using variety to present concepts with multiple types of instruction followed by a series of sense-making activities related to several learning modalities. Teachers scaffolded students carefully, using informal and formal assessment data to inform future instructional decisions and especially their plans to reteach or extend on a concept. The model is intended to provide insight into the value of DI for middle school science teaching.

Keywords: differentiated instruction, middle grades, best practices, science teaching
Dedication

I dedicate the work of this research to the love and support of those who made it possible and to the investment of a hope of good things to come. I would like to thank Drs. Spaulding, Collins, and Phelps for their patience and dedication during this work, Will Shelton for supporting it and arranging my professional circumstances to make it possible, Katelynn Bullock and Gail Schulte for their insights into data collection and the study’s instrumentation, the teachers in this study who showed a commitment and willingness to better middle school science education, Mom and Dad for listening and encouraging me, Kevin for setting the bar high, and especially Katie and Elise for…everything. Your faithfulness and unfailing love have made this possible and give it meaning. This is for you, in hope.

“Whatever you do, work at it with all your heart, as working for the Lord and not for men” (Colossians 3:23).
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Adequate Yearly Progress (AYP)

Differentiated Instruction (DI)

National Science Teachers Association (NSTA)
CHAPTER ONE: INTRODUCTION

For all the change in the world of the public school teacher, many challenges are ironically the same. One-room schoolhouses challenged teachers to meet the range of learning needs that a set of students brings into a single class (Tomlinson, 1999). Today, even with the dramatic change of the past century that saw transportation shrink the distances between communities and the advent of the Internet that linked people to more information than has ever been available, teachers still face the timeless challenge of meeting the learning needs of a diverse set of students in a single classroom. To address the diverse learning needs of a group of students, teachers are challenged to identify a variety of teaching strategies to best reach all of their students. Teachers must also continue to refine their instruction as their students and their classroom environment change in response to the ever-transforming social context. As the social context of classrooms change, so too must teachers’ knowledge of their students and their instruction as a response to that knowledge. Understanding what makes teaching effective and how to adapt instruction to meet the specific needs of the individuals is essential to ensuring that all students are given the best opportunities to learn.

Differentiated instruction (DI) is a system of teaching strategies based on a philosophy geared towards addressing classroom diversity including students’ various levels of achievement, levels of readiness, interests, preferences, and background experiences (Tomlinson, 1999; Sousa & Tomlinson, 2011). It is not one specific strategy, nor is it necessarily one set of strategies. It is a responsive pedagogy built upon knowing one’s students and adapting instruction to meet their needs. Therefore, DI may take on different appearances from classroom to classroom (Tomlinson, 1999). DI’s common intent is “to maximize each student’s growth and individual success by meeting each student where he or she is and assisting in the learning process” (Hall,
Strangman, & Meyer, 2003, p. 3). Essentially, the goal of DI is to create an environment where “all students get what they need” (Dotger & Causton-Theoharis, 2010, p. 22). Though the term differentiated instruction and the literature describing it gained popularity at the turn of the 21st century, the process of adapting instruction to meet the needs of students is not new to teachers. However, its current practice is often based more on teachers’ anecdotal experiences rather than empirically-based research. Some DI strategies, such as peer mediation and tiered activities, have demonstrated the ability to improve student achievement in empirical research (Mastropieri et al., 2006; Simpkins et al., 2009) while the bulk of what comprises DI’s practical value remains circumstantial. The crux of the matter is in identifying what elements of DI provide for the “high quality performance for all individuals and giving students the opportunity to develop their particular strengths” (Tomlinson, 1999, p. 24); in other words, what do DI and effective teaching practices have in common? This chapter, then, describes the background behind that question, its significance for me as a teacher and researcher, the problem and purpose statements of this study, its significance, the guiding research questions, the general research plan, and its limitations.

**Background**

Public middle school classrooms in the United States are diverse, presenting a unique challenge to teachers. Physically, some students have not yet begun puberty, and other adolescents are several years into it. Some students are building closer relationships with their friends and gaining a sense of independence from their parents. Others still depend heavily on adult authority figures in their lives for emotional security. Cognitively, some students are still developing concrete operations while others are mastering the abstractions of formal operations (Piaget, 1954). Academically, “the typical public school classroom contains 27 children whose
academic performance levels typically span more than five grade levels” (Hertberg-Davis & Brighton, 2006, p. 90) though other factors such as the discontinuation of academic tracking for students and classroom settings that include students with special education services may further expand the level of typical academic diversity. Racially, minority populations in the United States continue to increase while there remain significant achievement gaps between these groups and Americans of European descent (Slavin, 2005). Socioeconomically, public schools typically represent a middle class value system that emphasizes individualism and competition, values not necessarily supported by all the varied backgrounds from which students come, some of which instead emphasize community and cooperation to accomplish tasks (Slavin, 2005). Heterogeneous classrooms present teachers with the challenge of delivering instruction to students, already unique with respect to their prior experiences, learning styles, interests, beliefs, and attitudes, who are also dealing with a significant transition from childhood to adolescence (Tomlinson, 2001). Particularly in the current public school climate of stringent accountability and high-stakes testing, the question naturally arises, “How can I teach in such a way so that all my students learn?” The diversity in public middle school classrooms demands pedagogy that is effective for teaching a wide variety of students.

Differentiated instruction is an approach to teaching and learning that takes students of different abilities in the same class into account, as specific strategies are developed in order to maximize each student’s growth (Tomlinson, 1999, 2001). One research synthesis found that differentiated instruction supports effective classroom management, promotes student engagement and motivation, is responsive to students’ learning styles, and targets students’ optimal zones of proximal development (Heubner, 2010). However, transferring the results of this research can be problematic “as the selection and application of strategies are directed by
individual circumstances and needs, rather than by the uniform application of one strategy based on a skill or concept deficit” (Ernest, Heckaman, Thompson, Hull, & Carter, 2011, p. 192).

Many studies on differentiation focus on only one particular aspect of differentiation, such as the influence of administrative support (Hertberg-Davis & Brighton, 2006) or peer community (Latz, Neumeister, Adams, & Pierce, 2009), student peer mediated instruction (Mastropieri, Scruggs, Norland, Berkeley, McDuffie, Tornquist, & Connors 2006), how to adapt strategies for a specific student population like gifted students (Park & Oliver, 2009; Powers, 2008) students with learning disabilities (King-Sears, 2008), or designing a set of learning experiences for students of differing ability levels or learning styles (Felder & Brent, 2005; Dotger & Theoharis, 2010). With such a broad spectrum of literature, often focusing on studying one particular variable in controlled conditions, it can be difficult to pinpoint what differentiation means to teachers and how it is implemented in typical, non-experimental heterogeneous public middle school classrooms.

If administrative/peer support, classroom assessment data, and the cognitive readiness of students all can affect how a teacher chooses to differentiate instruction, it can be difficult to confidently assert which factors of DI are most effective across different classroom contexts. Differentiation includes such a wide variety of techniques, adapting or modifying content, process, product, and/or learning environment (Tomlinson, 1999, 2001), so teachers must select techniques from these domains of instruction that are most appropriate for their own classrooms. Therefore, teachers must be careful when learning from other teachers’ experiences with differentiation in choosing those strategies that will most benefit their own classroom. These challenges are important to consider when taking a holistic perspective on differentiated instruction in order to advocate for purposeful pedagogical decisions in practice.
Middle school science classrooms magnify the challenges of selecting from among the variety of teaching strategies and discerning which are the most appropriate differentiating strategies in light of a teacher’s specific contextual factors. First, at least in the setting for this research, science was unique because this content area typically hosts the most diverse groups of students. Unlike language arts and mathematics programs in the research setting, general education science programs do not offer resource classes for lower achieving students or advanced courses for higher achieving students. Language arts and mathematics programs provide these courses, taught by specially qualified teachers. Likewise, these two content areas typically offer advanced courses for students working significantly above grade level. However, science and social studies generally do not include these smaller, separate classes due to lack of resources and/or their exclusion from the Adequate Yearly Progress (AYP) school accountability goals. The science and social studies classes in the research setting included both students in the advanced pull-out reading and language classes and the lower-achieving students in the pull-out resource math, reading, and language arts classes. Since the pull-out placements are justified according to students’ level of achievement, it can be said that these science classrooms included the most diverse range of students’ academic achievement, thus providing an appropriate setting for studying the principles of DI to accommodate for this level of diversity.

In addition to the problem of adapting instruction to a diverse group of students in science classrooms, science also represents an underachieving content area. The National Assessment of Educational Progress (NAEP) in 2011 reported only 30% of eighth grade students scoring at or above proficiency with only 2% of those students scoring in the advanced category (National Center for Education Statistics, 2011a). The percentage of eighth grade students scoring at or above proficiency was higher in both reading (34%) and math (35%) (National
Center for Education Statistics, 2011b; National Center for Education Statistics, 2011c). So, while language arts and mathematics traditionally command more attention, it is important to realize that middle school science instruction is in no better condition. The effect that science and technology have on the American economy is dramatic, and developers of the *Rising Above the Gathering Storm* (2007) report identified K-12 education as one of the essential components to maintaining and improving innovative industries. Therefore, it is worthwhile to pursue more research on improving science achievement in middle schools, particularly research that considers the diversity that science teachers face. With this pursuit in mind, the National Science Teachers Association (NSTA, 2003a) recommends research geared towards improving science teaching and learning for *all* learners, and, similarly, research on practices that lead to more positive student outcomes. Since differentiated instruction is intended to accomplish those aims by acknowledging students’ differences and finding ways of teaching them meaningfully (Tomlinson, 1999, 2001), it seemed an appropriate avenue to explore with the intention of increasing achievement in middle school science. The open-ended nature of scientific inquiry naturally lends itself to a differentiated pedagogical style since students would be expected to approach questions differently. With the NSTA (2003b) encouraging the consistent and frequent use of inquiry to deliver content and DI aiming to maximize the capacity of a diverse range of students by offering multiple approaches to learn the same concept (Tomlinson, 2001), the use of DI as a part of best teaching practices in middle school science showed theoretical promise for raising the level of achievement in this underachieving content area.

**Situation to Self**

My motivation for this research stemmed from a desire to identify and explore teaching strategies, especially those considered as differentiating, that successful teachers used
effectively. “Differentiated instruction” has become a buzzword in many practitioner circles, but its efficacy has not yet been fully established empirically (Anderson, 2007; Ernest, Thompson, Heckaman, Hull, & Yates, 2011). However, DI may be misunderstood as a new methodology or approach to teaching. Tomlinson (1999), one of DI’s foremost champions, describes DI as how teachers attempt to maximize student learning. In other words, DI is an intentional instructional response to diversity. As such, DI is simply a description of how teachers meet the unique challenges that certain groups of students raise rather than a contrived instructional “silver bullet”. The responses to student diversity that lead to positive educational outcomes were what I was interested in pursuing. To that end, my fundamental goal was to explore and describe the role that DI might play in contributing to effective middle school science teaching.

With this motivation to contribute to literature exploring DI and its place in what is known about effective science teaching as an avenue to increase students’ academic achievement in middle school science, I also brought several philosophical assumptions to this research. These assumptions flow from a social constructivist paradigm where I relied on participants’ experiences as the fundamental source of data so that I might portray their experiences with DI. From these views, my role was to interpret patterns of meaning that synthesize the participants’ experiences. First, from an ontological perspective, teachers may experience the implementation of DI differently according to their own philosophical assumptions and the unique context of their classrooms. Since teachers’ experiences with DI differ, reporting their subjective interpretations of their experience was important for constructing the reality of DI’s implementation in effective middle school classrooms. Gathering teachers’ unique narratives delivered from their own perspectives about their experiences was an essential part of describing how multiple individuals experience the same phenomenon (Creswell, 2007). These different
perspectives were necessary to gain a larger perspective on how and why teachers make instructionally differentiating decisions.

The most accurate picture of instructional decisions may be gained from research conducted in the field, in this case the effective middle school science classroom, as I worked closely with the participating teachers to understand their implementation of DI, categorize it, and then synthesize it with other successful teachers’ experiences (Creswell, 2007). This epistemological assumption drove how I gathered data in this study as I spent time understanding the participants’ contexts (Creswell, 2007) by observing the teachers in their classrooms, talking to them about how they plan for instruction, and collecting classroom resources that demonstrate how and to what extent they implement DI so that I could develop an accurate understanding of what contributes to the participants’ classroom instruction (Corbin & Strauss, 2008).

My axiological assumptions became apparent as I took on the role of a human instrument for this qualitative study and even as the motivation for choosing the topic of research. In my own classroom, I have experienced both successes and failures with differentiated methods. Therefore, I place a high value on learning from more veteran teachers’ experiences. The perspectives on the value of DI held by the participating teachers emerged during data collection and analysis, and, as the human instrument, it is important for me to report any biases that may stem from our sharing of opinions on DI’s value (Creswell, 2007).

Qualitative researchers value personal and literary forms of reporting the data gathered in the study. The participating teachers themselves influenced the language I used to develop a synthesis of their perspectives and experiences with the implementation of DI. Giving a voice to effective teachers’ accounts of their own experiences by reporting thick and rich descriptions of these experiences lends itself to the transferability of this research (Creswell, 2007).
**Problem Statement**

Given the level of diversity and lack of achievement in today’s middle school science classrooms (National Center for Education Statistics, 2011a), it is essential that research continue to contribute to the existing knowledge of effective teaching practices. The NSTA recommends that more research be done to “examine questions that are relevant to enhancing science teaching and learning for all learners,” (Declarations section, para. 1) including research that extends the body of knowledge on theories of learning (NSTA, 2003a). DI might provide some insight into how to raise the quality of teaching (and therefore the level of achievement) in middle school science, but most of its empirical foundation is derived from individual interventions (Mastropieri et al., 2006; Scruggs, Mastropieri, Berkeley, & Graetz, 2009) often for only targeted groups of students (King-Sears, 2008; Park & Oliver, 2009; Powers, 2008; Scruggs et al., 2009) apart from DI’s broader philosophical context (Tomlinson, 1999, 2001). Further, the literature on DI can be difficult to transfer into different contexts, since its very nature is to be flexible and adaptable to the specific set of diverse students in a teacher’s classroom. Describing DI as a single phenomenon is a murky endeavor, full of qualifications and caveats, since it involves offering a broad variety of pedagogical strategies categorized by four domains of teaching—content, process, product, and the learning environment (Tomlinson, 1999, 2001). It was yet to be determined if, and how, DI might contribute to best teaching practices in science. Therefore, the problem of this study was that no such model describing DI’s role in effective middle school science teaching exists.

**Purpose Statement**

The purpose of this grounded theory study was to create a model describing how and to what degree effective middle school science teachers in American County schools (pseudonym...
differentiate instruction as a part of their pedagogies. The implementation of DI for this study was generally defined as a teacher’s adaptations and/or modifications to instruction based on students’ level of readiness, interest, preference, and background experience (Tomlinson, 1999, 2001). Effective middle school science teachers were defined as teachers who scored in the Level Five category (significantly above expectations) according to American County’s measure of teacher effect data, also known as a teacher’s value-added score, at least once during the last three years. A teacher’s value-added score is determined by an average of his or her students’ scores on the year-end high-stakes test compared to a state-produced projection. Best teaching practices were defined as the pedagogical strategies recommended by the NSTA (2003b) position statement on middle level science education and other related literature on effective science teaching. Essentially, seeking out the potential role or overlap of DI with effective science teaching served as the foundation for this study. DI was used as a filtering lens, along with what is already known about effective science pedagogy, with which to examine effective middle school science teachers to determine DI theory’s value in enhancing the academic achievement of middle school students.

**Significance of the Study**

This research was designed to add to the existing body of knowledge on DI, providing descriptions of the difficult-to-define concept (Ernest et al., 2011b) and explain its role in effective middle school science teaching. By systematically investigating the methods and ideas behind the practices of a group of effective middle school science teachers, elements of DI were identified, categorized, and synthesized into a model of how DI contributes to the more established teaching practices in science. In this way, practitioners may better identify and articulate best practices of teaching in middle school science.
Theoretically, this research was significant in addressing positive academic outcomes associated with DI as a holistic construct rather than a specific pedagogical practice in the typically diverse setting of middle school science classes. Though numerous studies on specific and individual differentiating strategies have been conducted (Ernest et al., 2011b; Mastropieri et al., 2006; Powers, 2008; Simpkins, Mastropieri, & Scruggs, 2009) and collectively have measured an overall large effect size according to Scruggs, Mastropieri, Berkeley, and Graetz’s (2009) meta-analysis, this research has been conducted primarily on samples of students with learning disabilities or gifted students. However, this narrow focus deviates from the intended scope of DI not as a specific strategy for one particular sub-set of students but rather as a way of thinking about instruction (Tomlinson & Allan, 2000). Limited research has been conducted on DI in its larger theoretical context as a method for addressing the whole spectrum of diversity in a class (Ernest et al., 2011b). This study used the broad ideology of DI as a lens for developing a model that identifies what elements of the theory are most effective and applicable to the implementation of best practices in middle school science classrooms. Practically, this research was significant in helping practitioners identify the elements of DI that may be most effective or applicable to their current teaching context by creating a model of how science teachers, utilizing best teaching practices, implement DI strategies that produce positive academic outcomes for their students. Research notes that in order for teachers to feel comfortable adapting instruction according to DI principles, they must experience quick success that demonstrates positive academic outcomes (Ernest et al., 2011b). The development of a model that explains how teachers that have already established a record of affecting these positive academic outcomes implement DI was meant to address just such a concern. The value of this study lies in explaining how experienced and effective teachers utilize differentiating methods as part of their
effective science pedagogy so that other teachers may learn these methods and adapt them to their own classrooms.

**Research Questions**

The following research questions guided data collection and analysis leading to the development of a model describing how effective teachers implement DI as part of best teaching practices in middle school science. Essentially, the aim of the research was to explain how and to what degree effective middle school science teachers differentiate their instruction and to explore the reasons that support their decisions about differentiation.

1. What best teaching practices do effective middle school science teachers employ?

The first filtering lens of this study was meant to uncover the pedagogical strategies effective middle school science teachers employ that reflect what is already known about the best teaching practices for this age group in this content area. The NSTA (2003b) makes recommendations for teacher characteristics, the curriculum and its delivery, and assessment strategies in a position statement for middle level science education. Using these recommendations as the general guideline but also drawing on other related literature, this study built on the existing knowledge about effective teaching practices in middle school science. The participating teachers have demonstrated the ability to produce positive academic gains in their students, so understanding how they conduct their classrooms and how it relates to what is known about good teaching served as a foundation for extending the body of knowledge on effective middle school science teaching.

2. How do effective middle school science teachers’ practices reflect DI principles?

At the heart of this study lies the problem that no model exists to describe the role of DI in effective middle school science classrooms. This research question was designed to address
the concrete and practical applications of DI theory that contribute to effective science teaching practices. Though some studies have shown a particular aspect of DI to produce desirable academic outcomes (Mastropieri et al., 2006; Powers, 2008; Scruggs et al., 2009; Simpkins et al., 2009), DI is a broad pedagogical philosophy that encompasses adaptations to the content, process, product, and learning environment of instruction (Tomlinson, 1999, 2001). In order to determine how, if at all, effective science educators utilize elements of DI, all of these aspects were considered. Research studies that do consider the whole of DI typically confine themselves to qualitatively describing how DI is successfully and strategically implemented in individual classroom contexts (Bailey & Williams-Black, 2008; Ernest et al., 2011a; Park & Oliver, 2009; Powers, 2008; van Hover et al., 2011) so that a limited amount of research exists that demonstrates the transferable value of DI in producing positive academic outcomes for a diverse set of students in the theory’s intended broad context (Ernest et al., 2011b). Since DI is intended to be a dynamic approach to pedagogy that responds to students’ differences and academic development (Tomlinson, 2001), it can be difficult to define that role across individual contexts. Teachers choose and apply strategies based on their own classroom needs (Ernest et al., 2011a). However, by designing a model that connected the similarities in DI implementation among science teachers with a demonstrated record of producing positive academic outcomes, the most critical or influential elements of DI that lead to learning growths were identified for pedagogical application and further research. By studying a group of middle school science teachers with a track record of developing students who make gains in achievement, this study started with the desired outcome and looked backwards to the teaching practices that produced it. Specifically, this study searched out those practices that reflect what is already known about effective science
teaching and looked for a relationship with DI principles. Then, those common DI principles held among the participants were synthesized to uncover the practical value of DI.

3. How do effective middle school science teachers’ beliefs about how students learn influence the way and the degree to which they implement DI techniques into their pedagogical practice?

Teachers’ beliefs about how their students learn influence the teaching strategies they implement, so it was important to explore what those beliefs are and weigh them against the principles of DI. In theory, teachers could adhere to some of the philosophical tenets of DI, such as acknowledging students’ differences and continually thinking of ways to adapt instruction to challenge students of all ability levels (Tomlinson, 1999), without fully articulating or agreeing with the larger philosophy of DI. A working or complete knowledge of DI is not necessarily a prerequisite for implementing it. DI itself is drawn from several existing educational theories such as Piaget’s (1954) cognitive constructivism, Vygotsky’s (1978) zone of proximal development, Sternberg and Zhang’s (2005) thinking styles, and an emphasis on the learning environment that Gardner and Montessori share (Vardin, 2003), and teachers likewise might reflect a patchwork of beliefs about learning, some of which are shared by DI. Teachers could demonstrate pedagogical beliefs similar to those espoused by DI but phrase them according to their own experiences and worldviews so that, if the model of DI were articulated to them, there could be discussions that lead to moments of ‘Yes, that is another way of saying what I already think and do.’ Teachers could also learn specifically about DI or some of its strategies from some professional development opportunity or even from an informal conversation with a colleague. To explore any potential commonalities between DI theory and a teacher’s pedagogical philosophy, as well as where the similarities may have originated, the data
collection was careful to include persistent classroom observations and participant interviews. In particular, the data analysis stage of the study provided an occasion to compare teachers’ beliefs and practices with the theoretical foundations of DI to discover just how intentionally or purposefully teachers applied DI.

4. How do the dynamics of a middle school science classroom, particularly the unique characteristics of its students (including socioeconomic status, ethnicity, cultural upbringing, and levels of academic achievement) and the availability of resources for enhancing the learning environment, influence teachers’ implementation of DI?

As participating teachers were observed, I explored their individual contexts that led to differentiated teaching strategies they selected. This was vital to discover any possible links between the responsive strategies and their contextual causes. Each DI strategy, belonging to one of the four domains of DI that include content, process, product, and the learning environment (Tomlinson, 1999, 2001), was tied to some influential factor or factors, as DI is a dynamic process of matching the learner to the learning (Tomlinson, 2001). Tomlinson (1999) writes of the learner population in contemporary public school as “bringing with them a greater range of backgrounds and needs” (p. 20). In order to justify effective middle school science teachers’ differentiating decisions, discovering the various needs their students bring to the classroom was essential to understanding why science teachers differentiate the way they do. As a result of recognizing students’ needs, the resultant model of DI implementation in effective middle school science classes describes how teachers responded with DI to the specific needs of their students, increasing the transferability of the model. The model addresses the flexibility with which DI was utilized by individual teachers as well as those elements of DI that were
common, especially the differences in how these teachers implemented DI according to the similarly perceived learning needs of their students.

5. What other factors influence teachers’ implementations of DI?

Though effective middle school science teachers revealed some degree of DI implementation according to the needs of their students, other factors influenced the strategies and degree to which teachers utilize DI. Some practitioners might express concerns about the time and energy required to appropriately differentiate instruction or even the moral fairness of the practice (Goodnough, 2010), resulting in the exclusion of some differentiating strategies. Teachers can also be influenced by the degree to which their administration encourages DI or experimentations with different teaching strategies (Hertberg-Davis & Brighton, 2006). They may philosophically agree with DI but be unable or unwilling to implement certain elements of it because of this pressure. Contextual factors like these and others influenced how teachers applied elements of DI in their classrooms and so were significant to address in the construction of the model that described how and to what degree effective middle school science teachers implement DI.

**Research Plan**

In order to develop the model that provides a synthesis of what DI elements are shared among middle school science teachers using best teaching practices that produce positive academic outcomes for their students, this qualitative study employed a systematic grounded theory approach. A grounded theory approach is most appropriate for generating a model, or extending upon an existing one, in order to explain a process common to the target population (Creswell, 2007). In order to generate the data for this model, data collection included first four consecutive classroom observations, the examination of teaching artifacts used during those
lessons, having participants complete a questionnaire about their differentiated teaching strategies, and conducting interviews exploring participants’ use of specific strategies and their beliefs about student learning. The analysis of this data through open and axial coding codified the common elements and themes present in effective middle school science teachers’ differentiating practices to become the constructs of a descriptive model (Corbin & Strauss, 2008). The emergent model integrated these constructs and categories, describing the relationship among them in order to develop an explanation of how effective teachers utilize DI (Corbin & Strauss, 2008). In this way, the emergent model identifies the key practices and beliefs of DI that may help to guide teachers’ implementation of it as a part of best teaching practices in middle school science.

**Delimitations**

This study was restricted in scope to middle level science education, classified as grades five through nine (NSTA, 2003b), in the Southern state that provided the research setting. Middle school served as the age range for the study, inherently providing a diverse population of students (NSTA, 2003b). Piaget (1954) describes this as a time when adolescents transition from concrete to formal operations—a cognitive element of the diversity—and many students also go through puberty during these grades, adding a physical element to the middle schools’ diversity. Hertberg-Davis and Brighton (2006) describe the typical public middle school classroom as one where students’ academic performance can vary up to five grade levels, adding an academic element to diversity. Together, these variables create a setting where teachers are faced with a unique kind of diversity, not to mention the typical descriptors of diversity that include gender, race, socioeconomic status, and ethnicity. In this complex environment, the tenets of DI based on adapting instruction to the learning needs of students may be most applicable and visible.
Restricting this study to the content area of science provides for a specific focus for reviewing the literature and identifying teaching strategies. The study intended to address a wide range of diversity within the observed classrooms so that any potential overlaps between best practices middle school science teaching and DI strategies might be identified. In the schools where research was conducted, science and social studies are unique since they both host a more diverse set of students than their language arts and math counterparts. While general education language arts and math teachers serve some students with learning disabilities in inclusion courses, they typically do not serve the same broad spectrum of students that science programs do which include both the lower achieving students taught in a language arts and/or math resource classes and the highest achieving students in pull-out programs for those classes. Given this wide range of diversity, middle school science provided a setting conducive to studying the theoretical tenets of DI.

**Definition of Key Terms**

Given the breadth of DI theory and the pedagogical tactics considered as best teaching practices in science, it is important to precisely define the terms that appear throughout this study as significant constructs. The following section defines these key terms to ensure clear and consistent communication of their meanings.

*Best teaching practices* refer to research-based pedagogical strategies that have been demonstrated to promote student learning.

*Differentiated instruction* (DI) is a teaching philosophy that utilizes strategies to adapt the content, process, product, and learning environment of instruction in order to acknowledge students’ diverse learning needs that include varying levels of academic readiness, interests, and learning needs. DI is an organic and evolutionary process where teachers continually gather data
on their students to respond with pedagogy that maximizes their capacity for learning (Tomlinson, 1999; Tomlinson, 2001).

(a) *Content differentiation* refers a modification to what concepts or skills the students are expected to master. It also includes the instructional materials that students use to access the instruction (Tomlinson, 1999; Tomlinson, 2001).

(b) *Learning environments* that support DI pertain to the physical setting of instruction and the emotional attitudes encouraged by the teacher that the community of learners is held accountable to (Tomlinson, 1999; Tomlinson, 2001).

(c) *Process differentiation* is an adaptation to the sense-making activity or activities that students complete to move to a deeper level of understanding the content. Essentially, it is a change to the ‘how’ of student learning (Tomlinson, 1999; Tomlinson, 2001).

(d) *Product differentiation* is a modification to the assessment of students’ learning that may include changes to format, type, and the depth of application the teacher requires (Tomlinson, 1999; Tomlinson, 2001).

*Fixed mindset*, drawn from the work of Carol Dweck (2006), refers to a teacher’s belief about students’ ability to learn. In this mindset, intelligence is generally regarded as a static quality. The learning environment can increase students’ potential for learning, but genetic predisposition is the dominant indicator of academic success (Sousa & Tomlinson, 2011).

*Fluid mindset*, in contrast to the fixed mindset, refers to the teacher’s belief that all students have the ability to learn new content given the proper supports and with the appropriate application of work ethic and persistence. In this mindset, teachers adopt an approach of identifying and providing the scaffolding a student needs, according to each student’s own
unique characteristics, to master new information that was initially out of reach. In order to philosophically frame the development and adaptation of instruction as well as create a suitable and challenging learning environment to maximize all students’ learning, the fluid mindset is a critical piece of the foundation for the model of DI (Sousa & Tomlinson, 2011).

*Learning profiles* are a synthesis of other theoretical constructs Tomlinson (1999, 2001) uses to describe students’ paradigms for learning. These include preferences for how to approach the content and the type of setting in which learning occurs. Learning profiles combine ideas from Piaget’s (1954) stages of cognitive development, Gardner’s (2011) multiple intelligence types, and Sternberg and Zhang’s (2005) thinking styles to describe both the natural inclinations and preferred methods for thinking about new content. Learning profiles are dynamic rather than static and may change according to the topic of the content (Tomlinson, 1999; Tomlinson, 2001).

*Readiness*, one of the characteristics teachers use to determine what differentiating adaptations are necessary for a particular student, is described by Tomlinson (1999) as “a student’s entry point relative to a particular understanding or skill” (p. 11). This concept of readiness, based on Piaget’s (1954) stages of cognitive development—particularly as adolescents move from concrete to formal operations—and the identification of what Vygotsky (1978) called the zone of proximal development, refers to a student’s prior knowledge and experience with the content.

*Scientific literacy* refers to students grasping a three-part process: first, students have some familiarity with the main theories or models related to the content; next, students realize how knowledge about the content was developed and defended; and lastly, students can
synthesize the first two parts to apply them to a novel inquiry National Research Council (NRC, 2005).

*Universal Design for Learning (UDL)* is a concept that seeks to create a curriculum and learning environment that is accessible for all students. Inspired by the architectural movement that brought about things like curb cuts and ramps alongside steps, UDL refers to adjustments that remove barriers to learning. It is founded upon the three principles of providing multiple ways to present content, flexible methods for students to apply or be assessed on content, and providing a variety means with which to engage students (Hall, Strangman, & Meyer, 2003).

*Zone of Proximal Development* is a construct developed by Lev Vygotsky (1978) to describe a learning experience slightly more difficult than the learner can successfully complete independently. With an expert to guide the learner, also referred to as scaffolding, the learner engages in a task that has not yet been learned but is not so difficult as to cause undue frustration (Tomlinson, 2001; Vygotsky, 1978).
CHAPTER TWO: LITERATURE REVIEW

Introduction

The purpose of this chapter is to examine the literature to describe differentiated instruction (DI), best teaching practices in middle school science, and the connections that may exist between the two. In doing so, I hope to provide the background for what has been researched and expounded upon in these two areas, underscore the significance of finding connections in order to explain the process by which effective teachers implement DI, and highlight the gap that this study seeks to fill. First, the literature on DI is described to provide a comprehensive definition for it that includes its theoretical foundations and the facets of instruction it includes and to explore how it has been categorized and measured for effectiveness in research literature. Then, the empirical literature on the best teaching practices for middle school/secondary science is examined to explain how effective science instruction is characterized. Next, the two areas are compared to identify any theoretical overlap that may connect them. This theoretical connection highlights the purpose for this study by identifying the gap in the literature that may be bridged by merging these two topics, both of which are intended to advance pedagogy.

Conceptual Framework

This study uses a conceptual framework to guide the development of a model that synthesizes the philosophical tenets and suggested pedagogical strategies of DI with empirically validated teaching practices in middle school science. A conceptual framework is appropriate for this grounded theory study to develop such a model. By using concepts from both DI and best teaching practices for middle school science, a conceptual framework directs the implementation of grounded theory design and its corresponding data analysis; the concepts are
used as the means to identify, observe, analyze, and synthesize the teaching practices of effective middle school science teachers (Castro-Palaganas, 2011). However, since DI serves as the focal lens for the study, it is also important to clearly articulate DI’s own theoretical framework in order to gain an understanding of its constituent concepts and how these components may contribute to effective middle school science teaching (University of Southern California Libraries, 2013). This framework includes the theory behind DI that leads to Tomlinson’s (1999, 2001) suggested teaching strategies within the larger conceptual framework of how the philosophy might relate to best practices teaching in middle school science. The framework also guides the application of this study’s grounded theory methodology. Then, with an understanding of the constructs of DI’s philosophy and the empirically validated pedagogy of best practices science teaching in middle schools, the study relies on observations, interviews, questionnaires, and documents for generating codes that lead to the development of a model to explain the conceptual relationship between DI and best practices teaching in this context.

The theoretical framework of DI used in this study rests on the model proclaimed by Carol Ann Tomlinson that, in turn, has its own synthesis of theories of learning. The “bedrock of differentiation” (Sousa & Tomlinson, 2011, p. 9) contains four elements: cultivating a suitable learning environment, a focus on essential concepts, consistent assessment of students’ understanding of the essential concepts, and the use of that assessment data to plan for and deliver instruction. DI “is a response to learner’s needs” (Tomlinson, 1999, p. 15) that includes adapting the content, process, product, and/or learning environment (Sousa & Tomlinson, 2011; Tomlinson, 1999, 2001). A teacher’s response is predicated upon understanding a student’s readiness level, interests, and learning profile (Sousa & Tomlinson, 2011; Tomlinson, 2001). Each of these measures of a student is built from other learning theories: a student’s readiness is
defined in terms of Vygotsky’s (1978) zone of proximal development; drawing on students’ interests rests on Piaget’s (1954) emphasis on prior experience and Sternberg and Zhang’s (2005) explanation of thinking styles; and finally, Tomlinson’s (2001) concept of learning profiles draws on the emphasis on the learning environment both Gardner and Montessori share (Vardin, 2003). With this theoretical framework, DI is presented as a kind of teaching philosophy applied to crafting a system of strategies, rather than being one particular teaching stratagem, that are to be used at the discretion of the teacher based on his or her recognition of students’ needs. It is important to stress that the model of DI is not presented as a teaching strategy but as so much more. It is a philosophy that extends into a number of classroom elements: the mindset of the teacher, learning environment, curriculum, assessment, planning and presentation of instruction, and even classroom management. A teacher adhering to this DI mindset is continually striving to connect students to content by purposefully structuring the presentation of content to be meaningful and authentic by applying the knowledge of his or her students as individuals with unique characteristics to guide the planning and delivery of instruction (Sousa & Tomlinson, 2011). Used effectively, “students’ academic motivation should be enhanced where there is a good fit or match between the specific aspects of a student’s academic motivation and the instructional environment” (Komarraju & Karau, 2008, p. 71).

Using this theoretical framework as a kind of lens with which to examine teachers’ pedagogical practices, the conceptual framework for the study rests on exploring the potential overlap and relationship between the concepts of DI and those of effective middle school science teaching.

**Differentiated Instruction**

As the conceptual lens for the study, the concepts constituting DI (including its theoretical underpinnings and conceptual domains) are examined in this section. Essentially, DI
is a pedagogical philosophy where “the teacher proactively plans and carries out varied
approaches to content, process, and product in anticipation and response to student differences in
readiness, interest, and learning needs” (Tomlinson, 2001, p. 7). Its roots in a variety of
educational philosophies mean that teachers may in fact hold to some part of DI principles, even
unintentionally, by subscribing to one of its theoretical components. Additionally, the domains
of DI that include content, process, product, and learning environment (Tomlinson, 1999, 2001)
may be characterized by an array of teaching strategies so that teachers may select from what is
most relevant and useful for their own classrooms.

**Theoretical foundations.** Tomlinson’s (1999, 2001) description of DI draws on the
ideas and philosophies of other learning theories including cognitive constructivism (Piaget,
1954), the zone of proximal development (Vygotsky, 1978), learning styles (Gardner, 2011),
Montessori’s emphasis on the learning environment (Vardin, 2003), and thinking styles
(Sternberg & Zhang, 2005). Even the mindset of the teacher is considered an essential element
blends some of these theories to describe a student’s learning profile that helps the teacher
identify how best to adapt the instructional domains of content, process, product, and the
learning environment.

**Cognitive constructivism.** DI is built upon the premise that learners are different from
one another. They have different preferred methods of learning, levels of readiness, and
interests. It is within the context of these differences that teachers design learning experiences
that are “engaging, relevant, and interesting” (Tomlinson, 2001, p. 5). These descriptives are
reminiscent of Piaget’s (1954) theory of cognitive constructivism that recognizes how
individuals actively incorporate knowledge differently based on their prior knowledge and
experience. Like Piaget, Tomlinson (1999, 2001) recognizes these differences in learners and applies the theory by advocating that instruction is most effective when a teacher can utilize his or her knowledge of students’ prior knowledge and experiences—their readiness and interests—to design learning experiences. Only by using the differences each learner brings to the classroom and creating learning events that are conducive to a student’s particular way of constructing knowledge can a teacher truly differentiate instruction. At its most fundamental level, DI is an application of cognitive constructivist theory.

**Zone of proximal development.** Tomlinson (1999, 2001) also draws heavily on Vygotsky’s (1978) idea of the zone of proximal development, incorporating the idea into her definition of students’ levels of readiness. Vygotsky (1978), like Piaget (1954) before him, recognized the individual nature of the learner and emphasized that learners may be pushed from their current level of understanding to a higher one than is independently possible through a process of scaffolding either by a peer or adult mediator. The degree and nature of scaffolding dictates changes to instruction so that the learning task is not too challenging, where students would get frustrated (the frustration level), and not too easy, so that students do not waste time on learning what is already known (the independent level) (Shabani, Khatib, & Ebadi, 2010; Sousa & Tomlinson, 2011). Scaffolding is intended to help students work at the peak of their potential, or at slightly more complex tasks than they could complete independently—the instructional level (Sousa & Tomlinson, 2011; Vygotsky, 1978). The goal of scaffolding is for teachers to help students internalize new knowledge, both understanding the new idea and being able to apply it in ways unique to their own contexts (Vygotsky, 1978). DI challenges teachers to continuously assess students to measure their readiness for learning tasks and then to use that data to make modifications to instruction (Tomlinson, 2001)—an application seemingly built on
the idea of fitting instruction to students’ zones of proximal development. Further, Vygotsky’s (1978) articulation of mediation can be extended to teaching strategies such as grouping students with their peers, providing some degree of student choice or otherwise engaging students with the content’s relevancy, and using an artifact to provide the teaching context (Shabani, Khatib, & Ebadi, 2010). Similarly, Tomlinson’s (1999, 2001) explanation of differentiating strategies includes flexibly grouping students, affording students choices and engaging them with relevant learning experiences (either with content or the means by which the content is addressed), and providing multiple ways of accessing content. In this way, Tomlinson’s (1999, 2001) articulation of DI draws on Vygotsky’s (1978) ideas on the zone of proximal development and scaffolding, incorporating them as a justification for differentiating and also as a means to accomplish it, respectively.

**Gardner.** Another learning theory Tomlinson’s (1999, 2001) ideation of DI builds upon is Howard Gardner’s (2011) description of multiple intelligences. Gardner (2011) theorizes eight different types of intelligences that all individuals possess in differing degrees and that learners might prefer certain types of tasks that relate more closely to particular intelligences. Though he acknowledges that assessing students for their ability in a particular intelligence is unreliable (Gardner, 1996) thus negating the potential for empirical validation, the theory finds value in recognizing that individuals approach learning in unique and preferential ways. Likewise, Tomlinson (1999) recognizes how utilizing students’ preferences for particular multiple intelligences is a part of addressing their interests and learning needs; in this way, a teacher can “build bridges between the learner and the learning” (Tomlinson, 2001, p. 9). Tomlinson (1999, 2001) advocates for providing multiple inputs that will help to create those bridges. Multiple inputs, for instance, might include using varied materials and methods for
accessing content. By drawing on Gardner’s (2011) theory of multiple intelligences even in spite of its lack of empirical evidence, Tomlinson (1999, 2001) finds at least theoretical justification for the uniqueness of individual learners that may be addressed in the classroom by adaptations to instruction that match it with the learning needs, interests, and preferences of individual students.

Thinking styles. Another important theoretical influence on Tomlinson’s (1999, 2001) conception of DI that underscores the importance of recognizing the uniqueness of students is Sternberg and Zhang’s (2005) identification of thinking styles. Similar to Gardner’s (2011) idea that students show affinity for certain types of tasks according to eight types of intelligences, Sternberg and Zhang (2005) advance the notion that students have a situational and varying preference for how to utilize their natural ability; it is significant that they distinguish thinking styles as a preference rather than a measure of ability. Though Sternberg and Zhang (2005) go into detail to describe how three basic branches of thinking styles exist, each defined by a branch of American government, Tomlinson (1999) describes them in terms of preference for creative, practical, or analytic tasks. Though Tomlinson (1999, 2001) does not emphasize the three thinking styles throughout her description of DI, she does explicitly name Sternberg’s (1985) work as a theoretical influence recognizing how students think and learn in different ways, and therefore that matching instruction to these different affinities and preferences may influence a student’s development.

Montessori. As Tomlinson (1999, 2001) recognizes student differences and teaches that the learning environment is critical to students’ success, her theoretical foundations reflect similar emphases of Maria Montessori’s. Montessori (1912) believed that teachers should understand students’ differences and modify instruction to best suit their needs. Further,
Montessori advocated the use of varied and multisensory learning activities to round out a student’s intellectual development. Likewise, Tomlinson (1999, 2001) views the learning environment as a place where teachers can gather informal and formal data about their students to create more effective learning experiences; she encourages that these experiences should be offered in a variety of formats to appeal to students’ interests and learning preferences. Tomlinson (1999, 2001) extends on Montessori’s emphasis on crafting learning experiences according to a student’s interaction in the learning environment (Vardin, 2003) by viewing the learning environment as a community of learners where each student should have some degree of responsibility for his or her own education and that of his or her classmates. To teach this responsibility, teachers should model community values like mutual respect and an expectation for growth. Instead of building an atmosphere where all individuals are uniformly equal, a differentiated classroom recognizes students’ individual natures and seeks to provide an environment where “fair means trying to make sure each student gets what she needs in order to grow and succeed” (Tomlinson, 2001, p. 23).

**Learning profiles.** Tomlinson (2001) synthesizes these theoretical constructs in her description of learning profiles. A student’s learning profile, she writes, can be categorized by students’ preferences or affinities for how group work is conducted, cognitive styles, the conditions of the learning environment, and intelligence types. Flexibly grouping students for learning tasks might include Gardner’s (2011) inter- or intrapersonal intelligences, or working with a mediator, reflecting a Vygotskian (1978) influence. Tomlinson’s (2001) descriptions of the variety of cognitive styles likewise include some references to Gardner’s (2011) intelligences, Piaget’s (1954) stages of cognitive development, and Sternberg and Zhang’s (2005) thinking styles. The conditions in the learning environment that should most
appropriately suit students harkens back to Montessori’s emphasis (Vardin, 2003). Finally, the intelligence types reflect Gardner’s (2011) intelligences combined with Sternberg and Zhang’s (2005) three thinking styles. A teacher who continually gathers this kind of information on his or her students and creates learning experiences within their zones of proximal development—stretching a student’s ability to independently complete tasks (Vygotsky, 1978)—is grounded upon Tomlinson’s (1999, 2001) foundations for differentiating instruction.

**Mindset of the teacher.** Having considered these elements of how students learn, it is also significant to address how a teacher thinks about students’ ability to learn. Drawing on the work of Carol Dweck (2006), teachers may take two mindsets—either intelligence is a relatively fixed commodity, the “fixed” mindset, or academic success is much more fluid according to the work ethic and persistence of both student and teacher, the “fluid” mindset (Sousa & Tomlinson, 2011). Fluid mindset teachers demonstrate belief in all students’ ability to learn by developing instruction that takes into account students’ unique attributes, pushing the students to accomplish what was once independently out of their reach. Fixed mindset teachers are more apt to categorize students according to ability, explaining academic success (or the lack thereof) by students’ problems or advantages outside the classroom. The mindset a teacher takes permeates the learning environment as a teacher communicates his or her belief in students’ ability to learn in word and attitude, influencing a student’s own sense of self-efficacy. Thus, a fluid mindset for a teacher is a significant element of differentiation as it shapes the attitude of a teacher in planning, delivering, and adapting instruction by providing a philosophical apologetic for working towards maximizing the learning opportunities for every student (Sousa & Tomlinson, 2011).
**Tomlinson's model.** Collectively, elements of Dweck’s (2006) mindsets, Piaget’s (1954) cognitive constructivism, Vygotsky’s (1978) zone of proximal development, Sternberg and Zhang’s (2005) thinking styles, Gardner’s (2011) multiple intelligences alongside his and Maria Montessori’s focus on the role of the learning environment (Vardin, 2003), provide for and shape the theoretical foundation for Tomlinson’s (1999, 2001) synthesized construct of learning profiles. These theoretical foundations for a student’s individual learning profile lead to the guiding principles and suggested strategies of DI’s application that are meant to address students’ differences. DI is a flexible, adaptable approach to pedagogy that varies according a teacher’s set of students and his or her teaching contexts; therefore, there is no single method for differentiating instruction. However, there are key concepts and indicators of a teacher who does differentiate. These include a teacher’s attention to student differences, focusing instruction on key concepts, aligning instruction with the data gathered from assessment, balancing class and individual norms/goals, flexibly grouping students, the collaboration of teacher and students to shape a respectful community of learners, and, particularly, modifications to the content, process, and product of instruction (Tomlinson, 1999). It is adaptations to these last four domains of teaching—content, process, product, and the learning environment—that are central to DI.

**Content.** The differentiation of the content of instruction includes modifications to both the ‘what’ of teaching and ‘how’ students access that information (Tomlinson, 2001). For instance, students might receive a different science vocabulary assignment based on their scores on a pretest over the material—adapting the ‘what’. The emphasis of the content is still shaped by a central concept, but cognitively ready students might be provided with extending opportunities (Bailey & Williams-Black, 2008). Further, students might look for the vocabulary information in different texts (e.g., a non-fiction magazine or a science textbook), some might
use the Internet, or others might work with a peer to gather the necessary information—modifying ‘how’ students access the content. Essentially, content differentiating strategies may be broken into six categories: (a) curriculum compacting that allows advanced students a chance for more independent study (Bailey & Williams-Black, 2008; Powers, 2008), (b) using multiple inputs to deliver instruction (Hall et al., 2003; Park & Oliver, 2009), (c) focusing instruction on key concepts, (d) creating mini-lessons for students grouped according to their knowledge of a newly introduced concept (van Hover et al., 2011), (e) utilizing material resources and/or student groupings to help diverse students better access the content (Hall et al., 2003; Mastropieri et al., 2006; Park & Oliver, 2009), and (f) learning contracts where students manage a set of agreed-upon tasks (Tomlinson, 2001).

Teachers may choose to differentiate the content of instruction based on students’ readiness levels, interests, or preferred way of learning. By using a pretest to appropriately identify students’ zones of proximal development, a teacher is using students’ readiness levels to determine how to adapt the content. Offering students choices in the content, often by allowing students a variety of sub-topics in which to specialize, differentiates the content by students’ interests. Providing for a variety of multisensory tasks helps to differentiate by students’ learning profile so that they may approach the content in a preferential way (Tomlinson, 2001). These techniques can even be used in tandem so that students, flexibly grouped either independently or in groups, can each study aspects in preferred ways of a central topic in order to provide a piece of the larger conceptual puzzle (van Hover, Hicks, & Washington, 2011).

**Process.** Process differentiation refers to a “sense-making activity” (Tomlinson, 2001, p. 79) that is “designed to help a student progress from a current point of understanding to a more complex level of understanding” (Tomlinson, 2001, p. 79). As the brain tries to create a pattern
with new and old information, a sense-making activity that is “readily comprehensible (makes sense) and [that] can be connected to past experiences (has meaning)” (Sousa & Tomlinson, 2011, p. 49) is much more easily retained, and thus proves a critical point in the learning process.

It is interesting to note here the overlap with the National Research Council’s (2005) inclusion of sense-making as an integral part of instructional best practices as students integrate new information with existing schemas by evaluating evidence and offering alternative explanations. Tomlinson (1999, 2001) advocates the same practice, including it as a part of her model of DI, characterizing the sense-making activity as being interesting to the student, requiring higher order thinking skills and the application of a key concept or skill to aid in its understanding.

Like with differentiating content, teachers can modify the sense-making activity by matching the difficulty of a task with a student’s readiness level, offering students choices so that they may choose what is most interesting to them, and by offering students a preferred learning method for completing the activity. Tomlinson (2001) writes that breaking students into smaller groups to match students’ readiness, interest, or learning profile with the sense-making activity allows for more appropriate matches with individual students than whole-class instruction. The sense-making activities are most effective when delivered in a variety of settings: cooperative ones with students grouped heterogeneously or homogeneously like learning centers, jigsaws, think-pair-shares, or peer-mediated groups (Mastropieri et al., 2006; van Hover et al., 2011) and even as independent work. Since more than one kind of activity is offered, providing a variety of activities and learning materials remains consistent with the theoretical foundations of Montessori’s (Vardin, 2003) work and also helps to create a learning environment appropriate for a diverse group of learners. The idea of an adaptive, responsive learning environment reflects the concept of Universal Design for Learning (UDL)—a construct emphasizing making
adjustments to the curriculum and to the setting of instruction. The goal of UDL is to remove any barriers by providing multiple methods for presenting content, affording students opportunities to express what they know of the content, and using multiple means to increase student engagement (Hall et al., 2003).

Though sense-making activities can be delivered in a surprising number of ways, five essential categories may cover the scope of this kind of differentiation: (a) journal and/or reflection activities, (b) all kinds of graphic representations or organizers for content, (c) problem-based or lab activities (Park & Oliver, 2009) where students must formulate a response to a particular concept, (d) role-playing activities including debates, and (e) learning centers and/or jigsaw activities (Bailey-Williams-Black, 2008; van Hover et al., 2011) where groups of students each focus on a particular aspect of the larger concept (Tomlinson, 2001). Offering tiered activities where students must master a simpler task with the content before moving onto more complex ones (Goodnough, 2010; Mastropieri et al., 2006; Simpkins et al., 2009) or the opportunity to choose from a list of tasks (Dotger & Causton-Theoharis, 2010; Goodnough, 2010) are also included since these teaching strategies differentiate how students will interact with the content (Tomlinson, 2001). These varying sense-making activities, appealing for all types of learners in the class, must still revolve around the central concept or skill that is the purpose for that lesson (Bailey & Williams-Black, 2008; Tomlinson, 1999); the goal is to integrate the schemas rather than making sure students enjoy the topic or providing some novelty to instruction.

Product. Differentiating the product of instruction refers to a long-term assignment rather than the process, or sense-making activity, where students’ understanding and/or applications of a few key ideas or skills are assessed (Tomlinson, 2001). Differentiated products
may replace or be used in tandem with more typical kinds of tests, possibly even offering different kinds of assessment formats (such as multiple choice, essay, or project-based assessments depending on students’ readiness levels and preferences) in order to broaden the range of methods offered to students for understanding, applying, and demonstrating their newly learned knowledge (Tomlinson, 2001; van Hover et al., 2011). They can be highly motivating when matched with students’ interests or talents, and, therefore, must be driven by clearly defined and high expectations that encourage growth in students’ independent understandings. These expectations must be carefully aligned with what students have already studied, or the content of instruction, and how they have made sense of the content, the process domain of instruction (Tomlinson, 1999). Though the product may change based on students’ readiness, levels, interests, or learning profiles, all differentiated products make clear what concepts or skills should be demonstrated and to what degree and are moderately structured in the learning environment as students brainstorm together, conduct workshops, or even edit each other’s work as they make progress towards the final product (Tomlinson, 2001). The product can also be used as yet another source of student data, particularly for informing the teacher what students and corresponding skills may need remediation (Ernest, Thompson, Heckaman, Hull, & Yates, 2011; Tomlinson 1999, 2001).

Four characteristics may be used to define effectively differentiated products: (a) the essential criteria and expectations of quality are made clear at the outset of the assessment; (b) the available format(s) of the product/assessment (Ernest et al., 2011a; Park & Oliver, 2009) that should be matched to student interest, readiness level, or learning profile (Tomlinson, 2001); (c) the scaffolds the teacher provides to guide students in applying the information (Park & Oliver,
Learning environment. Differentiating the learning environment is an essential factor of DI as it sets the tone for how learning takes place in the classroom setting (Tomlinson, 2001). Emotionally and socially, it is important to establish a community of learners where students feel safe and work together towards the common goal of cognitive growth (Maslow, 1987), reflecting a sentiment similar to humanist psychology’s views on motivation (Eggen & Kauchak, 2007). Establishing this environment, asserts Tomlinson (2001), includes the teacher and students collaborating on how the classroom runs as the classroom community evolves its understanding of fairness to mean that all students get what they need to succeed as opposed to identical treatment. With this understanding, the classroom may be better equipped to handle group and independent work that requires students to be working on different kinds of tasks, though they relate to the same central concept. In this way, the learning environment resembles the student-guided theoretical foundation of Montessori (Vardin, 2003) but also brings in elements of UDL to shape the arrangement of the class and its media to match students to their readiness levels, interests, and learning profiles (Hall et al., 2003; Tomlinson, 1999, 2001). The end goal is to create a classroom environment where students can work effectively in groups and independently on varying tasks that require different materials but that are most appropriate to help students develop their ability to independently complete academic tasks; in other words, the learning environment should be an organic response to its learners.

Conclusion. Tomlinson’s (1999, 2001) articulation of DI as a pedagogical philosophy, along with its own theoretical framework, serves as a lens to examine the teaching practices of effective middle school teachers. As DI theory is weighted against empirically validated
pedagogical techniques, I hope to identify the value of its constituent components, accounting for the larger conceptual framework for this study (Castro-Palaganas, 2011). Now that DI’s theoretical framework has been described, I turn to the research literature examining DI and its conceptual constructs. Describing the empirical research on DI can be challenging since “There is no one ‘right way’ to create an effectively differentiated classroom” (Tomlinson, 1999, p. 3). It is like creating a patchwork quilt, as studies focus on specific strategies or related components of DI rather than taking it as a holistic approach to pedagogy. However, the patches provide valuable insights into how DI can be applied effectively to improve teaching practices and produce more positive student outcomes. With these pieces of DI in place, a comparison can be made with the literature on the best teaching practices in middle school science instruction to identify the potential overlap between the two. This conceptual comparison informs and drives the data collection and analytic methods described in Chapter Three.

**Review of the Literature**

Though DI is intuitively popular among educators, its empirical support is far less prevalent. However, there is a degree of research literature that has assessed DI. More commonly, however, research focuses on particular elements of DI for its practical and effective use in the classroom. The following section analyzes the results of this research to describe differentiating strategies, including those tested in isolation of other DI pedagogical techniques, and their effect on a diverse group of students as well as the challenges associated with practical applications of DI. Then, this body of research on DI is compared with the strategies identified by the literature as being considered best practice for science instruction.
Assessment of DI’s Effectiveness

Because there is no prescriptive way of incorporating DI, finding research that measures its effectiveness is often a matter of identifying studies that researched either one differentiating strategy or a small set of them; as a holistic approach to pedagogy, quantitative studies lack the control necessary to account for the significant number of factors that make up DI. However, one meta-analysis (Scruggs, Mastropieri, Berkeley, & Graetz, 2009) coded a search with a number of terms used as special education interventions to measure their effect size. These interventions bear the hallmarks of differentiation: explicit instruction, or delivering small sets of instruction followed by guided practice and culminating in independent practice, is characteristic of applying the zone of proximal development in teaching and focusing on central concepts; study aids, graphic organizers, and computer-assisted instruction reflect the differentiation of materials (the content or how it’s accessed); self-questioning strategies and active learning are characteristic of sense-making (process) activities; and peer mediation is one of the flexible grouping strategies utilized in DI. Collectively, these interventions (or individual DI strategies) measured a large effect size of 1.0 using Hedges’ $d$; of these interventions, the researchers found that explicit instruction had the highest effect size (1.6) and using hands-on active learning the lowest (0.6) (Scruggs et al., 2009). Of interest to DI’s value in inclusive settings, the meta-analysis also found that effect size increased when researchers delivered the initial treatment and then followed up the interventions under the guidance of a combination of general and special educators (Scruggs et al., 2009).

Despite the limitations in most DI-related studies that can only account for a single strategy, there are studies that have explored DI as a larger construct of pedagogy as it is intended. For instance, a mixed-methods study had 35 teacher education candidates (TECs)
create lesson plans that targeted a key concept or skill, accounted for how student data influenced instruction, and applied instructional strategies according to Tomlinson’s (1999, 2001) four domains of content, process, product, and the learning environment. TECs were given the flexibility DI affords to craft different types of lessons for the learning needs of their specific set of students. The one group pretest-posttest design yielded quantitative results finding that TEC’s special education students’ posttest scores improved on average 30% from pretest scores. Additionally, 97% of the scores moved from failing to passing, with the one remaining failing student improving from 13% on the pretest to 56% on the posttest. While math scores improved more than science scores, the finding that there was no statistically significant difference across grade level suggests the transferability of DI to other contexts (Ernest et al., 2011b).

Similarly, a qualitative case study also showed the value of a DI-minded pedagogy by describing how one teacher systematically used data gathered in the classroom to guide future instruction (Ernest, Heckaman, Thompson, Hull, & Carter, 2011). Specifically, this special education teacher used pretests, a kind of self-assessment that used the pretest data to inform modifications of the immediate lessons, and then on-going assessments in the form of teaching reflections focusing on the effectiveness of the differentiating strategies developed from the self-assessments. These types of gathering data about the students are consistent with Tomlinson’s (1999) description of the strong bond between assessment and instruction. The researchers noted that the teacher’s adaptations to instruction based on the formal and informal data produced large effects, such as the illustration of one student who consistently failed multiple choice assessments to the change of scoring an average of 90% once the teacher differentiated these assessments to better match the student’s preference and affinity for verbal tests. Additionally, the researchers found value in the philosophical change in the participating teacher’s lesson
reflections, reporting a shift away from teaching objective to objective and towards teaching an objective until mastery as demonstrated by the data gathered in the classroom (Ernest et al., 2011a).

Though the research studies that have examined DI principles at the pedagogical level rather than an individual strategic one have demonstrated positive academic outcomes, these studies seem to have few controls to minimize threats to their validity. Much more common is the research study that measures the effectiveness of a particular teaching strategy. This methodology is much more suited to quantitative research and is somewhat in contrast to the mixed methods and qualitative studies that have examined DI in its larger, and more theoretically grounded, context. However, since DI is a collection of strategies, it is valuable to examine these individual strategies and their effectiveness when compared to more traditional types of instruction, particularly when the end goal is to espouse best teaching practices. Though, it should be noted that these strategies should be incorporated together and purposefully in light of the diverse students in a classroom, according to Tomlinson’s (1999, 2001) description of DI.

**Individual practices.** The individual differentiating practices that have been researched generally reflect that some portion or element of DI has been studied apart from the larger context of a differentiated classroom that incorporates all four domains of content, process, product, and learning environment (Tomlinson, 1999, 2001). Individually, the strategies reflect a differentiated philosophy as they adapt one of these domains for a specific intervention. While the strategy in and of itself may not be considered as a holistically differentiated approach to pedagogy, it does reflect the researchers’ aims of developing better teaching practices. As a part of studying the overlap between DI and best practices teaching, it is important to identify those effective interventions and strategies and then re-examine them in the light of the DI model.
With this mindset, the individual differentiating practices that have been studied include using assessment data to adapt instruction for individuals or whole classes (Bailey & Williams-Black, 2008; Ernest et al., 2011b; van Hover et al., 2011), a particular intervention as an added scaffold to support students with learning disabilities (King-Sears, 2008; Mastropieri et al, 2006), or as a kind of extension for gifted learners to stretch their cognitive development beyond more traditional, whole-class instruction (Park & Oliver, 2008; Powers, 2008).

**Planning and DI.** First, several studies have indicated the value of using data gathered in the classroom to inform and adapt future instruction (Bailey & Williams-Black, 2008; Ernest et al., 2011b; van Hover et al., 2011). Bailey and Williams-Black (2008) wrote a case study of three teachers found to be effectively differentiating for literacy instruction and noted all three used some form of pre-assessment data, generated from vocabulary exercises corresponding with the lesson’s story or other pretests, to determine the level of modifications for later assignments. All three teachers utilized this student readiness data (Tomlinson, 1999, 2001) to categorize students into groups for the actual delivery of the content (Bailey & Williams-Black, 2008). Likewise, gathering student data can also include a teacher’s self-assessing reflections on the effectiveness of a given lesson’s instructional activities (Ernest et al., 2011b); this might better inform a teacher of what kinds of activities and topics interested students and matched their preferred methods for learning (Tomlinson, 1999, 2001). Gathering student data in this way demonstrates that some differentiating teachers may not always collect individual data, instead opting to reflect on class-wide data. In other words, collecting student data to inform future instruction can be done both *within* classes, to adapt and modify for small groups of students, and *between* classes, to guide instruction for whole classes (van Hover et al., 2011). This latter type of differentiation might be more common among secondary teachers, due to their total number of
students. In any case, these qualitative studies (Bailey & Williams-Black, 2008; Ernest et al., 2011b; van Hover et al., 2011) each have highlighted the perceived value of teachers differentiating instruction according to student data gathered to determine students’ readiness, interest, or learning profile (Tomlinson, 1999, 2001).

**Students with learning disabilities.** Once teachers have gathered data to use in adapting future instruction for their students, the impetus becomes designing effective learning experiences based on that data. Some differentiating strategies applied as interventions for students with learning disabilities have demonstrated positive academic outcomes such as peer mediation, tiered or leveled activities (Mastropieri et al., 2006), explicit instruction, utilizing study aids, study skills instruction, self-questioning strategies, graphic organizers, active hands-on learning, and computer-assisted instruction (Scruggs et al., 2009). Of particular interest are the peer mediating and leveling strategies studied by Mastropieri et al. (2006) specifically in the context of middle school science instruction in inclusion classrooms. Students who are enrolled in special education and included in the general education science classrooms were a part of the experimental/differentiating group that was reported by the researchers as having higher posttest and end-of-the-year high-stakes test scores compared with a control group that received more traditional instruction (Mastropieri et al., 2006). The effective interventions included leveled activities that had students mastering objectives before moving on to more complex tasks, resembling a similar differentiating mindset to the one demonstrated by the participating teacher in Ernest’s et al., (2011a) study. The interventions also included utilizing peer-mediated question and answer tutoring sessions, reflecting the principles of flexible grouping and using experts to mentor still-developing learners (Tomlinson, 2001). A similar study using peer-mediated activities as the differentiating strategy for an independent variable found that both
general and special education students scored significantly higher on production-oriented tasks (those that did not provide answer choices) when compared to a control group receiving more traditional instruction (Simpkins, Mastropieri, & Scruggs, 2009). This finding suggests that differentiated teaching practices can enhance instruction for a mixed-ability group of students, providing more evidence that DI may be related to the broader category of best teaching practices. As discussed earlier, other individual differentiating strategies measured in Scruggs et al.’s (2009) meta-analysis also demonstrated positive academic outcomes ($ES = 0.91$ in science) for DI-related practices like explicit instruction, utilizing study aids, study skills instruction, self-questioning strategies, graphic organizers, active hands-on learning, and computer-assisted instruction. Collectively, these differentiating interventions averaged a mean effect size of 1.0 for special education secondary students in science, social studies, and language arts; explicit instruction was found to have the largest effect size at 1.6 and hands-on active learning with the lowest at 0.6 using Hedges’ $d$.

However, it is interesting to note that while students’ scores improved under the differentiating conditions, their attitudes towards science instruction were not significantly different than those in the control/traditional instruction group (Mastropieri et al., 2006). Similarly, Simpkins’s et al. (2009) study found that general and special education students scored significantly higher on differentiated production tasks, but not on the differentiated identification tasks, though they reported liking these less than production ones. While students do not necessarily have to enjoy DI more than other types of instruction in order to benefit academically from it, these studies suggest that differentiated teaching strategies used even in isolation from the larger DI context produce positive academic outcomes, and, therefore, may be related to best teaching practices.
**Gifted or high achieving students.** As with differentiated strategies developed for students with learning disabilities, other research-based differentiated practices have demonstrated positive outcomes for higher achieving students (Mooij, 2008; Park & Oliver, 2009; Powers, 2008; Simpkins et al., 2009). Many of these positive outcomes are associated with the unique psychosocial needs of higher achieving students. For instance, one study encourages the significance of differentiating activities to counteract the motivational, social, and/or cognitive challenges that underachieving gifted students may experience (Mooij, 2008) while another reports that DI helps to manage gifted learners’ challenging questions for the teacher, their ability to deal with perfectionism, and as a method for creating a psychologically safe classroom environment (Park & Oliver, 2009). In particular, Park and Oliver’s case study (2009) noted that thematic units, a variety in instruction (content/process) and the products that students create, flexible grouping strategies that included opportunities for students to be grouped hetero- and homogeneously according to ability, and the availability of the teacher to talk with the gifted student individually all were effective ways of meeting the developmental needs of gifted learners. Additionally, the differentiating technique of offering independent study to higher achieving learners has been shown to elicit positive responses from students who described the independent study as interesting, challenging, and motivational (Powers, 2008)—terms related to student engagement that reflect positive classroom outcomes. The common elements of these studies include making adaptations to the content, process, and/or product of instruction based on an understanding of these students’ unique needs including their zones of proximal development, but particularly reflect an emphasis on creating a learning environment that is both psychologically safe and that pushes students (even gifted ones) towards growth (Tomlinson, 2001).
Though positive academic outcomes may be more difficult to discern among high achieving students, there is some hint in the research that these students can benefit academically from DI along with the positive psychosocial outcomes. One quasi-experimental study ($N = 61$) measuring the effect of leveled activities and peer mediation used students’ scores on the previous year’s state test to separate students into low, middle, and high achieving classes. Then, inside these three classes, teachers ranked their students by perceived ability to match high/low students for peer mediation. Using curriculum leveling and the peer groups, students in the high achieving class showed significant increases on their posttests compared to the control condition.

In this study, both special and general education students who received the treatment demonstrated positive academic outcomes (Simpkins et al., 2009). This finding is significant as it suggests that similar kinds of differentiating activities, such as leveling and peer mediation, can have a positive impact on a mixed-ability group of students; in other words, it suggests that some differentiating activities may be universally effective for diverse groups of students.

**Challenges.** Though DI practices have been found to produce positive outcomes, they are not delivered without challenges. Research indicates that teachers have questions of the time and energy needed to differentiate lessons, concerns of equity and fairness (Goodnough, 2010), and the influence of administration to contend with when facing decisions about differentiating instruction (Hertberg-Davis & Brighton, 2006). Especially for new teachers, differentiating every lesson, every day may be a daunting task. Even with a strong support system of teachers who can collaborate on their ideas, DI requires time and energy to collect data on students and interpret how it should be used to adapt instruction (Goodnough, 2010). It is also important to factor in the time it takes to build and maintain a classroom management system capable of
supporting DI (Tomlinson, 1999). The amount of total time it takes to differentiate may not be seen as practical or valuable by all teachers (Goodnough, 2010).

Along with the challenge of setting aside time to prepare differentiated lessons, the environment of high-stakes testing in public schools may run counter to the principles of DI (Rebora, 2012). Some teachers feel that high-stakes tests “narrows the curriculum” (Jones & Egley, 2006, p. 767) hindering, or at the very least, not addressing the development of critical thinking and 21st century skills (Rebora, 2012). These tests, some teachers believe, do not accurately measure the sum of students’ skills (Jones & Egley, 2006). Since high-stakes tests are used as evaluative tools for teachers, teachers might experience the pressure of accountability to a multiple choice test (Rebora, 2012) as greater than the need to creatively find ways to meaningfully and richly assess students’ actual understanding and application of a skill or concept (Tomlinson, 2001). Then, the demands of high-stakes tests may precede teachers’ willingness to experiment and implement with DI.

However willing, some teachers may question how equitable or fair DI is for a diverse group of students. For instance, one might question how fair it is for a higher achieving learner to lose points for missing questions on material more difficult or complex than that of their lower achieving counterparts (Goodnough, 2010). Since students are not receiving identical treatment, some might suggest that they are not receiving equitable treatment. However, philosophically, Tomlinson (1999, 2001) would argue that fairness is each student getting what he or she needs to grow in learning; though not all elements of instruction will be identical, each student is guided by high expectations for growth.

Finally, teachers’ efforts at DI are subject to outside influences that can encourage or hinder how, or to what degree, a teacher implements DI. Administrative support is one of those
critical influences (Hertberg-Davis & Brighton, 2006). A case study that examined this phenomenon found that teachers’ ($N = 4$) responses and attitudes to DI mirrored those of their administration. The participants expressed that (a) teachers need administrative support to feel comfortable enough to experiment with, and eventually implement, DI; (b) that effective DI required an administrator who desired it and believed its implementation is possible; and (c) that encouraging teachers to adopt DI required some degree of administrative focus and support in its development (Hertberg-Davis & Brighton, 2006). Teachers’ differentiating methods may also be impacted by the educational policy of their school systems, specifically when that policy encourages teachers to focus instruction towards sub-groups of students. In any case, the level of support and professional development teachers receive for DI can influence how and to what degree teachers will implement it. So, while DI may find support in the research literature, certain challenges do exist to teachers’ efforts to effectively apply the DI model of pedagogy.

**Best Practices in Middle School Science**

Middle school science is an underachieving content area. The National Assessment of Educational Progress (NAEP) in 2011 reported only 30% of eighth grade students scored at or above proficiency with only 2% of those students scoring in the advanced category (National Center for Education Statistics, 2011). Lederman (1999) lamented “there is presently much dissatisfaction with the levels of both teachers’ and students’ understandings of the nature of science” (p. 917). In addition to this difficulty with content knowledge, teachers may also lack *pedagogical* content knowledge. Pedagogical content knowledge refers to an understanding of how to apply effective instructional practices. A teacher’s deficiency in this area could compound the problem of how to lead students to higher achievement scores. Teachers “including those with advanced science degrees, had difficulties tailoring activities and materials
to the needs of their students and monitoring students’ learning” (Lee, Brown, Luft, & Roehrig, 2007, p. 57). The challenge of teaching middle school science may lie with the necessity to teach core scientific knowledge, its dynamic nature, and the ability to apply that core knowledge during scientific inquiry (National Research Council, 2005).

Therefore, in order to promote more effective science instruction, it is essential to develop a thorough understanding of both content and pedagogical knowledge in science. Science is “a method of learning about nature” (Staver, 2005, p. 6) with three purposes: to prepare students to learn science in higher education, to prepare students for careers in the workforce, and to develop scientific literacy (Staver, 2005). Scientific literacy in particular nourishes students’ ability to ask scientific questions and understand how to find answers. It includes the ability to describe, predict, explain, and support or refute concepts with evidence to engage in conversations evaluating scientific information Banilower, Cohen, Pasley, & Weiss, 2010). With this understanding of the goal of science instruction, the question becomes, “What do effective teachers do when they are teaching” (Parkay, Anctil, & Hass, 2010, p. 319) to support the development of scientifically literate students? An evaluation of the literature on the best teaching practices for middle school science reveals that varying and effectively applied instructional activities (including differentiating practices) that are grounded in a constructivist theoretical framework and delivered in a purposefully created and responsive learning environment represent the core of effective science teaching.

**Framework of constructivist learning theory.** Effective science teaching is built upon the theoretical foundation that learners “do not passively soak up information to build a storehouse of knowledge” (Miller, 2011, p. 33), but instead view “knowledge [as] a process rather than a state” where “people ‘construct’ knowledge” (Miller, 2011, p. 33). An important
aspect of this construction is its active nature. Students must interact with new information, “adapt[ing] the educative event to fit and expand their individual worldview” (Kellough & Kellough, 2008, p. 231). First, teachers should take time to explore students’ prior knowledge and experiences. Connecting new information to these existing schemata increases students’ motivation to learn and establishes the new information’s relevance (Staver, 2005). Introducing discrepant events, an observation or idea contrary to students’ existing conceptions, bridges prior experience with new information and puts students into a state of disequilibrium, increasing intrinsic motivation (Lederman, 1999; NRC, 2005). Then, as students complete instructional activities, they look back to their initial ideas on the subject to reflect on and revise earlier thinking to make sense of their construction of knowledge (NRC, 2005; Staver, 2005).

**Constructivism applied to science.** This learning process, consisting of students’ active construction of knowledge from recognizing prior experience with new information, completing instructional activities, and finally reflecting on their thinking, includes unique challenges for middle school science classrooms. First, students have a wide range of prior knowledge and experience with scientific concepts and inquiry skills (Staver, 2005). This means that teachers must simultaneously address content and its application in inquiry. Additionally, teachers combat the idea that science is a static set of facts by emphasizing the dynamic nature of scientific knowledge (Banilower et al., 2010). The goal is to move students to an “understanding [that] scientific knowledge often requires a change in—not just an addition to—what people notice and understand about everyday phenomena” (NRC, 2005, p. 401). To achieve this goal, teachers deal with students’ preconceptions by understanding students’ prior experiences (NRC, 2005), by strategically administering instructional activities that include explanations coming in
stages (Banilower et al., 2010), and concluding those activities with students using evidence to support their new knowledge (NRC, 2005).

**Building on students’ prior knowledge.** Connecting to students’ prior knowledge makes instruction effective (Banilower et al., 2010) and relevant (Parkay et al., 2010; Staver, 2005). By making these connections, teachers implicitly communicate that knowledge is “progressing out of the learners’ experiences rather than as something outside of those experiences” (Parkay et al., 2011, p. 311). New information can then be grounded in real-life experiences (NSTA, 2003a) so that teachers establish the purpose for learning and, consequently, help their students realize the relevance of the information. In science teaching, these connections help to identify misconceptions (Banilower et al., 2010) and clarify students’ background knowledge (NSTA, 2003b). Addressing students’ preconceptions of new information is an essential part of the active construction of knowledge (NRC, 2005). Teachers may connect to students’ prior knowledge by asking probing questions (Herrenkohl, Tasker, & White, 2011) and using pre-assessments. Palincsar, Magnusson, Collins, & Cutter (2001) found that, in three of the four studied classes, normally achieving students \( n = 92 \) and students with identified learning disabilities \( n = 19 \) scored very similarly on pretests, suggesting that building on the prior knowledge and experiences of students’ with special learning needs is a critical factor in their success. Establishing some baseline of students’ prior knowledge gives teachers a launching pad for instructional activities while also setting the stage for students to become aware of their own thinking about new content, revisiting their initial ideas after instruction to make sense of the new information as they actively construct new schemata.

**Sense-making.** As students complete the instructional activities they should be offered time to reflect and revisit their learning in order to make sense of it and firmly establish the new
information into their existing knowledge. The on-going sense-making stage is driven by frequent formative assessments so that students can receive feedback and reshape their thinking. It includes using reflective assessments for students to look back at their misconceptions and track the progress they have made in their learning. Affording time for sense-making provides opportunities for students to evaluate evidence and look for alternative explanations (NRC, 2005). Sense-making, used concurrently with instruction tied to students’ prior knowledge and experience, helps students to actively construct knowledge and incorporate new information into existing schemata.

**Inquiry-based instruction.** An effective application of this learning process (connecting to prior knowledge, instruction, and sense-making) of particular interest in science is the use of inquiry-based instruction. Inquiry is most effective when it is used not as an added activity to reinforce new information but as a central mode of learning new content. When inquiry is integrated with the teaching of core content, it can help to build scientific literacy (NRC, 2005). Inquiry-based instruction inherently includes these stages of the active construction of knowledge. Students begin with their prior experiences to generate questions and hypotheses. Then, they complete instructional activities, often with individual components to address the group’s problem, and finally share their results and discuss inferences (Parkay et al., 2010). Since in true inquiry all student groups may not reach the same conclusions as they report their results to the class, students have the opportunity to see the dynamic nature of scientific knowledge and its emphasis on using data as evidence. In this way, students simulate the real world community of scientists (Herrenkohl et al., 2011).

**Situating instruction in the ZPD.** It is important to situate the process of connecting to prior knowledge, delivering instruction that includes discrepant events, and utilizing sense-
making activities to students’ levels of readiness. As teachers get to know their students and administer pre-assessments, they can identify the individual nature of students and their corresponding readiness level. This pedagogical knowledge can then be used to modify instruction so that learning is not too challenging so that students become frustrated, and not too easy where time is wasted on what students already know (Shabni, Khatib, & Ebadi, 2010). In science, teachers must recognize the content area’s complexity and that students will approach learning differently. Pretests, varying the complexity of questions, and utilizing concrete materials and learning experiences, are essential to matching students to their zone of proximal development so that the instruction and learning environment are developmentally appropriate (Staver, 2005).

**The learning environment.** An effective classroom environment is a critical component of students’ learning according to constructivist theory since it sets the stage to facilitate students’ thinking. Cognitive constructivism even defines intelligence as an adaptation to the environment (Miller, 2011), suggesting that the stimuli provided there will be the foundation for all the learning that will take place in the classroom. This learning environment is shaped by the attitudes, knowledge, disposition, and organization dictated by the teacher.

**High expectations.** First, an effective middle school science teacher communicates high expectations for students’ learning (Brophy, 2000). This includes the teacher’s belief that all students can learn, (Staver, 2005) but that the student is accountable for that learning (Brophy, 2000). However, communicating high expectations for students also implies that the teacher will provide support to struggling students, such as providing necessary extra time for assignments and reaffirming students with encouragement. In this way, the teacher and students work collaboratively toward the common goal of achievement, encouraging the responsibility of each
party (Brophy, 2000). The high expectations are matched with appropriately challenging, but not threatening, tasks (Staver, 2005). During instruction, the teacher builds students’ confidence by monitoring what students are thinking and adjusting instruction as needed by providing individual feedback based on students’ degree of progress from their prior level of knowledge (Brophy, 2005; Staver, 2005).

**Emotional safety.** With this attitude of high expectations for all students, the teacher removes a threatening level of pressure by being sensitive to students’ emotional well-being. This means communicating caring to students, despite their differences, by getting to know them (Brophy, 2000). It includes respecting and accepting their different perspectives, and allowing time to deal with mistakes and questions. In providing this time, the teacher encourages students to be risk-takers and active participants in their own learning (Wormeli, 2001). Engaging students to become active like this is a characteristic that only becomes evident in the upper echelons of Maslow’s (1987) hierarchy once lower level needs such as physical safety, feelings of belonging, and self-esteem are met.

**Collaboration.** Working collaboratively helps to create “a culture of respect, questioning, and risk-taking” (NRC, 2005, p. 415). It demonstrates caring while also providing opportunities to develop that quality in students (Brophy, 2000). Collaborative learning environments afford quieter students the opportunity to talk with other students first, such as in think-pair-shares or mini-conferences, which can encourage their willingness to talk in front of the whole group (Palincsar et al., 2001). Collaborative learning is useful for students to give and receive feedback (Brophy, 2000), particularly during inquiry activities as students help each other learn, using their data as evidence to support or refute each other’s’ ideas (NRC, 2005). Collaborative learning is most effective when its use is guided by its appropriateness for the new
content and when students are taught explicitly, such as from teacher modeling or role playing, how they are expected to work in groups (Brophy, 2000; Kellough & Kellough, 2008). Heterogeneous groupings are the appropriate choice for most activities since they provide the most academic, social, and emotional support.

**Effective Management.** It is the teachers’ responsibility to create this type of collaborative, emotionally safe learning environment with high expectations. Therefore, effectively using classroom resources such as time and materials is important to implicitly model for students what is expected of them; so important that classroom management, and the teacher-student relationships that drive it, have been shown to be indicators of student achievement (Marzano & Marzano, 2003). In order to manage classroom resources effectively teachers should “allocate most of the available time to activities designed to accomplish instructional goals” (Brophy, 2000, p. 10). Quick transitions and establishing the purpose for the instructional activity help to streamline the learning process. However, quality instruction also supports good management when students are engaged and monitored in appropriately challenging tasks with high expectations (Brophy, 2000).

**Qualities of an effective science teacher.** While establishing the environment for learning involves setting the tone and organization of instruction, it also includes the disposition and skills of the teacher. With the right qualities, the teacher him/herself can motivate students to reach the goals of high expectations by making connections to students’ real-world experiences and balancing intrinsic and extrinsic motivators (Banilower et al., 2010).

**The teacher’s self-efficacy.** Maintaining high expectations for students means that the teacher must also have the ability to teach those students to achieve those academic goals; in other words, high expectations for the students requires the teacher to have high expectations for
himself or herself as well. An optimal sense of self-efficacy includes accepting a major role in the accountability for students’ learning, while holding a belief in the teacher’s own effectiveness (Staver, 2005).

*The teacher’s content knowledge.* “Teachers with stronger content knowledge are more likely to teach in ways that help students construct knowledge, posing appropriate questions, suggest alternative explanations, and propose additional inquiries” (Banilower et al., 2010, p. 5). There is a correlational relationship between the teacher’s content knowledge and student learning (Banilower et al., 2010). Therefore, as teachers have a more complete understanding and are comfortable communicating their content, students are more likely to achieve at higher levels.

*The teacher’s pedagogical content knowledge.* Pedagogical content knowledge (PCK) for effective middle school science teaching is defined as “the knowledge that science teachers use to facilitate students’ understanding of scientific concepts and to encourage their scientific inquiries” (Lee et al., 2007, p. 52). It goes beyond an understanding of the content to an understanding of how to lead someone through the process of learning it himself or herself. It includes a knowledge of science, the instructional goals of applying it to scientific inquiry, the students and their differences, how the curriculum is organized, and the ability to effectively govern a variety of teaching strategies and assessments, especially those that include real-world application (Lee et al., 2007; NSTA, 2003b). This set of skills may be difficult for new teachers, particularly when it comes to teaching and monitoring students with special learning needs. Certainly comprehensive, new teachers should be encouraged that PCK is developed through experience as it becomes integrated with the teacher’s knowledge and values of teaching (Lee et al., 2007).
The teacher's ability to engage students intellectually. Teachers must motivate students to be involved with the ideas and concepts related to the explicit learning goal of instruction. The ideas and concepts must be powerful and meaningful to engage students in inquiry (Brophy, 2000; Palincsar et al., 2001). These powerful ideas must be communicated with the purpose for learning the instructional objective and how it connects to prior knowledge and experience; students need to know what they are expected to learn and why they are expected to learn it (Brophy, 2000). Students will retain new information better if they know “when and how to apply [the new skill or knowledge]” (Brophy, 2000, p. 17). Establishing this purpose for learning captures for students the meaning and relevance of new information, providing them with more reason to engage in the learning process of making connections, interacting with information, and then reflecting on it to incorporate it into existing knowledge (Brophy, 2000). Teachers may develop this ability to intellectually engage students by reflecting on what students will be thinking about as they engage in the instructional activity. Using interesting materials or cooperative learning strategies are not effective engaging tools in and of themselves, and so must be selected and applied with an understanding of how students will think through the instructional activity (Banilower et al., 2010).

Instructional strategies. Working from a constructivist learning theory framework and having established an effective learning environment, an effective middle school science teacher must purposefully choose the right types of instructional activities to provide students opportunities to interact with new information. These activities should have a clearly defined purpose, such as the acquisition of a specific skill or concept, and engage students (Thurlow, Syyan, Barrera, & Liu 2008). A teacher’s choice of instructional activities is influenced by the teacher’s style, the characteristics of his or her students, the school culture, the community, and
the availability of resources (Parkay et al., 2010). The most effective instructional strategies are ones that “are developmentally appropriate, meet students’ diverse learning needs, and recognize the importance of learning that occurs in social contexts” (Parkay et al., 2010, p. 315). In a survey of teachers ($N = 36$) to solicit responses about the most effective science instructional strategies, Thurlow et al. (2008) found that hands-on activities, modeling, labs, pre-reading strategies, daily re-looping where students generate a review of the previous class session, vocabulary development, graphic organizers, multiple and varied exposure to content, and using visuals were voted to be most effective; hands-on activities had the highest cumulative score. However, it is not necessarily a specific strategy that makes a teacher effective but rather the selected set of strategies and their calculated application based on characteristics of the students and the new content.

*Utilizing varying and multiple instructional strategies.* Effective teaching is varied, providing multiple ways of both presenting new content and having students process it. Effective teaching utilizes “a mixture of instructional methods and learning activities” (Brophy, 2000, p. 6). This includes both the modality from which instruction is delivered (auditory, visual, kinesthetic, etc.), or the input of instruction, as well as the types of tasks that students complete, or instruction’s output (Kellough & Kellough, 2008; Palincsar et al., 2001). “Modality integration (i.e., engaging more of the sensory input channels, using several modalities at once or staggered) has been found to contribute to better achievement in student learning” (Kellough & Kellough, 2008, p. 229) by engaging students with a more preferentially structured learning environment particularly with a group of diversely achieving students (Rayneri, Gerber, & Wiley, 2003) and students with ADHD (Brand, Dunn, & Greb, 2002). These modalities may be administered effectively through a combination of independent and cooperative work (NSTA,
that allow for multiple experiences providing evidence that leads to the same conceptual conclusions (Parkay et al., 2010). Therefore, it is not the mode of teaching, such as the traditional method (lecture, readings, independent practice, and a weekly lab) or the reform method (hands-on activities conducted in small groups where students choose their topics) that is as important as the teacher’s ability to engage students with the scientific ideas that are aligned with instructional goals and related to students’ real-life experiences (Banilower et al., 2010). The content itself should drive instructional decisions (Parkay et al., 2010), as teachers utilize assignments that should be varied and interesting to motivate student engagement, sufficiently new or challenging to constitute meaningful learning experiences rather than needless repetition, and yet sufficiently easy to allow students to achieve high rates of success if they invest reasonable time and effort. (Brophy, 2000, p. 23)

**Hands-on/laboratory activities.** As a part of this set of varying instructional modes and activities, hands-on activities are not only highly recommended by science teachers (Thurlow et al., 2008) and the NSTA (2003b), but they also provide the opportunity for students to engage in inquiry. Inquiry allows for simultaneous exploration of new content and the development of scientific literacy (NRC, 2005). The NSTA (2003b) even recommends that up to 80% of instruction be delivered through lab inquiry activities. However, it is important that these activities be implemented with the instructional objective in mind in order to engage students intellectually. For instance, “a laboratory activity performed only to confirm a previously presented idea is unlikely to deepen students’ understanding of that idea; students will likely focus more on finding the ‘right’ answer than on understanding the underlying concepts” (Banilower et al., 2010, p. 6). The engagement
that leads to understanding then only becomes realized when students are presented with a task that promotes an understanding of the ‘how’ of the concept, similar to Vygotsky’s (1978) idea of internalization, rather than simply observing a phenomenon that confirms what they have already learned. Likewise, students should “feel motivated to engage with the ideas, not just the materials,” (Banilower et al., 2010, p. 9). Then, the most effective lab activities are ones that inquiry-based, allowing students some decision-making power (and corresponding risk) in approaching open-ended questions that may produce different results from that of their classmates.

**Cooperative learning activities.** This type of inquiry learning may be facilitated by having students work in groups, sharing responsibility for learning tasks, and requiring evidence from each group member to reach conclusions about the concept being explored. Cooperative learning, by definition, is not simply having students work together, but rather it is students working with an interdependence to achieve a common goal that the group shares a grade for so that there is a vested interest in each other’s’ learning (Johnson & Johnson, 1994). In a supportive learning environment, collaboration can create “a culture of respect, questioning, and risk-taking” (NRC, 2005, p. 415). Cooperative learning groups are most effective when students are grouped with compatible personalities in mind and with a teacher that continually monitors group interactions and provides feedback (Palincsar et al., 2001). The teacher (or teachers in a co-teaching, inclusive classroom) should model “effective ways of engaging in small group interaction (e.g. sharing turn-taking, use of the materials, and finding a good match between the skills of the participants and the tasks to be done)” (Palincsar et al., 2001, p. 31). Therefore, cooperative learning in and of itself is not inevitably effective, but instead, it is a skill that must
be modeled and utilized at times when it appropriately matches the content, especially during inquiry.

Cooperative activities include a range of techniques (Kose, Sahin, Ergun, & Gezer, 2010) such as long-term group investigation where students work on projectors over a period of days to even months to model real-world businesses (Mandel, 2003), student team learning where students compete or complete tasks as a part of a team (Slavin, 1995), the structural approach where teachers utilize several modes or structures to organize a range of cooperative work (such as think-pair-shares, jigsaw groups, or even whole-class question and answer) instead of designing single cooperative activities (Kagan, 1989), and the Learning Together model that emphasizes “the principles of positive interdependence, individual accountability, face-to-face interaction, social and collaborative skills, and group processing” (Kose et al., 2010 p. 171). Learning within a community models the scientific community, as students collaborate to not only gather data as evidence, but also to use that evidence to support or refute inquiry-based claims about the content (Palincsar et al., 2001). These types of cooperative learning techniques have demonstrated better information retention, improved relationships among students, boosts to self-esteem, motivation, social development, and the ability to express one’s thoughts than traditional direct instruction. Likewise, cooperative learning has been found to be “more effective in teaching science than the traditional, individualistic, or competitive approaches” (Kose et al., 2010, p. 171).

Direct instruction. Though inquiry-based methods are so heavily encouraged by the NSTA (2003b) and cooperative activities have produced positive academic outcomes (Kose et al., 2010), direct instruction may still play at least some role in the middle school science classroom as a part of a larger, multifaceted approach to instruction. In contrast to the discovery-
based methodology of inquiry, direct instruction provides students the “information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture” (Kirschner, Sweller, & Clark, 2006, p. 75). Direct instruction may be demonized so that it evokes imagery of dry lecture and memorization of facts; however it is important to note how this definition includes an element of scaffolding to support students’ learning and is not necessarily incompatible with the hands-on and minds-on approach of NSTA (2003b). In fact, Kirschner et al. (2006) point out that it is through the direct instruction delivered during the scaffolding of more discovery-oriented activities where teachers step in to model a procedure, lead students through summarizing information, and/or spark a conversation about the task at hand that may make inquiry seem so effective. Direct instruction can contribute to students developing a foundation for new content by communicating fundamental points of the new content and by guiding students’ practice of essential skills (Parkay et al., 2010). Direct instruction can also help to eliminate any confusion about what students are expected to learn (Upadhyay & DeFranco, 2008). While the guidance that direct instruction affords can contribute to student learning (Kirschner et al., 2006; Parkay et al., 2010) and has even been shown to produce comparable learning gains to more inquiry-based activities (Cobern et al., 2010), it is not recommended or even mentioned as a part of the NSTA’s (2003b) position statement on middle school science education and so is not included as a part of the data collection on best teaching practices.

The effective use of variety. No matter what types of instruction and activities are selected, teachers must purposefully select their methods to meet students’ diverse learning needs and with thought to the best ways of communicating new content. For instance, direct instruction is “most appropriate for step-by-step knowledge acquisition and basic skills
development but not appropriate for teaching less structured higher-order skills such as writing, the analysis of social issues, and problem solving” (Parkey et al., 2010, p. 314). Therefore, direct instruction might be better suited to content that students have very limited prior knowledge and experience with; then, once some background knowledge has been established, other methods (e.g., cooperative or independent activities, hands-on labs) are more conducive to scientific inquiry. Likewise, providing students with background knowledge may require some use of the class textbook. Using the textbook should not be taboo for science teachers, since it can be used constructively as students make predictions about the text based on prior knowledge and then revisit those predictions, revising them based on the readings (Radcliffe, Caverly, Peterson, & Emmons, 2004). Inquiry learning is “best suited for teaching concepts, relationships, and theoretical abstractions, and for having students formulate and test hypotheses” (Parkay et al., 2010, p. 316). These higher-order thinking skills require background knowledge that direct instruction or textual activities are more aptly suited for.

Curriculum organization. The set of varied instruction and learning tasks a teacher employs must be properly organized to be effective. Teachers may use all kinds of learning tasks, from lectures to inquiry-based activities, but the “information is easier to learn to the extent that it is coherent—the sequence of ideas or events makes sense and the relationships among them are apparent” (Brophy, 2000, p. 17). Then, the steps of instruction should be small, appropriately paced, effectively communicated that invite interaction (without distracting digressions), demanding mastery of preceding steps before moving on, summarized, and connected with other learning followed by assessments that require students to put the learning into their own words and apply it. To achieve this kind of organization, instructional objectives should consider depth before breadth and be taught in a pattern that builds a network of ideas.
All activities and assessments should be aligned, directly helping to achieve the instructional objectives, and provide information for guiding instructional decisions (NSTA, 2003b). This coherency to specific skills and/or objectives should be driven by “practice [that] is distributed across time and embedded within a variety of tasks” (Brophy, 2000, p. 21). Tasks should build in complexity, incorporating scaffolding during guided practice at the beginning before moving on to independent practice (Brophy, 2000).

**Modeling.** In whatever learning strategies are selected to achieve the instructional objectives, modeling is a critical component to both demonstrating how students should interact with the information and with each other. Socially, it should be used to demonstrate how to work in groups effectively (Palincsar et al., 2001). Cognitively, modeling is important to teach metacognitive skills including making connections to prior knowledge. This cognitive modeling may be especially important when students must read for information (Radcliffe et al., 2004). Cognitive modeling is also significant to express how the student should choose strategies to approach problems and can be used effectively in conjunction with leading questions in order to guide students’ thinking through the learning process. Leading questions scaffold students’ thinking while showing them how to monitor their own thinking as they incorporate new knowledge (Brophy, 2000).

**Strategic assessment.** Assessment, like instruction, should vary and happen frequently, both informally and formally (Brophy, 2000; NSTA, 2003b). Formatively, carefully aligned assessments “can become effective learning tools” (Herrenkohl et al., 2011, p. 6). Frequent formative assessments help the teacher monitor students’ progress, create opportunities for feedback, and identify re-teaching and intervention needs. Assessment should be used to evaluate students and to make improvements in the delivery of the curriculum. Teachers should
use the results of the assessments “to identify learner needs, misunderstandings or misconceptions that may need attention; to suggest potential adjustments in curriculum goals, instructional materials or teaching plans; and to detect weaknesses in the assessment practices themselves” (Brophy, 2000, p. 30). Then, assessment is much more than just a platform for giving grades, but it serves to inform both student and teacher of their instructional progress.

Applying best teaching practices in science. Though middle school science represents an underachieving content area (NCES, 2011), there exists a wealth of research on how to apply constructivist learning theory to develop an effective learning environment and purposefully select instructional methods and activities proven to support students’ learning. Identifying a particular strategy to increase student achievement can be somewhat problematic in real-world settings, so teachers should be encouraged to employ a varied set of teaching strategies as they develop PCK. No one strategy can make a teacher effective, but knowing how to wisely implement a set of research-based strategies, according to the needs of students and the methods compatible with the content, may provide the best avenue for developing teacher effectiveness. The development of experience through experimentation with new strategies to incorporate them into routine teaching practice, together with pre-service training specific to teaching the nature of science and scientific literacy, offer the greatest hope for increasing students’ achievement in middle school science (Banilower et al., 2010; Herrenkohl et al., 2001; Lederman, 1999; Radcliffe et al., 2004).

Where DI and Best Teaching Practices in Middle School Science Meet

Differentiated instruction (DI) is a flexible, adaptable approach to pedagogy that is geared towards meeting the various learning needs of students in a single classroom (Tomlinson, 1999). It is a means to “match the challenge to the student, finding varied ways to help each
child stretch intellectually” (Wormeli, 2001, p. 71). DI’s key emphases are on the teacher’s recognition of students’ differences, aligning instruction and assessment, making modifications to the content, process, and/or product of instruction, teacher-student collaboration to shape the learning environment, flexible grouping strategies, and balancing class and individual norms and goals (Tomlinson, 1999). This description of DI and the consensus of this literature on best teaching practices for middle school science share similar theoretical underpinnings such as an emphasis on utilizing a recognition of how students learn to shape instruction, scaffolding, and matching learning tasks to students’ zone of proximal development (Brophy, 2000; Parkay et al., 2010). Likewise, several articles mention the tenets of DI, without specifically referring to DI, as evidence of best practices teaching. For instance, Kellough and Kellough (2008), researchers and authors of the resource guide Teaching Young Adolescents: Methods and Resources for Middle Grades Teaching wrote:

Teachers who are most effective are those who adapt their teaching styles and methods to their students, using approaches that interest the students, that are neither too easy nor too difficult, that match the students’ learning styles and learning capacities, and re relevant to the students’ lives. (p. 229)

The emphases on adapting instruction to the students, finding students’ readiness levels, and making relevant connections are all components of DI. Staver (2005) wrote that teachers should “adapt available curriculum materials and teaching strategies to fit the diverse needs of all students” (p. 16). Several sources reference using frequent formative assessments to gather data about students’ thinking in order to adjust instruction to meet students’ needs (Brophy, 2000; NRC, 2005; Palincsar et al., 2001). Implementing a variety of instructional modalities, including offering students choices, is another characteristic espoused by best teaching practices advocates
(NSTA, 2003b) and DI (Herrenkohl et al., 2001; Tomlinson, 1999). DI is even described as a part of pedagogical content knowledge as teachers recognize students’ differences provide multiple ways to engage in the content, addressing students’ difficulties acquiring new information, and assessing, as well as building on, students’ prior knowledge in order to develop instruction (Herrenkohl et al., 2001). While DI and the best teaching practices for teaching middle school science may be communicated differently and differ in their aims and scope, both share some fundamental theoretical and practical principles.

Summary

While the body of literature describing effective teaching practices in science is extensive, the literature on DI lacks some important empirical foundations. First, the model of DI needs more empirical basis to demonstrate positive outcomes to connect its theory with real practice (Ernest et al., 2011a). The current state of literature is somewhat limited in its examination of DI as a philosophical and holistic approach to pedagogy rather than the strategic use of a particular intervention (Ernest et al., 2011a; Ernest et al., 2011b). In order to address this gap in the literature, more research is needed that describes the extent to which teachers differentiate and the strategies individual teachers incorporate to effectively differentiate instruction (Goddard, Neumerski, Goddard, Salloum, & Berebitsky, 2010). Once a more complete image of DI is described in its intended theoretical context, then it will be able to be measured against the best teaching practices to determine its role, if any, in delivering a higher quality education.
CHAPTER THREE: METHODOLOGY

Introduction

The purpose of the methodology chapter is to describe the design and implementation of this qualitative study. A qualitative approach was appropriate for the research questions that explored how and to what extent effective middle school science teachers apply differentiated instruction (DI). Since no validated research instruments exist to measure the dynamic nature of DI, a qualitative approach provided rich data that was collected first-hand and in the natural setting of middle school teaching. The dynamic nature of DI means that teachers may implement it differently according to their pedagogical values and teaching contexts. Teachers may use different implementations that both produce positive academic outcomes for their students. This introduces a subjective element into what constitutes the most effective DI practices, and this type of open-ended investigation was better suited to a qualitative rather than quantitative research design. By richly describing the contexts in which these differing implementations arise, readers are able to make better comparisons to their own contexts (Gall et al., 2007). A qualitative approach was also more appropriate for generating a model of the role that differentiated teaching strategies and philosophies have in the production of positive academic outcomes for middle school students in science.

Design

I selected a grounded theory design to generate a model explaining the role of DI in effective middle school science instruction. This design uses raw qualitative data to build and develop its theoretical components (Corbin & Strauss, 2008) leading to an emergent theory or model (Gall et al., 2007). In this way, data was collected in the natural setting of middle school science classrooms and analyzed to identify the categories, themes, and context that attribute to
the development of a model. Its five main components—“the central phenomenon, causal conditions, strategies, conditions/context, and consequences” (Creswell, 2007, p. 68)—generated a rich description of effective middle school science teachers’ application of DI strategies. The phenomenon and strategies components addressed how effective teachers utilize DI in their instruction while the remaining three components of causal conditions, context, and consequences focused on how teachers’ DI practices are rooted in their beliefs about how students learn. By utilizing the systematic approach (Creswell, 2007) to a grounded theory design, the data collection and analysis process was somewhat structured for the development of a model that answers the research questions. As a beginning researcher, Corbin and Strauss’s (2008) work served as a template and example for me to follow in data analysis. Though not fully structured into a step-by-step process, a systematic approach helped to “to think more self-consciously…about data” (Corbin & Strauss, 2008, p. 9). This flexible structure included the cooperating techniques of open and axial coding, exploring the context, identifying the process (how the interlinked concepts were applied within the context), and finally building the theoretical model upon the foundation of a core category (Corbin & Strauss, 2008).

Qualitative research is dynamic, so the analytic techniques Corbin and Strauss (2008) explain and demonstrate provided the tools with which to mine insights from the data as the theoretical constructs became apparent through data collection. For instance, Corbin and Strauss (2008) advocate the use of a paradigm, “a perspective, a set of questions that can be applied to data” (p. 89), as one of the tools that helped to structure data analysis. As I systematically made use of these analytic tools during the fluid, constant comparative process of data collection and analysis, the grounded theory design afforded me the opportunity to build a model of DI’s role in effective middle school science teaching from the data itself.
Research Questions

The following questions framed this study and guided data collection leading to a model describing how differentiated instruction relates to best teaching practices in middle school science:

1. What best teaching practices do effective middle school science teachers employ?
2. How do effective middle school science teachers’ practices reflect DI principles?
3. How do effective teachers’ beliefs about how students learn influence the way and the degree to which they implement DI techniques into their pedagogical practice?
4. How do the dynamics of a middle school science classroom, particularly the unique characteristics of its students (including socioeconomic status, ethnicity, cultural upbringing, and levels of academic achievement) and the availability of resources for enhancing the learning environment, influence teachers’ implementation of DI?
5. What other factors influence teachers’ implementations of DI?

Participants

I employed a theoretical sampling process in order to gather the participants for the study. Theoretical sampling provided the flexibility to purposefully select participants for their ability to add substance to the data until it was saturated sufficiently to develop the model (Corbin & Strauss, 2008). In this way, “analysis guide[d] the research” (Corbin & Strauss, 2008, p. 146). Once the emergent model began to take shape, discriminately sampling participants provided data to either confirm or disconfirm the theoretical constructs of the model (Creswell, 2007).

Before I began to sample for participants, I obtained IRB approval (see Appendix A) and the approval of the school district where the data was collected. With both of these permissions, I began theoretically sampling for participants. For the purposes of this study, I selected teachers
who were most likely to utilize the recommended best teaching practices for middle school science as evidenced by their success at leading students to high achievement. To identify participants, I first looked for middle schools within the American County Schools (pseudonym) district that were the likely home for science teachers with a demonstrated record of producing academic achievement gains in their students. Specifically, I accessed the state website that provides school, grade level, and departmental achievement gain scores, also commonly called teacher effectiveness or value-added scores, to search out middle schools with science departments averaging the highest rating of effectiveness score (Level Five). These scores measure the average learning gains of a grade level department by comparing students’ scores to a projected growth estimate (calculated for each student) the state provides. The achievement estimates are calculated by the value-added assessment system of the state and are determined by students’ previous achievement while other variables, such as race or socioeconomic status, are theoretically controlled (Tennessee Department of Education, 2012). Grade level departments that averaged two standard deviations above the projected growth estimate would be considered as a Level Five as it is calculated for individual teachers. Since individual teacher’s value-added scores are not public information, this method seemed the most appropriate for initially identifying likely participants. Then, per the mandate of the school district’s research policy, I emailed principals (see Appendix B) of those schools with grade level science departments that average the Level Five effectiveness score and asked for permission to conduct research in that school along with possible recommendations of teachers who might be interested in participating. Of the middle schools in the district, each school had at least one science department that met the Level Five criterion sometime in the past three years, and six of those schools’ principals gave me signed written permission to begin research. Having obtained that
written permission according to the guidelines of the district research policy and the IRB, I contacted the teachers via email using a recruitment letter for the study (see Appendix C) that included a digital copy of the informed consent document (see Appendix D), and a form of some basic information that included questions about teaching experience, certifications, and the critical item about value-added scores from the past three years (see Appendix E). It is important to note that because value-added scores are intended only for individual teachers and their administrators, the question was answered voluntarily even though it served as the objective criterion by which teachers are selected to participate in the study. The initial group of potential participants included 22 of an eligible 28 teachers that responded to the email and recruitment letter, 16 of which were interested in participating in the study. Seven of those teachers who agreed to participate and individually scored at the Level Five criterion sometime in the past three years (as indicated on the recruitment form) were followed up with to schedule the next phase of research. Six teachers provided consent but did not score at the Level Five effectiveness rating sometime in the past three years and so were thanked for their willingness to participate but were not invited to continue with the research. The remaining three teachers who initially responded with interest did not return their recruitment letters, and so, without knowing whether they met the scoring criterion, were not considered to participate in the study.

Teachers scoring at a Level Five (significantly above expectations), the highest level, were expected to be the richest source of data for this study. These teachers have seen their students average a score of two or more standard deviations above their estimated achievement, demonstrating a significant degree of success in leading their students to positive academic outcomes. Theoretically, these teachers seem most able to reflect the DI model’s fluid mindset (Sousa & Tomlinson, 2011) since their students, on average, demonstrated achievement higher
than what was projected by the state according to each student’s past achievement scores. Since there is no minimum achievement score in this measure and each student is compared to his or her past performance, teachers scoring at Level Five have demonstrated the ability to lead a diverse set of students to higher levels of academic success than they have previously experienced. It was also expected that teachers scoring a Level Five effectiveness rating would be the most likely to utilize the NSTA’s (2003b) recommended teaching practices for middle school science. Thus, this group of teachers makes up the most appropriate population to sample from for their ability to contribute data as to how DI might fit into the best teaching practices.

By seeking out participating teachers who have scored a Level Five within this timeframe, I began gathering data from teachers who may have scored the criterion level in the past year, so the teachers’ methodologies are fresh, as well as data from teachers who have seen their scores drop from the highest effectiveness level in the recent past. Teachers whose scores have varied were able to offer insights into the variables that account for those changes; in other words, they elaborated on the teaching practices or contextual themes that have contributed to Level Five scores while also recognizing differences that may have caused their scores to drop.

Next, I asked initial participants for other contact leads based on their suggestions of other effective teachers they may know in the county. They were able to recommend other teachers they knew to be effective or that may have influenced their teaching practices, providing an opportunity to employ the snowball sampling method (Creswell, 2007; Gall et al., 2007). These suggestions were then followed up with according to the permissions I received from the middle school principals. Three teachers were recommended in this fashion. One taught at a school that did not provide written permission for the study. Another did not respond to the initial email and recruitment letter. The third recommended teacher responded positively to the
email, met the scoring criterion on the recruitment letter, and participated in the study. In this way, I followed Corbin and Strauss’s (2008) recommendation for using data analysis to guide theoretical sampling by using the Level Five scoring criterion to identify the target population and teacher recommendations to follow up with potential participants that could provide theoretically rich data. A sample size between 20 and 30 participants is consistent with Creswell’s (2007) recommendation for grounded theory studies, but the sample size of eight was sufficient since the themes and categories became fully saturated with the data provided from the study’s eight participants given the specificity of the selection criterion. This smaller sample size, selected for their ability to provide rich examples of effective middle school science teaching and without regards to age, gender, ethnicity, or teaching experience, was appropriate since participants provided data redundant with the themes and categories that had already been developed concerning the implementation of DI. Additionally, a sample size of eight was practical for the depth of the study’s research questions and the time restraints with which I had to conduct the research.

These methods led to the selection of eight participants (see Table 1) representing five middle schools in American County Schools.
The participants ranged in their science teaching experience from Henry teaching in only his third full year to Elise and Fred who both were in their twelfth year. Five of the participants had scored a teacher effectiveness rating of Level Five in each of the past three years. Elise and Fred recorded one lower rating, a Level Four and Level Three respectively, sometime in the past three years. George, having had his specific teaching assignment change each of the last three years, recorded a decreasing trend in his teacher effectiveness scores from Level Five three years ago to a Level One in the most recent school year. The variation in teacher effectiveness ratings proved
to be a rich source of data on what elements of teaching these participants believed to be the most crucial to achieving those high ratings.

**Setting**

I chose American County Schools as the setting for this research for its convenience (since I teach in the district) and for its professional development focus in recent years. Of particular interest to this study, American County Schools has hosted a DI conference, lasting two full days, in the summers from 2009-2011 before re-framing the conference in 2012 as the Best Practices conference and in 2013 for the implementation of Common Core standards. The renaming of the conference, conducted in a surprisingly similar manner to the DI conferences, seemed to be in response to the new teacher evaluation system launched in the 2011-2012 school year, and then, in 2013, as a response to changing curricular standards. Some schools’ administrations require teachers to attend, but not all. Many teachers elect to participate, since it completely fulfills the required allotment of annual professional development hours in this county. Since American County Schools have placed such an emphasis on DI/best practices, as evidenced by the opportunities offered in professional development, this seemed an optimal site for exploring the role of DI in effective teaching, particularly in the apparent overlap of how DI and best practices are perceived. The simple renaming of the summer professional development conferences between 2011 and 2012 suggests that the school district considers DI as comparable to best practices but is empathetic towards the pedagogical demands of the new teacher evaluation system. By renaming the conference in 2012, attendees were provided with information within the specific context of improving teacher practice to score highly on the teacher evaluation system as opposed to a context focusing on DI that may have been perceived by teachers as more limited in scope and not as helpful for the perceptually all-important teacher
evaluation scores. Anywhere from 85-100% of teachers’ evaluation scores are generated from administrative observations and student achievement data on the end of the year high-stakes test, so, naturally, teachers are drawn to professional development specifically geared towards meeting the criteria on observational evaluations and teaching strategies that have been demonstrated to promote students’ achievement. However, the district’s former emphasis on differentiated instruction might introduce some practitioner bias to the study as many teachers share the same influence from those earlier iterations of the county-wide professional development conference and the same types of administrative/peer support for the practice.

The Researcher's Role

Working from a social constructivist paradigm, I have acted as the human instrument (Lincoln & Guba, 1996) to gather data from teachers’ experiences with DI, interpret them, and finally integrate them into a model of the effective implementation of the practice. As such, it is important to understand my role in the research setting and possible biases that could have arisen in my interpretations. I gathered data from teachers within the county that I also work in, taking advantage of prior associations and connections to identify and ask for possible participants. Two of the participants are colleagues that I have worked with in the science department of the school where I work (one current and one past), possibly introducing a bias into how I have interpreted these participants’ experiences. Since we have shared some of the same in-service training, it is possible that I may have been affected by our shared experiences. However, member checks with other participants during analysis and an expert review of my observational protocols may have helped to mitigate this bias.

Additionally, potential bias exists in my valuation of DI. My interest in the approach to teaching began during graduate work where I conducted action research on the time-on-task
effect of choice—a component of differentiating instruction to students’ interests (Tomlinson, 2001). This interest continued as the school district that hired me emphasized differentiated instruction, offering multiple professional development opportunities related to it. From this background and interest, I have chosen to further delve into DI for this dissertation. However, now that I have conducted a much more extensive review of the literature on the topic, it has been a process of discovering how little I really understood of DI as a young teacher attempting to apply its principles in my own classroom or hearing how others have utilized it. The more I have read about DI, the more questions I have about how teachers (including myself) have attempted to apply it practically in light of how extensive the model truly is. In other words, the more I have read to understand the model of DI, the more tension I perceive between its theory and practice. Therefore, this study was the result of my exploration into that tension so that I might describe DI’s practical value as a part of effective science teaching.

**Procedures**

I received IRB approval (see Appendix A) and the consent of American County Schools before I began to collect any data. Once I received these approvals, I identified eight teachers who met the selection criterion during the sampling process already described in the participants section. I obtained participants’ written informed consent prior to the first observation before data were collected. Also prior to data collection, I pilot tested the observational instruments with the help of a fellow teacher from my own school who was not one of the study’s eight participants and an instructional facilitator in the school district. The feedback from the pilot led to a streamlining of the observational instruments’ formats and more clearly defined definitions and boundaries for the criteria the instruments measure. Data collection involved four consecutive in-person observations, a DI questionnaire, interviews, and gathering classroom
artifacts. At the outset, teachers were informed that the purpose of the study was to explore best teaching practices in middle school science. In my first contact with participants, I emphasized that they have already demonstrated this expertise, underscoring that I only wanted to study how these effective teachers normally conduct class. Participants were informed that I was not evaluating their methods nor did I have any expectations about the kinds of teaching strategies they utilized during the observations. Rather, I wanted to study the normal ebb and flow of their instruction since it resulted in significant learning gains for students. With the participants’ understanding, I hoped to prevent any changes in behavior due to the Hawthorne effect (Gall et al., 2007). All data gathered from these classroom observations were recorded on two observational protocols (one for best practices and one for DI) instruments described later in this chapter. Participants were reassured that my intent was not to evaluate them on how they implemented DI but only to observe how the theory might contribute to their effective teaching practices. Prior to the interview, teachers were given a questionnaire concerning their perceptions and use of DI. I collected the questionnaire data prior to the interviews in order to target certain ideas or teaching strategies more completely during the interview. Interviews were scheduled at the participating teacher’s school during a planning period or after school. The interviews were semi-structured, taking advantage of an interview protocol containing a basic outline of the questions that were asked. Interviews were recorded, transcribed, and reflected upon with researcher-generated memos. I kept a digital and hard copy folder of each participating teacher’s data for later analysis.

**Data Collection**

The primary methods of data collection in this study were classroom observations, a DI questionnaire, an interview, and the collection of any relevant classroom artifacts that
demonstrate DI practices. Collecting multiple forms of data, particularly those taken in the field, is characteristic of qualitative research and serves to increase the trustworthiness of the findings through data triangulation (Creswell, 2007).

**Observations**

Classroom observations provided one of the richest sources of data for how teachers actually utilize the recommended science teaching practices and DI during instruction, despite what later interviews revealed about how they articulate their pedagogy and implementations of DI (Corbin & Strauss, 2008). I personally observed each participant four consecutive times within a single unit in their curriculum. Classroom observations were pre-scheduled within a two-week window in the second quarter of the school year so as to not inconvenience teachers and to ensure that the daily lesson consisted of authentic teaching and would not be interrupted by other school activities such as testing, pep rallies, etc. These observations were conducted at the participating teachers’ home schools, lasting one class period typically consisting of around forty-five minutes. Observations were scheduled so as to take participants’ class preferences into account (so far as it could be arranged with other participants being observed on the same day) and sometimes included only general education students and sometimes a blend of general and special education students depending on the inclusion procedures of the participant’s school. In order to ensure that the observational data was authentic in the case of observations in an inclusion class, I asked teachers during the interview to distinguish between IEP-mandated differentiating techniques and those that the teacher selected personally. As noted earlier, either setting can potentially provide rich data since even typical classrooms include students with a range of academic abilities (Hertberg-Davis, 2006). Each participant explained my presence in the classroom to the students during the first observation, and I had very limited interactions with
the teacher and students, putting me in the middle-ground position of a participant observer (Creswell, 2007).

Observational data consisted of two filtering lenses: one of the best teaching practices supported by the research literature on science pedagogy and one of DI. Therefore, two instruments, and thus two perspectives for each observation, were used to gather observational data (see Appendix F) for the development of descriptive and reflective notes (Creswell, 2007; Gall et al., 2007) according to each lens. In order to facilitate accurate data collection on these two instruments, participating teachers were audio recorded during the observations so that, as I transcribed the observations, I could clarify and/or review notes made on the research instruments. Additionally, a committee member could review these audio recordings as evidence to support the codes I generated during data analysis.

DI observational protocol. First, the DI protocol shown in Figure 1 is structured differently to record how elements of the four domains of instruction—content, process, product, and the learning environment—resemble Tomlinson’s (1999, 2001) model of DI. On the front side of the protocol, descriptive notes will record observations about the apparent differentiating strategies among the four domains of content, process, product, and the learning environment (if any) that the teachers employ. Within each field of the DI observational protocol’s table, I noted the DI strategies teachers implement along with a brief short-hand description of how it was used for more specific coding during data analysis. The domains of instruction are categorized according to Tomlinson’s (1999, 2001) work and the research literature related to DI by teaching strategies that characterize it or by prompting questions leading towards descriptions of how elements of instruction were differentiated.
**Figure 1.** DI observational protocol.

**DI content domain observations.** In the content domain, six differentiating strategies are suggested by Tomlinson (2001) from which I have structured the protocol: (a) curriculum compacting as a type of targeted independent study (Bailey & Williams-Black, 2008; Powers, 2008), (b) using multiple inputs such as different texts and resource materials to deliver
instruction (Hall et al., 2003; Park & Oliver, 2009), (c) focusing instruction on key concepts and principles instead of drill-driven facts, (d) creating mini-lessons to break students into groups according to their level of understanding on a newly introduced concept (van Hover et al., 2011), (e) utilizing material resources or flexible student groupings to help students better access the content (Hall et al., 2003; Mastropieri et al., 2006; Park & Oliver, 2009), and (f) learning contracts.

**DI process domain observations.** In the process domain, I have narrowed down the wealth of differentiating sense-making activities (Tomlinson, 2001) into five categories: (a) journal/reflection activities, (b) graphic organizers including mind-maps and models, (c) problem-based or lab activities (Park & Oliver, 2009), (d) role-playing or debate, and (e) learning centers/jigsaw activities (Bailey-Williams-Black, 2008; van Hover et al., 2011) where groups of students each focus on a particular aspect of the larger concept (Tomlinson, 2001). Providing students with tiered activities (Goodnough, 2010; Mastropieri et al., 2006; Simpkins et al., 2009) or the ability to choose from a list of activities (Dotger & Causton-Theoharis, 2010; Goodnough, 2010) are also included here since these teaching strategies differentiate how students will build knowledge about the content (Tomlinson, 2001).

**DI product domain observations.** In the product domain, I recorded differentiating strategies according to four questions derived from Tomlinson’s (2001) description of high-quality differentiated product assignments: (a) how are the essential criteria and expectations of quality made known; (b) what is/are the format(s) of the product/assessment (Ernest et al., 2011a; Park & Oliver, 2009); (c) what scaffolds are used to help apply the information (Park & Oliver, 2009); and (d) what, if any, are the modifications made for students’ varied readiness, interests, and learning preferences (Hall et al., 2003; Tomlinson, 2001).
**DI learning environment domain observations.** In the learning environment domain, I focused only on those aspects where a teacher provided some type of adaptation according to his or her students, such as how students are grouped and providing environmental supports rather than on the more broad suggestions Tomlinson (1999, 2001) makes for an effective learning environment. Though the characteristics Tomlinson (1999, 2001) describes such as mutual respect, teacher-student collaboration, and high expectations are significant, they are universal in nature as opposed to being an adaptation according to students’ readiness, interests, and learning preferences; as such, those characteristics are more representative of the literature on best practices teaching (Brophy, 2000; NRC, 2005; Staver, 2005) than the DI philosophy of responding to students’ varied learning needs. Since DI was the focal lens for the study, those characteristics were omitted from the observational protocol in favor of strategies that teachers might use to adapt their learning environment to the needs of their students. Two broad questions encompassed this domain: how are students grouped and encouraged to contribute in cooperative work; and what environmental supports or accommodations does the teacher provide? It is important to note that differentiating how students are grouped in the learning environment may be distinguished from groups intended to differentiate the content; differentiated student groupings in the learning environment focuses on forming functional groups where each member contributes as opposed to, in the content domain, a focus on matching a peer mentor to provide support to a less expert learner (Tomlinson, 2001). Though these observational notes from the four domains of DI were descriptive, they were also corroborated and compared with data from the interviews to ensure their validity.

**DI reflective notes.** The reflective notes on the back side of the protocol focused on providing room for in vivo codes that represented significant portions of data taken directly from
teachers’ words or actions as well as questions that I pursued during focused and axial coding for comparison among all the participants’ data (Saldaña, 2013). The observational protocol also provided space to a sketch of the teacher’s classroom environment so that I could follow up during the interview stage to inquire about how it might reflect the teacher’s philosophy of learning or aid in that particular domain of DI (Saldaña, 2013). Finally, the last portion of the protocol gave room for notes that compare the observational data with the interview data. Since DI is an adaptation to students’ readiness, interests, and learning preferences, and these characteristics are not easily observed, it was essential to use the data gained from interviews to support and explain the observational data for valid analysis.

**Best teaching practices observational protocol.** The best practices observational protocol shown in Figure 2 used a similar structure by breaking instruction into the four domains of content, process, product, and learning environment (Tomlinson, 1999, 2001) in order to most accurately gather data looking for any potential overlap of DI with effective middle school science pedagogy. Though using the structure of the four instructional domains to categorize best practices literature is artificial, it does not take away from the recommended practices and may prove helpful during analysis. The teaching strategies measured by this protocol used the NSTA (2003b) position statement on middle school science education as the focal point but also include supporting literature on effective instructional techniques. Like the DI protocol, the best practices observational protocol had space for reflective notes, including a section for noting preliminary ideas on potential overlap with DI, and a section for making comparisons with the interview data later during analysis. Unlike the DI protocol, this one allowed for recording the timeline of events during the observed class. The heart of the protocol was in identifying which of these events correspond with the best practices literature.
<table>
<thead>
<tr>
<th>Timeline</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How are concepts <strong>connected</strong>? __________________________</td>
</tr>
<tr>
<td></td>
<td>_______________________________________________________</td>
</tr>
<tr>
<td></td>
<td><strong>Connected</strong> to students’ experience? __________________</td>
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<tr>
<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td>What are the <strong>inputs</strong>? ________________________________</td>
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<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td>Did students have a choice of input or in how to approach the content?</td>
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<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td><strong>Modeling</strong> cooperative: ______________________________</td>
</tr>
<tr>
<td></td>
<td><strong>Modeling</strong> cognition: _______________________________</td>
</tr>
<tr>
<td></td>
<td>How are <strong>experiences</strong> with the content encouraged? ______</td>
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<tr>
<td></td>
<td>_______________________________________________________</td>
</tr>
<tr>
<td>Process</td>
<td><strong>Independent</strong> work activities: ________________________</td>
</tr>
<tr>
<td></td>
<td><strong>Cooperative</strong> activities: ____________________________</td>
</tr>
<tr>
<td></td>
<td><em>(Long-term investigation  Structural  Learn Together)</em></td>
</tr>
<tr>
<td></td>
<td>Did the collaboration move from small to large groups? ______</td>
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<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td>Was evidence used to support/refute group ideas? ________</td>
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<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td>Did each group member have a defined role? _____________</td>
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<tr>
<td></td>
<td>_______________________________________________________</td>
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<tr>
<td></td>
<td><strong>INQUIRY:</strong> __________________________________________</td>
</tr>
<tr>
<td></td>
<td>Did the inquiry deliver content, or support already covered content?</td>
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<tr>
<td></td>
<td>_______________________________________________________</td>
</tr>
<tr>
<td></td>
<td>How did students engage in the inquiry? (circle)</td>
</tr>
<tr>
<td></td>
<td><em>designing investigations  using scientific reasoning</em></td>
</tr>
<tr>
<td></td>
<td><em>using equipment  recording data  analyzing results</em></td>
</tr>
<tr>
<td></td>
<td><em>discussing the findings</em></td>
</tr>
</tbody>
</table>
### Reflective Notes

<table>
<thead>
<tr>
<th><strong>Product</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Formative or summative? (circle)</td>
</tr>
<tr>
<td>Format?</td>
</tr>
<tr>
<td>Modified?</td>
</tr>
<tr>
<td>Any observable way the assessment data is used to drive future instruction?</td>
</tr>
</tbody>
</table>

### Learning Environment

<table>
<thead>
<tr>
<th>How are students encouraged to become engaged?</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are students’ emotional safety supported?</td>
</tr>
<tr>
<td>How does the teacher account for student diversity?</td>
</tr>
<tr>
<td>How does the teacher manage activities to maximize instruction?</td>
</tr>
</tbody>
</table>

### DI Leads

<table>
<thead>
<tr>
<th>Comparison with Interview Data</th>
</tr>
</thead>
</table>

*Figure 2. Best practices observational protocol.*

**Best practices content domain observations.** In the content domain, the protocol used a series of questions to generate data on how the participant demonstrated effective teaching practices. Each component was derived from either the NSTA (2003b) position statement or
related literature. First, Brophy (2000) emphasized the importance of organizing the curriculum so that powerful concepts are connected into meaningful units so that instruction is coherent; therefore, how the participant connected the lesson’s concept(s) or daily objective(s) with previous learning was recorded. These connections can also be made with students’ own experiences (NSTA, 2003b), including using examples relevant to the particular group of students, revealing the influence of Piaget’s (1954) cognitive constructivism.

Next, the instrument provided space for recording the inputs of instruction so that I could describe how variety (Brophy, 2000) in instruction might be utilized and also to note if students have a choice in how they approach the content either by a preferred input or by the objective’s open-endedness (NSTA, 2003b). In order to guide students to successfully navigating the concept, the teacher may model certain behaviors like how to work as a group (Palincsar et al., 2001) or how to think about the content (Radcliffe et al., 2004), so space was devoted to recording how the teacher modeled students’ cognitive approaches to the content.

Finally, the NSTA (2003b) also recommends that teachers encourage students’ formal and informal experiences with the curriculum through methods such as field trips, guest speakers, collecting data in a real-world setting or more informal experiences by using analogies with relevant examples or by helping students take fresh perspectives on previous experiences (e.g., how Newton’s laws of motion affect the gameplay of Angry Birds). Used in conjunction with the timeline of events, these questions helped reveal how the teacher reflected what is already empirically demonstrated about effectively relaying the content of science instruction.

**Best practices process domain observations.** In the process domain, the protocol provided space for me to record the type of sense-making activities the teacher used and how those activities were structured. First, I categorized the activities according to their independent
or cooperative structure, a blend of which the NSTA (2003b) recommends. If cooperative activities were used, it was important to understand the structure that makes them effective. Three major types of cooperative work exist: (a) long-term investigations used to model real-world tasks (Mandel, 2003); (b) the structural approach where a variety of cooperative activities are arranged according to specific structures such as think-pair-shares or jigsaw groups (Kagan, 1989); and (c) the Learning Together model (Kose et al., 2010) where group members complete individual tasks as they work towards a group-wide conclusion. Within these three categories, a community building approach may be taken where students share information in the small groups before sharing it with the whole class (Palincsar et al., 2001; Parkay et al., 2010), students may be required to use evidence to support or refute group ideas (NRC, 2005), and individual students’ work may be limited to a more narrow, specific task that contributes to the completion of the group task (Johnson & Johnson, 1994).

Also included within the observational protocol’s process domain was the major component of effective science pedagogy: inquiry (NSTA, 2003b). Since inquiry is the cornerstone of the NSTA’s (2003b) recommended best practices for science—a strategy that should be used as much as 80% of instructional time as a central mode for communicating and having students discover content (NRC, 2005)—ample space was provided for describing how the participant utilizes the teaching practice. First, I recorded a basic description of any inquiry-based activity I observed. Then, I identified whether the inquiry was used to convey the content (NRC, 2005), the recommended approach, or as a supporting activity for previously taught concepts (Banilower et al., 2010). Finally, I recorded what steps of scientific inquiry the participant required the students to engage in, if any. The steps of inquiry might include designing an investigation, using scientific reasoning, measuring data with lab equipment,
recording data, analyzing results, and discussing the findings (NSTA, 2003b) that could also entail discussing ambiguities in students’ results (Herrenkohl et al., 2011).

**Best practices product domain observations.** In the product domain, the focus was on identifying the type of assessment and how the participant used it to inform instruction. The first three questions of the protocol were meant to describe the type of assessment whether formative or summative, the assessment’s format, and identifying any modifications. Each of these questions was geared towards describing the assessment itself. Here, it is important to note how the protocols were used in tandem over a period of four days so that I could observe the variety of assessments the participant utilized along with how the assessment was embedded within the instructional goal(s) of the lessons (NSTA, 2003b). Additionally, space on the protocol was devoted to noting the observable ways the assessment data was used to inform future instruction (NSTA, 2003b); again, this section was more fully described at the end of observed lessons with the help of reflective notes to fully capture how the role of assessments fits into a teacher’s effective science pedagogy. So, the significance of these questions was more fully realized collectively from the sequence of assessments rather than as a single-use strategy.

**Best practices learning environment domain observations.** Finally, the protocol consisted of a series of questions related to how the participant utilized elements of the learning environment to support instruction. I wanted to identify how students were engaged with instruction. Intellectual engagement is a key component to create a learning environment conducive to real learning and achievement (Brophy, 2000; Palincsar et al., 2001). Once students are engaged in instruction, it is important that individual students feel emotionally safe (Brophy, 2000) to pursue the instructional goal, particularly during inquiry (NSTA, 2003b), where students need time to deal with their mistakes and questions (Wormeli, 2001). As
students worked, I used questions on the protocol to describe how the participant dealt with the diversity of students in a public middle school classroom, including his or her behavior (NSTA, 2003b) to ensure that students made the most of instructional time (Brophy, 2000) reflecting an effectively managed classroom (Marzano & Marzano, 2003). These characteristics of student engagement, supporting emotional safety, and accounting for student diversity to maximize instructional time were the significant indicators of an effective middle school science classroom that the protocol was designed to record.

Both of these instruments were used in a pilot of this research plan, once the IRB had approved of it, conducted with a fellow teacher I have worked with the past two years. I also enlisted the help of an instructional facilitator in the school district who is experienced with both science teaching strategies and DI to help pilot these instruments. Prior to the pilot, we traded emails to review the instruments, examining in detail the strategies they were designed to describe and answering any questions the facilitator had with the protocol. We conducted an in-person observation together of my fellow teacher who was not a participant in the study, meeting afterwards to compare and discuss our findings. Having the aid of an instructional facilitator during the pilot lent a degree of trustworthiness to the protocols as we compared our observational notes and discussed how best to categorize what we observed according to the four domains on each protocol. Through this process of review, I was better able to define each category so that during the actual study I could more quickly and easily sort data. For instance, in the content domain of the Best Practices observational protocol, the facilitator and I discussed the distinction between how concepts are connected and how concepts may be connected to students’ experiences. This discussion helped me to be more specific in sorting data during the observations, specifying the item about how concepts are connected to mean how the teacher
explicitly linked two or more learning objectives. We defined the next item, how concepts are connected to students’ experiences, more specifically to record how the teacher took one learning objective and presented it in terms of how the student might have come in contact with the concept outside of school. By piloting these instruments prior to collecting data, I practiced to be more adequately prepared to collect data on two separate instruments during a single observation as well as taking advantage of the opportunity to become more familiar with the format and descriptive items of the protocols.

Observations provided the opportunity to explore the teachers’ practical and daily strategies of best teaching practices and differentiation that make up the heart of this study’s data. Epistemologically, this was essential since the most accurate picture of instructional decisions can be gained from research done in the field as I worked closely with participating teachers in order to understand and describe their teaching practices and implementation of DI (Creswell, 2007).

**Questionnaire**

Prior to the interview, participating teachers were given a hard copy of a DI questionnaire (see Appendix G) and, for convenience, were also emailed a link to a digital copy delivered via Survey Monkey. This questionnaire was primarily used to gather information about the types of differentiating strategies teachers self-reported themselves using. The DI items were based on the same premises of the observational protocol, using the same strategies listed with the content and process domains of instruction. For these two domains, teachers simply circled the briefly explained differentiating strategies they use at any time during the school year. I used these items to compare with the observational data and to serve as prompts or leading questions during the interviews to find out more detailed information about the teacher’s pedagogy. Only very
general criteria for identifying if teachers differentiate instruction were given in the product and learning environment domains. For the product domain, I asked if the participating teacher allowed for different types of assessments or student products (Tomlinson, 1999, 2001) and what the most commonly used alternatives/adaptations were. With this basic information, I was able to follow up in more detail during the interview and ask any clarifying questions so that I accurately understood and recorded precisely how the teacher differentiated. The learning environment domain contained two main items about how students are grouped and changes to the classroom the teacher made according to the needs of their students. The first asked if groups are static or dynamic, revealing whether participants follow Tomlinson’s (1999, 2001) call for flexible groupings, and, as a sub-question, what criteria (random, convenience, ability, interest, or student preference) was used to form groups. Of these criteria, grouping students according to ability (Mastropieri et al., 2006; Park & Oliver, 2009; Tomlinson, 1999, 2001) and interest (Tomlinson, 1999, 2001) would clearly reveal a differentiating teaching philosophy at work; however, any combination of criteria could hint towards adapting activities for the benefit of the students. The last item asked teachers to circle what kinds of changes they made to the classroom to support students’ learning: seating arrangements (Tomlinson, 2001), audio-visual or other learning-stimulating resources (Hall et al., 2003; Tomlinson, 2001; Vardin, 2003), and providing alternative or supplementary texts (Hall et al., 2003; Tomlinson, 2001). Again, this item helped me to compile basic information with which to compare to the observational data and to follow up on during the interview. The data gathered collectively from the questionnaire was used to corroborate observational data, and provide me with prompts and appropriate open-ended follow up questions during the interview. In this way, observational, survey, and
interview data were used in tandem to more richly describe how and why teachers implemented their teaching strategies, including those related to best practices in science and DI.

**Interviews**

Individual standardized open-ended interviews were conducted with the participants at their home schools (Gall et al., 2007). One audio recorded interview, lasting approximately thirty to sixty minutes, was scheduled for each of the participating teachers, though I also asked participants for the opportunity to request follow-up interviews to provide an opportunity for member checks where teachers provide feedback of the emergent model. The interviews used an interview guide (see Appendix H) to moderately structure the interview process and to provide space for recording reflective notes after the interview has been conducted (Creswell, 2007), including room for in vivo codes for later analysis (Saldaña, 2013). The interview guide used open-ended questions to structure the interview around the study’s research questions, providing follow-up questions that were informed by observational and questionnaire data as needed to narrow the interviewees’ responses to more specifically answer the research questions.

These open-ended interview questions, shown in Table 3, provided avenues for exploring the participants’ beliefs about teaching and their pedagogical practices to see how their responses compared with the literature on effective science pedagogy and a differentiated pedagogical philosophy.
Table 2

*Interview Guide*

---

**Interviewee:**

**Date:**

**Time:**

**Setting:**

**Deliver introduction to the interview.**

**Questions**

I. How did you decide on teaching science?

II. As you have gained experience in a science classroom, how has your teaching evolved?

   A. With respect to instructional goals?

   B. Organization of the curriculum?

   C. Activities and assessments?

III. How do you think students learn best?

   A. How do your teaching practices reflect those beliefs?

   B. How do you engage students with your teaching?

   C. What role does inquiry play in your teaching?

   D. How do your students’ characteristics influence how you teach?

      1. Does a student’s readiness level change how you’ll teach him or her?

      2. What about their personal interests?

      3. Preferred methods of learning?

   E. How do the resources available to you affect your teaching practices?

      1. How do you use what you have to meet students’ needs?

IV. What do you know about differentiated instruction? How would you define it?
A. If at all, how does DI theory influence your approach to planning/delivering lessons?

1. How do you use it apart from accommodations required by IEP’s?
   a. How do you change what students learn (the content) or how students access it based on their individual characteristics?
   
20. What adaptations do you make for how students learn the content—the processes that you have students make sense of the content—including how students are grouped to complete activities?
   b. Do you allow students to turn in different products or ways to express what they’ve learned? If so, what alternatives do you allow?
   c. What changes do you make to the learning environment based on what you know about your students?

It is important to point out that some teachers might not have associated their teaching philosophy or pedagogy with either set of teaching practices but, in fact, could share many similarities with them. Therefore, asking open-ended questions with a series of opportunistic follow-up questions derived from the observational and questionnaire data was essential to discovering any potential overlap the participants’ effective science teaching practices have with DI.

I opened the interview by asking how the participant decided on teaching science. This question was intended to both break the ice and frame the interview within the context of science pedagogy. Next, leading off from the previous question, I asked participants how their teaching has evolved as they gain experience with teaching science, particularly with respect to instructional goals, the organization of the curriculum, and how they designed and implemented
activities and assessments. This set of follow-up questions was meant to explore how participants have developed pedagogical content knowledge, a critical element of effective science teachers (Lee et al., 2007). These opening questions were used in conjunction with the best practices observational protocol to create an accurate description of how the participants implement the empirically demonstrated science teaching practices that serve as one of the major lenses of this study.

Then, I delved deeper by asking participants about their teaching philosophies, examining how they thought students learn best and how they put those philosophies into practice. The intention was to explore any possible overlap in the participants’ teaching philosophy with the theoretical foundations of recommended science teaching practices and DI. Specifically, I listened carefully for responses that shared similarities to Piaget’s (1954) cognitive constructivism by mentioning ideas like the individual nature of learning, the role of prior knowledge and personal experiences, and the active building of knowledge. Additionally, from a differentiation perspective, it was important to listen for explanations related to acknowledging students’ differences particularly with respect to their zone of proximal development (Vygotsky, 1978), their interests, and/or learning styles (Tomlinson, 1999, 2001). If teachers’ descriptions of their teaching philosophy in action began to reflect the DI principles of adapting content, process, product, and/or learning environment (Tomlinson, 1999, 2001), I allowed myself the opportunity to skip ahead through the interview guide to appropriately follow up for more specific details. In most cases, I continued using the order of the interview guide to delve into the practical application of teachers’ philosophies, including how teachers engage students in instruction (Brophy, 2000) and the role of inquiry (NSTA, 2003b) in their teaching practices to more fully develop a description of how the teacher utilized best teaching practices in science.
I then transitioned from questions related to how students learn best and teachers’ corresponding teaching practices into the direct application of DI by asking participants how students’ characteristics influence their teaching. This question and its sub-components related to students’ readiness levels (Shabni et al., 2010; Tomlinson, 1999, 2001; Vygotsky, 1978), interests (Piaget, 1954; Tomlinson, 1999, 2001), and learning styles (Gardner, 2011; Sternberg & Zhang, 2005; Tomlinson, 1999, 2001) provided a natural transition from the lens of best practices to that of DI. In order to gauge the gap between what the teacher believed is best for students and the reality of his or her current circumstances, I asked about the availability of classroom resources and how teachers utilized these to deliver pedagogy consistent with their teaching philosophy. The aim here was to recognize the limitations teachers may have in realizing their ideal learning environment for practicing their philosophical beliefs about teaching and learning. Additionally, a follow-up question about how those resources were allocated for meeting students’ needs provided the opportunity for teachers to explain how they created and shaped their learning environments in response to students’ interests and questions—a reflection of Montessori’s (1912) emphasis on the role of the learning environment in developing the natural inclinations of learners (Vardin, 2003) or to stimulate certain types of learning preferences (Gardner, 2011).

The final major question addressed teachers’ knowledge and conscious or unconscious application of DI by asking explicitly what the teachers knew about DI theory and how they defined it. This particular question allowed me to roughly gauge how much a specific knowledge of DI correlated to its practical use in these classrooms identified as being effective. Here again, I paid particular attention to references of acknowledging students’ differences with respect to readiness levels, interests, and learning styles and, as a natural result, adaptations to
the content, process, product, and/or learning environment of instruction (Tomlinson, 1999, 2001). Since all teachers claimed to have some degree of knowledge about DI, I followed with sub-questions specifically about how the theory influenced teachers’ planning and delivery of lessons before moving on to the sub-questions related to each domain of instruction.

The goal of this final set of questions was to investigate how participants might adapt instruction according to its four domains (Tomlinson, 1999, 2001) in order to uncover what teaching strategies the participants utilized that were associated with DI either in Tomlinson’s (1999, 2001) books or in the research literature on DI. Specifically, I first asked participants about any changes to the content domain of instruction, including access to it, based on their knowledge of students. Either as prompts or examples of these adaptations, I listened for teaching strategies such as groups used to deliver mini-lessons (Bailey & Williams-Black, 2008; Tomlinson, 2001; van Hover et al., 2011), extension opportunities or independent studies (Bailey & Williams-Black, 2008; Powers, 2008; Tomlinson, 2001) compacting or leveling instruction (Tomlinson, 2001), or any other modifications that made the content of instruction universally accessible (Hall et al., 2003; Tomlinson, 2001). Exploring how teachers might differentiate the process of instruction, the sense-making activity (NRC, 2005), included listening to participants’ responses related to flexibly grouping students including peer mediated (Mastropieri et al., 2006), interest (Tomlinson, 2001), or readiness-leveled groups (Bailey & Williams-Black, 2008; Tomlinson, 2001; van Hover et al., 2011) and creating multiple activities for students choose from (Tomlinson, 2001; Vardin, 2003) particularly when those choices reflected attention to supports for students with special learning needs (Hall et al., 2003). Differentiating the product of instruction would include teachers allowing for multiple outputs (Tomlinson, 2001) and even using the data gathered from assessments (varied or not) to inform and modify future instruction
(Ernest et al., 2011b). Finally, I explored how participants might differentiate the learning environment by listening for comments related to offering a variety of materials (Vardin, 2003) including alternative texts or supplementary materials (Hall et al., 2003; Tomlinson, 2001) or making changes to the classroom in order to make content more accessible for all types of students (Hall et al., 2003). This set of possible questions were conceptually joined together by their exploration of how participating teachers applied the recommended best teaching practices in science and DI theory (whether consciously or unconsciously). Collectively, they provided data that could supplement and be triangulated with the observational and questionnaire data to provide a more holistic picture of the participants’ beliefs about student learning and how their pedagogy reflected those beliefs, including the possibility of intentional or latent DI principles that fit into the larger schema of effective science pedagogy.

After each interview, I developed reflective notes based on my initial reaction to the interview, transcribed the interview, and took the opportunity on the first read-through to pre-code by using rich text features to identify striking quotes or ideas and to begin jotting preliminary in vivo codes for later analysis (Saldaña, 2013). Ontologically, it was critical to gain a variety of perspectives on science pedagogy and DI in order to fully develop a model depicting the role of DI in effective middle school science teaching, so I continued research until the observational and interview data began to provide theoretical saturation of themes and categories (Corbin & Strauss, 2008).

Documents

The last data source were documents (including the correspond memos I created from them) collected during the observations or interviews. I recorded the documents using an artifact checklist to manage what data was gathered (see Appendix I) and as an aid for coding the data.
At the time of the observations, I collected copies or made scans of relevant documents that included lesson plans, activity hand-outs, and references to the media used to convey content to be used in describing teachers’ pedagogy and implementation of DI. Teachers’ lesson plans, in-class activities, reflective notes on their teaching, etc. were used to gather data on specific teaching and differentiating strategies and how those strategies had been adapted for the participants’ own classrooms. With these documents, I added to existing analytic memos to think deductively about how a particular document demonstrated a teacher’s philosophy and/or implementation of effective science pedagogy and DI (Saldaña, 2013). Creating these reflective notes was particularly useful as a complement to interview, questionnaire, and descriptive observational data. Methodologically, describing instructional decisions and motivations in detail with the data from interviews, observations, and relevant documents was essential before seeking out the connections and patterns between teachers’ theories of teaching and actual practices of differentiation (Creswell, 2007).

Data Analysis

As the data were collected from observations, questionnaires, interviews, and the relevant documents, I began the analytic process of transcribing and organizing the data. In the master password-protected digital folder, the data were arranged both according to participant and according to instrument. Therefore, each participant had his or her own file, complete with the two observational protocols, completed questionnaire (available via the Survey Monkey website), transcribed interview, and digital teaching artifacts. Additionally, I created another set of folders to arrange the data by instrumentation, so that, for instance, all DI observational protocols were in one folder for convenient analysis. As a participant’s data were collected and organized, I began the initial identification of significant phenomena demonstrating DI use and
its relation to effective middle school science teaching. This included making constant comparisons during analysis to look for similarities and differences in the data (Corbin & Strauss, 2008) to begin identifying first the essence-capturing codes and later the categories that linked the codes into a coherent pattern (Saldaña, 2013). Through the processes of initial, axial, and theoretical coding, I developed the emergent model by identifying the significant phenomena in the data, relating these conceptual chunks to each other to create and describe categories before finally integrating the categories and their codes together under the umbrella of the crucial category—the crux of the emergent model that explains the role of DI in effective middle school science teaching (Saldaña, 2013).

Throughout this process of coding, it was essential to use analytic memos as a way to ask questions about the data, begin categorizing significant ideas into codes, track thoughts related to grouping codes into categories, and generally probe the meaning of the raw data (Saldaña, 2013). Saldaña (2013) writes that “analytic memo writing is the transitional process from coding to the more formal write-up of the study” (p. 50). Likewise, Corbin and Strauss (2008) refer to the very process of “memoing” as a method of analysis. More specifically, it was an opportunity to openly explore the data, identify and develop codes, ask questions about the data, relate the codes to one another, and develop a narrative of the data. The primary purpose of the analytic memos was to generate the codes that were used to develop the model describing the role of DI in effective middle school science teaching. The initial memos included the rationale behind the code choices by identifying conceptual chunks from the data and codes’ operational definitions, providing the necessary information to develop a codebook (Saldaña, 2013). The codebook was managed as a rough draft in a hard copy notebook representing the process of adding and organizing codes by their conceptual chunks. I used the codebook to build concept maps from
the digital application Inspiration to help identify the relationships among codes. Once the data (and corresponding codebook) were saturated, I had the analysis necessary to transform the raw data into the findings presented in Chapter Four.

**Open Coding**

According to the systematic approach to grounded theory, I first used open, or initial, coding beginning with in vivo coding to take note of the concepts that stood out to me among the data (Saldaña, 2013) to identify the initial set of analytic codes that represent some phenomenon that was significant for describing DI or best teaching practices (Corbin & Strauss, 2008). This first cycle of coding also included process coding where I paid particular attention to the words and actions teachers used during the data collection process to describe individual participants’ approach to DI in the context of his or her best teaching practices (Saldaña, 2013).

I began the first cycle of coding (Saldaña, 2013) by examining the data from each participant as it was collected from the observations, interviews, questionnaires and any copied relevant document for the initial codes. The initial codes represented chunks of data that characterized the same concept (Corbin & Strauss, 2008). Codes represent “significant phenomena” (Gall et al., 2007, p. 467) that “share sufficient similarities that they can be considered instances of the same construct” (Gall et al., 2007, p. 467). Saldaña (2013) suggests that I should have expected to develop codes for 80-300 different significant ideas. This process of open coding allowed me to reduce the data into codes that provide the concepts for describing the emergent model (Corbin & Strauss, 2008). Codes sometimes contained sub-codes, or properties, to describe multiple perspectives of the same idea; for instance, *grouping strategies* may be a differentiation technique that includes a continuum from one end, where a teacher seats
a single student next to a helpful peer, to the other end where a teacher may assign all students into homogeneous ability groups for a cooperative assignment.

**In vivo coding.** The beginning stage of open coding included in vivo coding where I recorded codes in the language of the participant “when something in the data appears to stand out” (Saldaña, 2013, p. 93). In order to develop this initial set of codes, I read the interview transcriptions, observational protocols with corresponding audio transcriptions of the participant teaching and respective reflective notes, questionnaire data, and any collected documents to identify key words or phrases that described themes or similar ideas in the data. I used in vivo codes to record the actions and phrases that stood out to me from the observational and interview data.

**Developing the process.** Among these initially identified in vivo and open codes that represent the significant phenomena of the data, I identified the process by which participants select and apply differentiated teaching methods that is the phenomenon for the emerging model (Corbin & Strauss, 2008). The process also described how teachers change their implementations of DI according to the differences in their contexts. Process coding occurred in two stages: as an initial pass through the observational instruments and interview transcriptions followed by a second pass through as the categories in the data, and their relationships began to emerge. Initially, process coding was interwoven with the in vivo codes generated from my field notes during classroom observations. Process codes often included “-ing” words to describe the actions of the teacher during the lessons; so, process and in vivo codes overlapped here since they both recorded the explicit words and actions of the teacher as opposed to a deeper level of analysis. Once the categories began to emerge from the data and the interview/questionnaire data had been collected, a second pass through the initially developed process codes was
essential to review the data in light of the developing theoretical analysis to see how the process codes related to other categories (Saldaña, 2013). Once the overarching process and its sub-processes was identified and defined by observational notes, similarities among relevant documents, or textual quotes gathered from the interview and observation transcriptions, the same constant comparative process was applied to describing the facets of the process and its causes, contingencies, context, and consequences with a conditional matrix. Analytic memos were developed to delineate each of these aspects in light of their theoretical categories. This description of the process served as the focal point for the emergent model using the concepts identified during open and axial coding (Corbin & Strauss, 2008).

**Open codes from analytic memos.** Throughout this initial coding process that includes in vivo and process codes, I developed analytic memos to gather together these key words or thematic ideas that described the blossoming codes as I moved from gathering data from a participant, reflecting on it, and going back into the field to gather more data based on the direction of my theoretical sampling (Corbin & Strauss, 2008; Saldaña, 2013). This part of the “memoing” process was meant to break down the raw data along with the previously developed in vivo and process codes into manageable chunks categorized by their similar concepts according to each individual participant. Each concept represented a separate code, and I continued to gather data until each code was saturated enough to describe and account for variation from teacher to teacher. As data were collected, the codes began to develop clearly defined definitions so that, as more data were collected and analyzed, new chunks could be carefully classified as a similar instance or a new concept (Gall et al., 2007). Researcher memos used abbreviated ciphers to designate the separate codes to facilitate the analytic process (Gall et al., 2007).
Since coding is cyclical, Saldaña (2013) describes open coding as reading through the raw data and the already collected in vivo codes and “to reflect deeply on the contents and nuances of your data and to begin to take ownership of them” (Saldaña, 2013, p. 100). Thus, the in vivo codes were a part of the analytic process of open coding as I moved from raw data to theoretical constructs that represent the data. Likewise, analytic memos from the initial process codes aided in the analysis of how teachers differentiate instruction as I compared and reviewed codes across the participants. The initial analysis during open coding was the beginning of the constant comparative process that guided and direct further data gathering (Saldaña, 2013).

**Axial Coding**

Then, engaging in the second cycle of the analytic process with axial coding, I looked for the connections between codes, grouping them into categories, and describing the contextual conditions that influenced middle school teachers’ DI implementations (Corbin & Strauss, 2008; Saldaña, 2013). Whereas the data began to be broken apart into conceptual chunks during the first cycle of coding, the goal of axial coding is “is to strategically reassemble data” (Saldaña, 2013, p. 218) so that related codes can be grouped into categories. Distinguishing between major and minor categories helps to develop the emergent model (Saldaña, 2013).

As these initial conceptual codes developed, I simultaneously engaged in axial coding as data were gathered. Using the constant comparative process that included moving back and forth from reviewing the collected written data and going back into the field to collect more data (Corbin & Strauss, 2008), I pursued the codes that appeared across the different participants’ data. Then, I compared the codes (and their corresponding analytic memos) that emerged from one individual participant’s data with the rest of the participants’ data to identify similarities and differences among them as well as looking for any conceptual links that categories shared. In
other words, as I broke down individual participant’s data into conceptual chunks during open coding, and I related these chunks back to each other as they continued to develop during axial coding (Corbin & Strauss, 2008; Saldaña, 2013). This included writing analytic memos, some of which included diagrams or tables, to begin describing these relationships (Saldaña, 2013). Additionally, focused coding strategies were used during axial coding to identify those codes that appear most often among participants to help discover the categories that have the most transferability (Saldaña, 2013). Analytic memos sketching the “network relationships between and among concepts” (Saldaña, 2013, p. 45) facilitated the analytic process of axial coding. So, the goal of axial coding is “reassemble the data” that was broken into conceptual chunks during open coding, paying particular attention to sort out these chunks into “dominant” and “less important” categories (Saldaña, 2013, p. 218). This analytic stage added the next layer to the emergent model, eventually building towards the integrative summit (where the crucial concept will be identified) as the most important or salient concepts were uncovered. Saldaña (2013) suggests that 15-30 categories should be sufficient to group codes according to their conceptual patterns. As Corbin and Strauss (2008) explain, open and axial coding naturally blend together and are only artificially separated to make a distinction between the type of analysis they lead to. Open coding developed concepts that emerged from the data while axial coding related the concepts to each other. Saldaña (2013) postulates that it is at this stage of analysis that I would recognize when saturation has been achieved. I recognized this saturation as the concepts were neatly described, their relationships characterized into categories, and the most significant categories brought to the forefront of analysis as I began to build the integrating model upon the crucial category.
**Coding for context.** As the concepts were developed and linked together through open and axial coding, Corbin and Strauss (2008) state that the next analytic task is to describe the context of these concepts. This included mining the data for the conditions that these concepts and categories took place in. Describing the context includes both a micro and a macro level. The micro level included the conditions that middle school science teachers face in their daily classroom routine that may affect how they employ DI strategies. The macro level of context focused on the social, political, and historical conditions that have produced the micro conditions (Corbin & Strauss, 2008). For instance, the macro level might include the development of federal legislation that, in turn, impacts teachers’ daily classrooms (the micro level). Here, the process codes and corresponding analytic memos developed initially from individual participant’s data describing how teachers select and utilize differentiated teaching methods was especially helpful. The result of these codes of context was a Conditional/Consequential Matrix that provides the background for the concepts and, particularly, the emerging crucial category. This matrix, though flexible in its representation given the nature of the study, was represented as a ring of concentric circles with an individual participant’s response to differentiating for individual students in the center and the largest macro conditions, in this case the state-mandated curriculum objectives, on the outside. Each ring had some level of influence moving towards or away from the center and was grounded in the collected data. With this matrix, the crucial category and its process were supported and more richly described being properly situated within its context (Corbin & Strauss, 2008).

**Integration**

Finally, these categories of codes were integrated into a theoretical model, built upon and linked to the crucial category that described the role of DI in effective middle school science
teaching (Corbin & Strauss, 2008). The goal of theoretical, sometimes called selective, coding is to find the theme of the data that accounts for all categories and their constituent codes (Saldaña, 2013). For the purposes of this study, this stage of analysis sought to explain how and what differentiated teaching methods effective middle school science teachers selected and applied by answering “questions to explain the phenomena in terms of how they work, how they develop, how they compare to others, or why they happen under certain conditions” (Saldaña, 2013, p. 224).

Using the analytic memos related to the development of concepts (open coding), how the concepts are related (axial coding), the process of how teachers plan for and implement those concepts describing their differentiating teaching methods and best practices for science (process coding), and the conditions in which all those concepts and categories exist or were applied (context coding), I reached a conclusion on the core category. The core category represents the main theme of the collected data on which to build the model that has emerged from the data (Corbin & Strauss, 2008). The emergent model provided a framework that linked the categories and themes identified during open and axial coding, the process by which teachers implemented them, and the context in which they existed, fitting the concepts and categories into an overall structure that described how and to what degree effective middle school science teachers implemented DI (Corbin & Strauss, 2008; Saldaña, 2013). While the study may not have generated an entirely new theoretical model or paradigm of DI, it applied and extended its pedagogical philosophy to the specific context of how it is used in effective middle school science teaching. The identified categories and their relationships, linked under the umbrella of the core category, defined the role that DI plays in effective middle school science teaching (Saldaña, 2013).
In addition to describing the emergent model narratively, I organized the findings into a visual figure representing the set of propositions that described the emergent model. The visual model was first hand-drawn to ensure all relevant ideas were included before being digitized. The process of differentiating the best practices of science pedagogy described in the model took the form of a timeline or flow-chart, visually representing the organization and meaning of the emergent categories to address the study’s research questions (Creswell, 2007).

**Trustworthiness**

In order to build the trustworthiness in the emergent model, I gave special attention to the credibility, confirmability, transferability, and dependability of the data collection and analysis process (Lincoln & Guba, 1996). First, persistently observing teachers four consecutive times during a single unit helped to ensure that I had witnessed their typical strategies for implementing DI. This immersion in participants’ classrooms was an important part of developing credible data. Record-keeping, particularly of my analytic memos, demonstrated how coding, re-coding, and other analytic processes added to the credibility of the data (Saldaña, 2013).

Additionally, observational data was triangulated with the interviews, collected documents, and questionnaire information provided a holistic account of effective teachers’ perceptions and use of DI to build confirmability. Analytic memos that documented my personal relationship to the ideas and data gathered in the field also helped me to separate my own feelings from the perspectives of the participating teachers. The transcriptions of both the observed lessons and interviews helped to establish the confirmability of the codes I developed as evidence that was reviewed by committee members. Since the codes were grounded in the raw data, I used segments of this data to demonstrate why I had generated a particular code or
described it in a certain manner. Participants themselves were asked to review portions of my analysis during and/or after their interviews to confirm or disconfirm my notes from the observational protocols to ensure that I did not impute motives onto participating teachers (Saldaña, 2013). Once these data were more completely analyzed, I solicited some participating teachers to review and provide feedback for the propositions and categories of the emergent model to provide credibility to my analysis.

Transferability was enhanced through thick and rich descriptions of the participants, setting, data collection methods, and procedures for analysis in order for readers to judge the value of generalizing my conclusions to other populations and contexts. The analytic memos themselves, sometimes using metaphors or symbols to convey general ideas or themes, increased the transferability of the study as they helped to develop the model (Saldaña, 2013).

Accruing dependability was a matter of keeping meticulous records throughout the study. All information generated by the study (e.g., correspondence with participants, copies of all interview transcriptions and observational protocols, folders of questionnaires and documents, journals of researcher memos) was kept in hard copy form and/or digitally, choosing the most convenient and appropriate form for each type of information, as an audit trail for the study. In this way, the results of this study may be considered as trustworthy as these qualitative methods allow.

**Ethical Considerations**

Ensuring confidentiality and providing an appropriate level of security for all data maintained the ethicality of this study according to IRB standards. Since all data collection was conducted in person, I was the only one to handle the data in its most raw form. All research instruments used coded identifiers in place of participants’ names, and the cipher for these codes
was stored in a key-locked file. At the conclusion of each participant’s data collection, I removed the participant’s name and code from the cipher so there was no lasting link to participants’ names. Pseudonyms were used for the setting, all participants, and any mention of students’ names during transcriptions in order to provide a reasonable level confidentiality during analysis and the reporting of the study’s findings. I locked all hard copy data collected from participants in a code-locked file, stored in my home office closet, to ensure that no one else had access to this information. I created a master password-protected file on the computer used to record and analyze the study’s data to restrict access to the information to only myself. All digital data, including transcriptions of the interviews as well as the digital files used to categorize the collected data, were kept in this password-protected file. Since no other ethical issues arose during the study, no analytic memos were necessary to document those instances and record ideas on how best to approach them morally and sensitively (Saldaña, 2013).

Conclusion

By utilizing these grounded theory methods, I developed a model addressing the research questions of this study. Namely, the emergent model describes the role DI plays in the delivery of effective middle school science teaching effective and the process that led participants to this type and degree of DI implementation. Since effective teachers may implement DI differently, and yet still produce positive academic outcomes for their students, a qualitative approach was most appropriate for this study as teachers’ experiences were explored and synthesized into the development of a model that describes the similarities and differences in teaching philosophy and pedagogy.
CHAPTER FOUR: FINDINGS

The purpose of this study was to develop a model describing how effective middle school science teachers differentiate their best teaching practices, if at all. The study was guided by five research questions examining the components of that purpose: (a) what best teaching practices do effective middle school science teachers employ? (b) how do effective middle school science teachers’ practices reflect differentiated instruction (DI) principles? (c) how do those teachers’ beliefs about how students learn influence the way and the degree to which they might implement DI techniques? (d) how do the dynamics of a middle school classroom influence how DI might be implemented? and finally (e) are there other factors that influence teachers’ use of DI? This chapter describes the model that answers those questions, developed from an examination of the eight participants’ philosophies and pedagogies.

Description of the Participants

Since the eight participating teachers were the source of the codes and themes from which the model was built, it is helpful to introduce their profiles to help in the interpretation of the model and to determine its transferability. The study’s participants were selected on the criterion that each had scored at the highest level of the state’s teacher effect, or value added, component on their teaching evaluations at least once in the past three years. The teacher effect score measures students’ achievement gains by comparing a student’s score on the end of the year high-stakes test against a state-produced projection. The highest score, a Level Five, is earned when a teacher’s set of students averages two or more standard deviations above the state-produced projection. While sharing some similarities other than just earning the highest score on the teacher effect component of their evaluations, the teachers who served as
participants for this study have unique backgrounds that have shaped their teaching philosophy and resulting pedagogical style.

Alice

Alice was in her fifth year of teaching sixth grade science after having earned a bachelor’s degree, and she scored at Level Five, the highest rating, in her teacher effect data each year. She holds an elementary license and is certified to teach all the core subjects in sixth grade (Recruitment Letter), but she described being drawn to science because she was not as strong in that subject in school and wanted to learn more about it. Further, she explained that teaching science keeps her “connected with God” (Interview) as she enjoys thinking about how God made everything. Her mother was also a teacher and had influenced Alice’s teaching style (Interview).

Alice’s class had just finished learning about the concept of energy sources and was beginning a unit on convection. In one class period I observed, there were no students having a special education designation, but there were two students who had seating accommodations. One student sat near the front and towards one corner so as to be closer to the front whiteboard and projector screen on the adjacent wall while the other would sit or stand next to the teacher when she worked under a document camera to help keep pace with classroom notes. Several types of direct instruction characterized her teaching style where she regularly connected to previously learned or upcoming content. She blended visual and kinesthetic elements throughout instruction that featured lecture, notes, short media clips, and whole-class questioning. As all the time during her four observations was spent working as a whole group, a characteristic that stood out was her personal classroom interactions that demonstrated how she cultivated relationships with the students in building a community that valued cooperation to achieve tasks (Observations #1-4). A theme of cyclically reteaching content stood out from her pedagogy, matching her
description of how she believes students learn best, describing how she “[slows] down and [stops] and then [reteaches] the next day and not waiting until a test has been given” (Interview).

Brad

Brad held a master’s degree and had been teaching science for 11 years (Recruitment Letter) at the time of the study. Before he began his teaching career, he worked in environmental science at a nearby state park. Through that line of work, he realized he enjoyed the teaching aspect of his job and entered a graduate program to be certified to teach biology at the secondary level. The increase in pay that came with a move to education was also an incentive, and though Brad expressed enjoying the structure of teaching middle school and interacting with students, he said he still might be working at parks if it were possible to pay his bills (Interview). Brad had scored at the Level Five highest rating for teacher effect scores in each of the past three years (Recruitment Letter).

During my four observations, Brad’s eighth grade science class was beginning a unit on adaptations. Three students were classified as an English Language Learners (ELL) and were intentionally seated next to high achieving peers with personalities amenable to helping those ELL students stay in the flow of classroom events (Interview). Careful classroom management and the logical sequencing of his sense-making activities characterized Brad’s teaching style. He used direct instruction while students kept pace with note-taking guides featuring students’ illustrations of some key vocabulary followed by sense-making activities that utilized the information on students’ notes to help them process ideas through application activities like creating and describing a fictional animal adapted to a specific ecosystem (Observations). He explained his teaching as process:
Here’s like the wave that I do. This is every time. Notes every time, fill in the blanks. They’re going to have to prove to me that they understand the concepts through questions or a Venn diagram…and that takes a lot of time for them to prove to me they understand it. Once they got it, then we’ll do a little bit more hands-on. (Interview)

Christine

Christine was in her ninth year of teaching science. She holds a bachelor’s degree in biology (Recruitment Letter), and, like Brad, did not immediately begin teaching after graduation but came to the profession later (Interview). Christine has scored at the Level Five highest rating for teacher effect scores in each of the past three years (Recruitment Letter). I observed a seventh grade inclusion class that blends students with special education services in with general education students (Interview).

I observed Christine’s class during the final days of a unit on Earth science, of which natural resources was the final topic. Consideration was given to strategically placing students with special education services next to helpful peers who could help them keep up with classroom activities such as taking notes (Interview). Her class was characterized by a strong emphasis on developing and maintaining positive relationships and a blend of carefully scaffolded teacher-led and cooperative activities such as a jigsaw activity on natural resources where students shared information about one resource with their group and a baseball-style review game. Direct instruction was the primary mode for teacher-led activities like a lecture-based review and the development of a graphic organizer on the important terms of the unit, providing opportunities for Christine to model thinking strategies for her students (Observations). Christine attributed her effectiveness as a teacher to the sense of community in her learning environment and how she persistently works with students toward an understanding
of a concept. The relational element was especially evident during one observation where she set aside the content to deliver a speech encouraging her students, saying at one point “I think a lot about you…You matter to me,” (Observation #2).

Diana

Diana has been teaching science throughout her four-year career, despite originally wanting to teach English Language Arts with her middle grades (4-8) certification (Recruitment Letter). Her mother taught science and helped her find resources early in her career, and she developed a love for teaching science in her first year, wondering why she ever wanted to teach English (Interview). Diana holds a bachelor’s degree. She scored at the Level Five highest rating in her teacher effect scores the past three years (Recruitment Letter). Diana and Christine teach seventh grade science at the same school and generally keep the same pace through the curriculum and even use many of the same resources and activities.

Diana’s class was also learning about natural resources and spent the four lessons I observed moving through a jigsaw activity that had student groups (none of which included students receiving special education services) researching and presenting on alternative energy sources to fossil fuels. Each group researched one energy source for the majority of the first two lessons before groups took turns presenting their research during the last two lessons. Therefore, it was more difficult to characterize Diana’s teaching since I primarily observed one type of activity, but Diana showed that she was very involved managing the class, both with a focus on clearly explaining her expectations and directions for sense-making activities and in monitoring students’ work (Observations). During her interview, she talked about incorporating different ways to approach the content, giving thought to each topic on how students might hear, see, and write and/or draw the concepts. One idea that resonated throughout the interview was her
Elise tied for the most experienced science teacher in this study with 12 years of experience, having both an elementary (K-8) certification and 5-8 emphasis in science (Recruitment Letter) at the time of the study with her bachelor’s degree. Elise was drawn to science education after being inspired by a high school physics teacher. Like Diana and Alice, Elise also has teachers in her immediate family (Interview). Elise’s most recent teacher effect scores put her into the top category for two of those years, and one Level Four rating, or an average of up to two standard deviations above the state’s projections for learning growth for her set of students, in the most recent year (Recruitment Letter).

Elise’s seventh grade class was beginning an entirely new unit, moving from Earth science topics to life science topics, and beginning that study of biology with the concept of cells. The class did not include any students receiving special education services. Clearly organized, connected lesson plans and the carefully thought out use of classroom resources (including time) characterized Elise’s teaching. Since I observed the beginning of a new unit and its first topic, I was able to watch how Elise utilized a KWL chart and class discussion as a kind of pre-assessment before reading an analogy-based story about the parts of a cell to present new content. This was followed by several activities, such as a mini research project, foldable, and graphic organizer, that were all designed to reinforce students’ ability to identify the parts of a cell and describe their function. Students could also access Elise’s school website outside of
classroom hours to find other helpful resources like informative websites and digital flash cards. Based on the variety of sense-making activities I observed, her statement, “You figure out they don’t all learn the same way…I do incorporate a lot more [kinesthetic] movement, just different ways to teach them because, you know, one kid may understand it through pictures and another kid may understand it through an analogy,” was consistent with the reflection of her teaching (Interview).

**Fred**

Fred was tied with Elise for the most science teaching experience, clocking in 12 years and holding a bachelor’s degree and the K-8 core subjects certification (Recruitment Letter). Similar to Diana, Fred originally thought of teaching another subject—history. Taking the first open teaching position, Fred found himself teaching science and developing a passion for it (Interview). In the past three years of his teaching, Fred has scored at Level Five, the highest rank, in two of those years and a Level Three, or meeting the state’s projected expectation for learning growth during the most recent year (Recruitment Letter). Consequently, Fred was able to share some unique insights into teacher effect scores during his interview that shed light onto possible causes for their changes.

Fred was at the end of a major section in his curriculum and spent the four lessons I observed reviewing a set of content standards, assessing students with a benchmark on those standards, and then remediating them. A tremendous level of organization and use of technology characterized Fred’s teaching. Fred consistently had students (none which were receiving special education services) working from laptops using Classroom Performance System (CPS) clickers for assessments, and using his school website. The website was used to display the daily classroom agenda, providing enrichment and remediation with a series of instructional links.
organized according to content standard, and completing sense-making activities. All of the tasks based on these technologies were developed in such a way as to provide Fred with specific data on individual students for each individual standard (Observations). I observed this information being used each day to guide at least some of the activities that a student would complete during the lesson. Fred explained that he developed this pedagogical system in response to his previous teaching effectiveness scores. Reflecting on how his teaching has developed, he provided the analogy:

Let’s say you hired me to put a swimming pool in your backyard, and I came in and put a deck. It can be a great deck, but you hired me to put in a swimming pool…I was teaching science, but I wasn’t necessarily focused on the very specific objectives they had hired me to teach. (Interview)

George

George has been teaching science for eight years and holds a master’s degree with a K-8 core subjects teaching certification (Recruitment Letter). George volunteered in different classrooms during college and found that he enjoyed middle school, and in particular middle school science (Interview). Like Fred, George has seen his teacher effect scores change significantly over the past three years, moving from a Level Five, to Level Three, and even a Level One, or an average of two or more standard deviations below the state’s projections for learning growth for his set of students, in the most recent year (Recruitment Letter).

George’s sixth grade class was finishing a unit about how currents affect the Earth’s weather and was beginning to explore other concepts about weather, such as the water cycle and types of clouds. In the class I observed over the course of four days, there was a group of four ELL students who had obvious accommodations such as read aloud testing where they would be
pulled out to a different room to have the assessment read to them by an Educational Assistant (EA). George’s class heavily emphasized vocabulary. Each day, George had students engaged with at least one activity based solely on reviewing the key terms associated with the concepts being taught. This included a period of direct instruction that was reinforced with a kinesthetic motion students would learn for each key term. Students also used the textbook to find definitions and other information about terms. The class regularly played the vocabulary game ‘I have, who has?’ where each student had a card with one term and then a different term’s definition and the class tried to string together successful identifications of the terms’ definitions by standing up when a student’s term’s definition was read (Observations). George explained the philosophy behind these pedagogical strategies, explaining, “Especially with science, it’s its own world, its own language that once they know the language, they can start filling in the pieces and getting the concepts,” (Interview).

Henry

Henry had the least experience of any participating teacher, only being in his third year of teaching science. He holds a bachelor’s degree with a secondary certification in biology and also a K-8 certification in science (Recruitment Letter). Henry was interested in science in college, and his girlfriend at the time (now his wife) encouraged him to pursue teaching. He enjoyed student teaching (Interview) and has scored at the highest teacher effect rank in both of his first two years (Recruitment Letter).

After having just learned about the parts of cells, Henry’s seventh grade class was beginning to learn about things that cells do—processes like diffusion, cell division, and photosynthesis. In the class period I observed for the four observations, Henry explained that his students primarily come from a lower socioeconomic demographic and that he often struggles
relying on support from students’ parents (Interview). Henry’s teaching was characterized by direct instruction supported by plenty of visual examples and stories or analogies to illustrate concepts along with an emphasis on vocabulary. After the material has been covered via direct instruction, Henry’s teaching style relied on a system of learning centers, allowing students to process the new content in a variety of ways that included writing short stories, using iPads from the school’s mobile lab to take advantage of a digital assessment system called Study Island, creating a graphic organizer, studying with vocabulary flash cards, and reserving time for a grade recovery center where students can make-up or retake assignments (Observations).

Henry justified his pedagogy stating:

Lecture’s definitely looked down upon, but I see it as the best way to introduce material because I’m just like, ‘Here’s what you need to know. Here’s how it interacts’…and then from there, we’ll run with it so we’re to do two days of lecture this week, and the rest of the week, we’re using the material. (Interview)

**Differentiating Best Practices in Middle School Science**

Though these effective middle school teachers demonstrated a wide range of teaching techniques and differences in style, each used elements of DI in order to strengthen, support, and/or focus their teaching practices. As discussed earlier in the methodology section, each participant filled out a questionnaire (Appendix G), was interviewed (Appendix H), and was observed four consecutive days during which I filled out a best practices observation protocol, a DI observation protocol (Appendix F), and gathered teaching artifacts (Appendix I) to provide the data for describing how the participants conducted their classes. The data led to the development of a model (see Figure 3) showing how DI principles or strategies were applied to their best teaching practices. This model most accurately describes teachers’ best practices and
differentiating elements that serve to categorize the significant axial codes in the data according to four phases of instruction: (a) planning, (b) teaching, (c) assessing, and (d) reteaching/extending. It is important to point out that the four phases are somewhat fluid as teachers move back and forth among them according to their own style, curricular purpose, and perception of students’ needs, but the overall flow of instruction always moved forward along the continuum from planning to teaching, teaching to assessment, and assessment to reteaching and/or extending. The four phases, serving as categorical umbrellas for themes in the data, provided a structure for the model of instruction. Certain similarities became apparent in the data, both in how teachers executed strategies of best practices science teaching and how they differentiated those strategies. The following model illustrates how and to what degree effective middle school science teachers differentiated their best teaching practices by describing the similarities in pedagogy and teaching philosophy that was revealed during data collection.

In the following sections of this chapter, I describe the themes and codes that were generated for each phase of instruction. The discussion of each phase begins with the best teaching practices the participants demonstrated and how those practices were influenced by DI principles or utilized differentiating strategies. Then, I explain the context in which those teaching practices were chosen including the intended scope of teachers’ differentiation and the contextual factors that influenced the emergent codes and categories. This description of the model reveals how and to what degree effective middle school science teachers differentiated their instruction.
Figure 3. Model of differentiating best teaching practices in science. This figure represents how and to what degree effective middle school science teachers differentiated their instruction. The more transparent the blue best practices box, the more differentiated that phase of teaching is. The blue rings represent teachers’ intended scope for differentiation.
Planning

Effective middle school science teachers considered several factors when planning instructional activities and how they would be delivered. Themes that emerged from the data belonging to best teaching practices for science included factors like focusing on a big idea, connecting that big idea with others in the curriculum, planning for the best way to communicate and make sense of that particular concept, and then teaching the concept in a safe learning environment where instructional time can be maximized (see Figure 4). Teachers differentiated those best teaching practices when recognizing students’ differences in order to provide instruction that offered several avenues for learning, planning for a variety of resources to present the concept in different ways, and developing the community of the learning environment to build their engagement into the content. Teachers’ plans for differentiation took into consideration middle school students’ general characteristics that might influence how they learn a concept. Because teachers described formulating lesson plans based on broad categorical characteristics like learning styles or preferred methods for learning, I considered this phase of instruction to be the third most differentiated.
Planning for best practices. Effective middle school science teachers proved to be precise in their planning. They considered the big ideas in the content, how students would be expected to demonstrate their knowledge of the content on the end of the year high-stakes test, the essential vocabulary necessary to understand the content, and how they could present the content logically to move from simple to more complex ideas. The concepts themselves in the content standard also influenced how a teacher presented them, with some concepts being more conducive to certain types of activities. With an understanding of precisely what they needed to teach and how it might be best presented to students, teachers then created plans that included examples for direct instruction that would help students connect concepts. These connections included how students may have experienced the content in their own lives, how new content is related to previously learned information, and/or how the current concept will relate to information taught later in the year. During the planning phase, teachers also purposefully designed their learning environments to create a safe atmosphere where instructional time could
be maximized. The learning environment included the design of classroom management systems to reinforce appropriate student behaviors, routines that gave structure to classroom expectations, and the development of an engaging and fluid learning environment. Given all of these emergent themes, the planning phase proved to be an essential foundation for implementing the best teaching practices for science.

**Focusing on a big idea.** Best practices planning started with focusing on the concept(s) contained in the state’s mandated content standard. Alice explained the precision of identifying the big ideas contained within the content standards, discussing in her interview how she has moved “away from the book so that [students] could just have kind of what they needed and not so much detail.” Fred described teaching the essential ideas as “alignment” (Interview). He gave the powerful analogy recorded in his participant profile of being hired to put in a swimming pool and instead building a deck to explain how critical alignment was to improving his teacher effect scores over the years. He described a “laser focus” (Interview) that teachers should use to concentrate their plans, preventing them from spending time on non-essential content. Fred also spoke about “[cutting] out the fluff” (Interview) and, likewise, Henry discussed not “[going] into a lot of the side notes” (Interview).

Both Brad and Henry expressed during their interviews that alignment is critical to communicating clear expectations to the students about what they should know at the end of a lesson or unit without any ambiguity. They both stressed the importance of the teacher’s ability to present explicitly and precisely what the student is expected to know. Henry even went further with the idea, explaining that this is why he does not rely on inquiry-based teaching methods. He explained:
A lot of people will do things where the students discover the knowledge, and I’ve found very little success with that. I found a lot of times the good students find the knowledge, and the low students don’t. And then the low students are left with this sense of being lost. (Interview)

During the observations, planning for alignment was expressed as teachers gave explicit statements at the beginning of class about what students would be expected to learn and then used activities that focused on the big ideas of the concept. For instance, Diana’s first observed lesson featured her beginning class by asking students what they would be learning that day. The responding student read the objective directly from the board, and then Diana proceeded to explain a jigsaw research project that would conclude with student groups’ presentations as directed by a research guide (Appendix J, Teaching Artifact #1) while non-presenting students filled out a separate listening form. Diana began with a simple statement about the learning objective on natural resources. Then, after explicitly explaining to students what and how they would be learning about resources, she also developed research and listening guides to precisely define what students should know about natural resources (Observation #1 Diana). Similarly, Alice, Brad, Elise, Fred, George, and Henry all typically began lessons by stating the learning objective for the day or expecting students to write it from a designated spot in the room, often times even doing both (Observations).

The big idea and test-taking. The concepts students were expected to learn were also communicated in terms of how students would demonstrate that knowledge on a test. Both Alice and Fred mentioned during their interviews how they relied on sample test questions provided by the state’s department of education. Fred elaborated, “What makes those questions good are, it is what the test is going to look like” (Interview). Brad mentioned a similar idea, explaining that
he’s tried “to tailor [assessment] more to what they’re going to see on [the end of the year high-stakes test],” (Interview). By focusing the objective of instructional plans with sample assessment questions, or at least recreating their own similar questions, teachers focus precisely on what the state requires students to know.

_The big idea’s relationship with vocabulary._ Four teachers reiterated the notion that students would grasp the big idea if they understood the associated vocabulary. Henry told his students, “I will tell you the secret to this chapter right now: if you memorize the vocabulary, you win. If you learn all the vocabulary, understand the vocabulary, and how it interacts, you’ve got the chapter down” (Observation #1 Henry). Diana stated, “If they don’t learn anything else in your class, it sounds bad to say, but if they know what those words mean, they can get 75% of their [end of the year high-stakes test].” Elise and Henry emphasized that comprehending vocabulary was particularly important for ELL students as they master a concept (Interviews). George even wrote his master’s thesis on the topic of students’ retention of vocabulary and its effect on assessment outcomes. He explained that the vocabulary in science is so unique that students must first understand the terms before they can piece together the concepts (Interview).

Teachers planned for ways to teach and reinforce this vocabulary throughout a unit. Alice, Diana, Elise, and George designated large sections of their wall space for word walls where essential vocabulary terms could be displayed (Observations). Christine explained that she takes time to break down the new words and then gives students a way to remember their meanings during direct instruction (Interview). During my third lesson with Christine, I observed her stopping a direct instruction-based review to write down vocabulary terms on the whiteboard with brief definitions for students to copy as she talked about ways to decode the word or relate it to students’ everyday experiences. She had planned her instruction to include
an example with the term *crude oil* by asking the students to think if they had ever heard an adult call a behavior crude as a way to help them associate the idea of unclean and dirty with crude oil. Alice and George planned strategies to reinforce their sixth graders’ retention of vocabulary by teaching them motions associated with the new terms and then playing games based on the terms. I watched Alice’s students compete in games of Simon Says with these vocabulary motions (Observations #2-3 Alice). After George described the key terms of a new chapter to his students and taught a motion to associate with each term (Observations #1-2 George), students participated in a class competition of a vocabulary game ‘I have, who has’ (Observations #3-4). In this game, each student had a card with one term and the definition of a different term. The first student would read his or her definition, and the student *who has* that definition would stand up and state the term the definition belonged to. If the term correctly matched the definition, George would have the student read the definition to the next term on the student’s card, and the chain of the game would continue.

The most common way teachers taught new words was by planning activities where students could visually represent new terms. One main component of Alice’s class notes was a graphic organizer where students would follow along with her working under a document camera to fill in prepared blanks on the organizer (Appendix J, Teaching Artifact # 2). Diana (Interview) and Elise’s (Observation #2) students’ science notebooks contained graphic organizers where students were required to identify, label, and describe the new terms. Henry had his students draw the stages of Mitosis while labeling the names of important cell parts. Brad’s students would periodically pause in their class notes to illustrate important vocabulary, like when they added in a picture of an adaptation that helped an animal of their choice getting food. Students had some flexibility in how they completed the illustrations, and they drew
examples ranging from things like angler fish fishing to the huge teeth of a carnivorous dinosaur (Observation #1 Brad).

*Teaching the big idea by moving from simple concepts to more complex ones.* Teachers planned instruction by identifying the big idea of a content standard and then developing ways to present the aspects of that concept in a logical, sequential way so that students move from simpler ideas to more complex ones. For some teachers, like Elise and Fred, this meant considering what background knowledge students would need before learning the big idea of the concept. Both explained in their interviews that, though they generally followed the scope and sequence of the curriculum laid out by American County Schools, they each could point out instances where students might better understand the big idea with some other piece of knowledge first, demonstrating how they adapt the sequence of content standards according to their professional judgment. Fred discussed one example dealing with the content standards on the periodic table and how he rearranged the sequence of the big ideas leading to an understanding of that concept by teaching about what an atom is before describing what makes one element different from another (Interview). Elise mentioned a similar idea, stating, “I just feel like there needs to be a preface to some of this curriculum. There [are] some things they need to know beforehand” (Interview).

Likewise, a couple teachers talked about starting with the very basic ideas of a concept and then working deeper. Diana mentioned going back to what students should have learned from the curricula in previous grades about a concept, hooking into students’ prior knowledge (Interview). George described using direct instruction to relay the basics and then having students repeat it back to him. His goal was for them to repeatedly hear information to get “to the basic parts so they can start building from that” (Interview) through the previously mentioned
strategies of giving students key phrases for terms, teaching kinesthetic motions, and playing the ‘I have, who has’ game. Only after starting with the concept’s basic ideas (in this case, the vocabulary) did he have students begin reading the chapter in the textbook that described the concept (Observations #1-3 George). Alice also demonstrated the same theme, using increasingly complex daily oral quizzes at the end of each of her lessons (Observations #1-4 Alice).

Teachers articulated that some big ideas are best taught when broken down sequentially to move students from simpler to more complex understandings of the concept by helping students master a step-by-step process. One example came from Brad’s class, as he described teaching about density (the big idea) by first reviewing the multiplication and division required to calculate density. Then, he would have students apply that skill by teaching them “the magic triangle” (Interview) to help them set up the formula necessary to solve for density. Then, he would have them practice his three required steps for calculating density: write the equation, plug in the numbers according to their units, and then solve (Interview).

**Connecting concepts.** Once the what of teaching was firmly established, teachers demonstrated that they planned for ways to connect students to the learning objective of a particular lesson. Sometimes, these connections were made with students’ personal experiences or other real-world examples. Other times, the connections related new content to what had been previously learned, or, conversely, what they would be learning later in the curriculum. Teachers made these connections by gathering student-generated responses about their prior knowledge, allowing teachers to focus more precisely on building new knowledge by connecting it with students’ lives inside and out of school, and by using teacher-directed examples to lay a foundation for the class’s prior knowledge.
Connecting to students’ experiences. These effective middle school science teachers planned for the examples they used during instruction to help students directly connect their own personal experiences with a given lesson’s learning objective. Elise described this strategy saying, “They learn best if they can relate to it” (Interview). For instance, Elise used analogies for the parts of a school by reading a story to relay content about a cell’s organelles. She explained how the nucleus could be represented by the school office because that’s where the principal (or the boss of the school) tells everyone else what to do just like DNA does inside the nucleus (Observation #2 with Elise). Christine encouraged students to think of ways they already use one of the 3 Rs (reduce, reuse, recycle) in their own lives at home, asking one student as a review game question, “How could you, in your life, use one of the three Rs?” (Observation #4 Christine). Alice used this strategy prolifically as a part of her direct instruction, asking students often to think of content in terms of experiences they may have had. For example, she assigned homework one night for students to go home and look inside their oven, searching for a fan in the back that would identify that oven as a convection type (Observation #2 Alice). Making connections with students experiences inside and outside of school was not only used to help draw them into learning about the content but also to provide an entry point for students to hook new information into their prior knowledge.

Connecting new content to real world examples. The connections teachers made also included how the learning objective at hand had application to real world examples that students would be familiar with but not necessarily have directly experienced for themselves (in contrast to the previous section). Brad used this strategy to provide a number of examples when explaining to students the concept of genetic bottlenecks, giving examples such as the endangered status of cheetahs, how cockroaches become resistant to pesticides, and how
antibiotics can leave behind drug-resistant strains of diseases (Observation #2 Brad). Christine and Diana connected their learning objectives on natural resources to real world examples by showing their students a short video on one company’s mission to produce cleaner energy by using biomass (Observation #2 Christine; Observation #4 Diana). Christine explained, “I knew that they would love to see that guy climb up a steaming pile of poop and so, and that got their attention,” (Interview), describing how making this kind of connection with the real world helps students become engaged with the topic, especially when she can find a high interest example.

*Using a teacher’s experience as a bridge.* Teachers sometimes used their own experiences as a way to model connections. Elise used her daughter as an example, telling students about how a case of strep throat is related to a certain kind of bacteria cell (Observation #1 Elise). Similarly, when teaching his seventh grade students about mitosis, Henry showed students how the body healing itself is really nothing more than that process of mitosis where cells make more cells. He shared a story about the origin of one of his scars and, therefore, how students’ own scars are related to mitosis (Observation #2 Henry).

*Connecting to past and future content.* Teachers also made connections to tie together related topics in the curriculum. During one lesson about convection and air currents, she discussed a heavy thunderstorm that had moved through the area the night before and brought in some of the leaves that had been blown around during the storm, taping them to her whiteboard. She introduced to students the vocabulary term *deciduous* and informed students that these leaves blown around during the storm were evidence of the type of biome they live in, a concept coming months later in the curriculum (Observation #3 Alice). In effect, she created a shared classroom experience talking about the storm and its relationship to air currents that she could then draw on later as a starting point for the new concept.
Teachers also often connected one lesson’s learning objective to the lesson immediately prior—students’ most recent experience with the content. Brad began each lesson by reviewing the previous lesson’s objective. Sometimes, this involved reviewing homework (Observation #3-4 Brad) or starting class by asking questions about ideas from the previous lesson (Observation #2 Brad). Alice also used this strategy, first tying in the new topic of convection with the previous topic of energy sources by explaining how energy from the sun creates convection currents with Earth’s atmosphere to create wind (Observation #1). Then, each following day, she took time at the beginning of class to review the convection-based learning objective from the previous lesson to sequentially and logically walk students through the concept, always encouraging students during the end of the day quiz to think about the energy source, the previous concept, when answering questions about convection, the current topic (Observations #2-4 Alice). Elise had a similar tactic, often using the current lesson’s bellwork to review either an important idea from the day before (Observation #2 Elise) or to walk through a question students struggled with on the previous day’s assessment (Observation #3 Elise).

**Assessing students’ prior knowledge to make connections.** Teachers were better able to plan for making these connections by first determining what students already knew about the topic. Some teachers used traditional pretests as the means for finding out what students know in order to connect with that prior knowledge. Alice (Interview), Diana (Interview), and Fred (Observation #1) consistently used formal pretests to determine students’ level of prior knowledge to better plan the what of teaching for new concepts. Alice explained that she used that pretest data to identify what big ideas or concepts students already know, laughing about the differences among students each year (Interview with Alice). Fred gathered that data to target future instruction, requiring students to use his website to find resources that are designed for
specific content standards students score lower in (Observation #1-2 Fred). Diana called her pretests “anticipation guides” (Interview) and reviewed these at the beginning of the unit, asking students to raise their hands to agree or disagree with statements about the content. At the end of the unit, she used the same anticipation guide to see how students’ responses had changed. Elise’s pretesting strategy is similar but less formal, as I observed her discuss a whole class what-do-you-Know-What-would-you-like-to-know-what-did-you-Learn (KWL) chart to introduce cells, writing down students’ volunteered responses on a giant sticky note and then hanging it in the room (Observation #1 Elise).

**Using the content to influence pedagogy.** Another guiding force in how teachers planned was the influence of the learning objective itself. Teachers stated that certain concepts lend themselves to certain kinds of instruction and so utilizing those methods produced higher levels of, or more efficient means to, student understanding. When I asked Brad how he thought students learned best, he said, “It just depends on the topic” (Interview). He went on to explain that though he likes hands-on activities and giving students an opportunity to draw concepts in the content, some topics were better communicated in other ways. He brought up the example of dichotomous keys, explaining students learn best with lots of practice and experience reading dichotomous keys. Likewise, with density, students need practice calculating density more than they need to draw pictures of it. Both Diana and Elise alluded to some topics being better suited to visual, hands-on activities like creating foldables, with Diana specifically mentioning Earth science as one of those topics (Interview) and Elise adding the layers of the Earth (Interview).

Henry continued the theme, saying that he likes to take his students outside for some activities when topics can be demonstrated kinesthetically. He was excited to teach his current chapter on cell activities, stating, “Some chapters I do [go outside], like this chapter, we’ve got like three or
four things we go outside for” (Interview). Teachers planned their instruction and activities based on their perception of the best way to communicate that concept’s big ideas.

**Maximizing instruction time in a safe learning environment.** One of the keys of planning these effective middle school science teachers demonstrated was supporting their instructional plans with classroom organizational structures that made students feel safe but also communicated high academic standards, especially in how teachers and students cooperated to maximize class time for instruction. This included the systems teachers used to manage their classrooms and communicate their expectations clearly, fluidly transitioning between ideas, and strategizing ways to develop a more engaging environment.

**Classroom management systems.** In differing degrees of complexity, teachers structured their classes with various systems for reinforcing expectations for how students should act during class. How the teacher and students interacted within those systems guided how the planned instruction and activities were implemented so that time spent on learning tasks could be maximized. Brad explained that the teacher-side of that interaction was critical to maximize learning time, responding to how students learned best by saying, “Me speaking less and them actually doing the work because I think that’s teachers’ biggest downfall is they talk too much…you try to minimize how much you talk and maximize the students’ work on task.” Alice, Fred, George, and Henry mentioned during their interviews how the time spent during the lesson can be influenced by students’ side of that interaction, particularly by students’ behavior. Alice explained:

If my class is loud, we’re not going to do the get up activities because I can’t rein them in as quickly. I only have so much time, and there’s information they have to know. If
the class is quiet, then we’ll get up and move more and do more of the silly stuff.

(Interview)

Henry described how students’ behavior influenced how he grouped students during cooperative work, and how it can lead to students being removed from a group if they’re too social to remain on task. In his words about these too-social students, “If they’re interacting, they’re not listening,” (Interview). Developing expectations and habits of teacher-student interactions allowed both sides to act in such a way as to maximize instructional time.

In some cases, teachers created more detailed systems to organize instruction to achieve the goal of maximizing instructional time. Fred arranged his class into two teams of students. Each team was represented by a student captain’s name written on the board where Fred keeps a record of checkmarks. Student teams earned checkmarks “based on a variety of small things typically: whether or not they have their books, whether or not they have their agendas or their homework or they’re talking out of turn,” (Interview). Fred described:

Rather than giving somebody an ‘X’ for misbehaving, I’ll give a checkmark for the other team. And so immediately you have on the spot correction, which doesn’t require me to do any nonsense paperwork sent to the principal, and you know, [the student has] a vested interest because now that team is losing. (Interview)

At the end of a designated time period, the team with the most checkmarks earned a working party where students can bring in food and drinks to enjoy as they continue with typical classroom instruction (Interview). Other teachers, like George and Henry, used a system of learning centers to regularly structure instruction (Interview with George; Observations #3-4 Henry). George even gave each class a “status,” designated by happy or sad faces next to the
class period’s number written on the whiteboard. I observed him downgrade one class after a number of students failed to complete a homework assignment (Observation #4).

Other teachers used a basic set of classroom routines to begin and end class that were designed to maintain classroom expectations and maximize time spent on learning tasks. Alice’s students utilized daily objective sheets, beginning each day by writing the learning objective and then using the same sheet to record their answers to a brief oral quiz at the end of class (Observations #1-4). In this way, she streamlined the process of making the learning objective explicit at the beginning of class and tracking daily formative assessment data. Similarly, Elise and George consistently started the day with bellwork questions, setting students up for the big idea of that day’s lesson by framing the learning objective with these guiding questions (Observations). Other teachers like Brad, Diana, and Fred began class with students writing down or responding to a daily agenda posted on a whiteboard or projected on the screen (Observations). Christine’s class even had a routine to begin as she entered class from hallway duty. Her students would begin applause-like clapping to signal the start of class (Observations). The common theme of these routines was that teachers maintained a system by which students knew exactly how to begin, what was expected of their behavior during class, and, in some cases, how students should end the day as well.

Other routines were built into specific activities so that students knew what to expect during that type of activity, thereby streamlining the amount of time spent organizing the activity and maximizing students’ work time on it. One common routine was the use of a science notebook or folder where students stored all their classroom work. I observed Brad, Christine, Diana, Elise, George, Fred, and Henry’s classes all use some form of this routine to complete activities ranging from recording the daily agenda or completing bellwork, taking class notes,
and even as a place to paste in lesson activities so that information would all be gathered in one central location (Observations).

Alice’s class provided another interesting example of an activity-based routine. Whenever Alice used her projector for things like displaying notes or to show a YouTube video, she would have students rotate their desk from facing the front of the room to turn to the side wall where the projector screen was located. Instead of simply telling students to turn their desks to face the screen, she told students to rotate their desks the same way as the sun rotates (Observations #1-4). In this way, she could use an organizational routine to also reinforce one of the big ideas from a previous unit.

Elise used a number of small routines that used classroom materials to streamline instructional activities like a color-coded cup system at lab tables where students could visually let her know their working status. Green cups represented that students were working without problems, yellow cups that students had a question but could continue working, red cups that students needed help immediately, and blue cups to signal the group was finished. She also kept a box of activity materials at each desk clump that held things like a printed copy of a story read in class or art supplies (Observations #1-4).

When students worked on laptops in Fred’s class, each student had a designated number that corresponded to a particular laptop that students would use at a specific lab station (Observations #1-4). Not only did students know where and how to begin this kind of activity, it also facilitated Fred’s ability to monitor students’ work from his teacher computer where a software program displayed students’ screens, arranging them by the laptop’s number. He had a similar system in place for students’ CPS clickers that he used to deliver assessments. Each student was assigned a particular clicker number, located in a designated spot on a bookshelf.
(Appendix J, Teaching Artifact #3) in the room, so that he could anonymously display scores at the end of class as well as ensure that each student put his or her clicker away (and in the correct spot) at the end of class (Observations #1 and 3).

Some other routines could be used to get students’ attention quickly. Some were simply vocal, such as when Elise would call out for students to touch their heads and look at her so she’d know they were listening (Observation #4) or when Diana would ask her class ‘Who’s talking?’ to which students would provide the choral response ‘They are,’ pointing to the group of students about to make a presentation (Observations #3-4). Diana also used the combination of a projected daily timer and turning the lights out to signal transitions (Observation #2). Others required minimal equipment, such as George’s use of a dog training noisemaker to bring students’ attention back to him at the end of questions that led to some discussion (Observations #1 and 3).

Fluidity. I developed a code for fluidity to define the combination of seamlessly transitioning between lessons and keeping students working at a constant pace during the current lesson so that instruction time would be maximized. Students would transition between lessons as teachers told students at the end of class what to expect from the next day’s lesson or by picking up that next lesson from where the previous one left off, thereby creating a feeling of continuity and immersion with the content. One such example was Brad’s adaptations unit, where students during my third observation worked most of the class period on a poster drawing and describing an imaginary organism’s adaptations to its ecosystem. Then, during the next lesson, Brad immediately picked up with this assignment, asking students to share what they had created. Though students began the next class by writing in their agendas, Brad maintained continuity between his lessons using his activities as a bridge. Diana’s jigsaw activity on natural
resources created a similar environment as students continued their research from the first lesson to the second and also as the class easily picked up with groups’ presentations from the third to fourth observations.

Elise and Fred maintained fluidity by using data collected from the students in the previous lesson to guide the transition into the next lesson. Elise chose a specific bellwork question for the second lesson after noticing that students struggled to explain the role of a particular cell part during the previous lesson. Fred used students’ scores on a review activity and following benchmark assessment during the first and third lessons as the starting point for what activities students would complete during the second and fourth lessons. In this way, after students saw their scores on review and benchmark, they knew exactly where to begin with the next class’s activity, so there was no time lost explaining to each student what they needed to do. Alice used a similar technique, as her daily oral quizzes often times repeated questions from earlier lessons so that students would leave class understanding how what they have been learning ties together (Observations #2-4).

Teachers also developed continuity by providing brief previews of the next lesson’s learning objective and/or activities at the end of class. For example, during my first observation, Elise explained to her students the drawings and research students would complete in subsequent lessons to understand the concept of cells she introduced that day. Diana told her students what she expected of them when they came to class for that second day of research including how students would conduct the research. She even specified certain details they should look for as they prepare their presentations. Henry previewed what the learning centers would look like after he had presented the content through direct instruction and notes during the first two observed lessons. Though short, these previews set some expectation for what students would be
learning and what they would be doing in the next class, so that the teachers would not lose time explaining what would need to be accomplished, and how the concepts were connected.

**Developing an engaging environment.** The last component of teachers’ plans that involved maximizing instructional time was developing and nourishing an engaging learning environment where students could come to class with some expectation of what they would be learning, knowing that a teacher who cared about them would help them reach the objective for learning. Teachers demonstrated a variety of strategies for engaging students: giving students roles to facilitate a lesson, creating an interesting learning environment, developing rapport with students, and interacting with students as they worked.

Teachers involved students in the creation of a classroom community by giving them certain roles to facilitate the workings of that community. Alice’s class used a rotating system of “runners” (Observations #1-4), where one student from each row of desks would collect the daily objective sheets from folders kept at the lab stations, distributing these at the beginning of class and turning them in at the end. Fred also gave students jobs, using some students to lay out and power up laptops from the school’s mobile lab, assigning other tech savvy students to serve as “computer technicians” during students’ work time, and even giving others the task of serving as “mighty warriors” who were in charge of passing out and collecting the lesson’s materials (Observations). Fred’s two-team classroom management system also helped to promote the idea of students’ roles in the classroom, giving each a stake in working towards the goal of accomplishing typical classroom tasks to win the competition and enjoy food during the working party (Interview). George gave students that opportunity to feel like a mini-community, comparing classes’ performances on a vocabulary review game and quiz to promote a sense of competition, teamwork, and achievement when one class excelled (Observations #2-4). George
told the class that I observed that they were the first to complete the ‘I have, who has?’ vocabulary game, and the students celebrated their success with cheers and high-fives (Observation #4).

Teachers also found ways to tie students’ roles into instruction. For example, Diana’s jigsaw activity had student groups taking the role of a teacher, researching a natural resource for two lessons before presenting to the class their findings. During her instructions, she emphasized that students within each group should present equally, promoting the value of students’ active roles in their group’s research and presentation. She also developed a listening guide requiring an active role on the other side of presentations (Observations #3-4). Alice and George both utilized activities where students were expected to give choral and kinesthetic responses, encouraging each student’s active participation in the class response. Alice gave each student a responsibility to rotate their desks to set the room up for some activities as well as expecting the choral response “open circuit!” or “close circuit” any time she flipped the lights to use the projector screen (Observations #1-4). In these ways, teachers advanced the feeling that individual students had roles in the larger classroom community and that an individual’s actions affected the outcomes of that community.

Teachers also engaged students by creating interesting, stimulating classroom environments. There was a static aspect to creating an exciting learning environment, where teachers put things in the environment to spark students’ engagement, and there was also a dynamic element, where the teacher personally injected enthusiasm into the environment. One static example was that each teacher decorated his or her walls with instructional posters and/or student work to add interest or encourage students’ contributions (Observations). Christine used more than wall décor as her room included lava lamps and a dressed up full-size skeleton. The
lava lamps visually demonstrated the idea of convection (Interview), and the skeleton could be used to show the placement of organ systems. Alice, Brad, Christine, and Diana all had class pets: a guinea pig, snake, fish, and tarantula respectively (Observations). Elise used music during students’ independent work time to enhance the classroom environment. Elise, Fred, and Henry used their schools’ mobile labs that included either laptops or iPads or a combination of the two to not only make certain instructional activities more efficient but also as an engagement tool that students looked forward to using (Interviews). The intention was to create an environment that students look forward to coming into and interacting with.

Dynamically, the teacher was a critical element in the development of a stimulating, interesting learning environment. During his interview, Fred emphasized how important “[having] an energetic teacher who’s just dedicated to getting it across to you” (Interview) was to student learning. George led the development of a classroom environment students are excited about by preparing his students for an impromptu song at an upcoming pep rally. During two lessons, George led his class in practicing a water cycle song to the tune of “Oh, Susannah” that, at his signal, his sixth grade science students were encouraged to stand and sing during a school-wide pep rally (Observations). Alice’s students begged to play a Simon Says game based around kinesthetic motions for vocabulary terms (Observation #3). Alice’s fast-paced enthusiasm in leading the game hooked students into the competition as they intensely focused on becoming the winner. Christine used shock statements to get students’ attention and increase their energy level. During my observations, she talked about her “dam scrapbook” (Observation #3) in reference to teaching students about hydroelectric power and even dropped a hint about an activity later in the year on genetics when students would “make babies” (Observation #3).
Teachers supported students’ active roles in responding in the learning environment by being actively involved themselves, prompting and working with students during class. Brad and Diana during their interviews talked about how they arranged their classroom’s desks so that they could easily circulate among their students as they worked. Brad moved among his students during his adaptations poster activity, prompting some to continue working while asking others questions about their drawings. He even occasionally stopped and addressed the whole class, once chastising them for being too social and reminding them to stay on task (Observation #3). Diana also moved among her students as they worked in groups on their natural resource jigsaw research. She moved from group to group, using the same color-coded cup system as Elise to note which groups had questions for her (Observations #1-2). Henry moved among his learning centers, using a strike system to prompt their engagement with the task at hand. Elise moved among students as some worked on their cell drawings at their desks while others worked individually at lab tables on organelle flash cards, using the cup system to signal when they were finished and needed feedback (Observation #3). Christine noted in her interview how critical this kind of teacher proximity was for students to gain from an activity, explaining that she did not want any students to feel like they were being left behind if she moved on before they were finished. Her proximity with students as they worked made it possible for her to continually check on students’ progress while also helping to keep them engaged.

Finally, as teachers interacted with students, they developed rapport with the students to nourish an emotionally safe, exciting classroom and encourage them to achieve. Brad demonstrated one simple example of this, stopping to joke with one student whose animal resembled the mythical chupacabra. He and the student laughed together about certain characteristics of the drawing (Observation #3). While certainly a minor interaction, it spoke to
the larger feel of Brad’s classroom environment where students felt comfortable enough with
him to laugh together rather than feeling browbeaten for insignificant details of their work.
Henry also incorporated this rapport-building with engagement strategies, using his students’
names for examples he explained during direct instruction, such as when he used one female
student’s name when talking about the diffusion of perfume particles (Observations #1-2). Alice
and Diana also used students’ names in their examples to make connections with the content and
the interests of their students, particularly when students’ interests were related to sports
(Interviews). George described in his interview how he pursued students’ interests during
discussion to connect it with the content at hand. Elise noted in her interview that sharing stories
about her personal life was one way to build that rapport with students. From Elise’s comments,
it seemed that by showing students that the teacher is a person with a life outside of school, he or
she can pave the way to getting to know students as people by taking that first step towards
building a relationship. Fred spoke to the idea of seeing students as people rather than as merely
students, explaining how he combatted frustration with difficult students:

I pray for them before I come into the building. I pray to be loving and patient and kind
towards all my students, and I’ll specifically think of the ones that are annoying the heck
out of me, and I’ll say to myself, help me love this child like he’s my own son.
(Interview)

Fred went on to say that this helped him cut students a little more slack since he is never exactly
sure what students are dealing with in their own lives that can affect their performance and
attitude at school. His perspective showed how caring about students as people motivated him to
build rapport that contributes to an emotionally safe classroom. Christine provided the most
dramatic example of developing an emotionally safe classroom as she spent nearly half a lesson
passionately and tearfully explaining to her students that they matter and that she cares about them (Observation #2). She later informally explained to me that she was responding in particular to one student who had dropped a note into her “dropbox,” an empty tissue box for students to communicate privately with Christine, that described a difficult situation at home that left the student feeling unloved and uncared for. Using instructional time to tell students how much the teacher cares for them is a powerful way to communicate not only caring but also the safety within that class’s walls. Without these teachers’ interest in knowing and interacting with their students, the relational component of a safe, exciting learning environment would suffer.

**Differentiated planning.** Effective middle school science teachers demonstrated ways of differentiating their instructional planning by adapting their plans to meet the needs of specific set of students. This differentiation was grounded in recognition of students’ differences which led to teachers creatively finding ways to engage a diverse set of students. As a result, teachers planned for a variety of resources designed to accommodate the range of students’ differences to a unit’s learning objectives.

**Recognizing students’ differences.** Teachers’ differentiation during the planning stage of instruction began with a few fundamental philosophical assumptions: (a) middle school students come into science class at different stages of readiness; (b) they learn at different levels; and (c) they learn in different ways. The study’s participants expressed or implied these beliefs which influenced how teachers planned for instruction in order to provide a degree of differentiated instruction that was consistent with their ideas on how students learned best. George framed the idea of differentiating planning, emphasizing its importance by saying “your teaching style has to completely depend on your read of the students at that time” (Interview).
Though not all teachers expressed the need for differentiation as strongly as he did, they had in common elements of DI that influenced their teaching philosophies.

*Readiness.* Teachers differentiated their plans based on their perceptions of students’ readiness levels, or their ability to understand and apply the big ideas that make up the concept. During the planning phase, their idea of readiness was founded on an understanding of the typical abilities of middle school students and generally included categorizing students into high, middle, and low ability groups. Christine discussed the importance of recognizing “what types of things are they capable of at this age” (Interview). Elise described the value of more concrete objectives and activities for middle school students, stating, “Anything that’s tangible, not abstract, they seem to engage better with that” (Interview). Brad provided an example of considering the readiness levels of his set of eighth grade students when asked about inquiry-based instruction, explaining that if his activities were too open-ended, they could leave students simply confused and unsure of what they were supposed to do or learn from the lesson (Interview). Brad recognized how these characteristics of his students influence his plans when he said during his interview, “I realized kids’ attention span is only so much, but even though I realized that, I still try to press it a little bit.” Therefore, Brad broke up his direct instruction into smaller segments adjusted to their attention spans. He used mini-activities like illustrating notes, giving students time to predict upcoming blanks in the notes, and using stories to communicate examples in between longer portions of his lecture (Observations #1-2). Similarly, Henry noted, “This year specifically I’ve noticed reading competency being a problem where like I can ask a kid, you know, ‘What do you do in this situation?’ They can tell me, but if they read it, they’re lost” (Interview). This understanding of his students’ characteristics led to pedagogical decisions like using direct instruction first to present content before asking students to find information
from the text or other activities requiring some prior knowledge on the topic (Observations #1-2).

As teachers considered their students as a whole, they gave thought to the general readiness levels of middle school students with an understanding that individual students come into their class at varying degrees along the spectrum of readiness. All the teachers in this study implied or expressed students’ different levels of readiness, often times communicating the idea in terms of three separate categories: high, middle, and low. Diana, Fred, and Henry used the specific terminology of high, middle, and low to classify groups of their students (Interviews). Henry defined these groups for his school, saying:

So here, we do low, medium, and high. And I’m mostly defining low as the kids who generally do poorly on tests and struggle learning the material. Medium is just your basic kids. And high are like the kids who you probably want to go put in spectrum [a gifted resource advanced reading/language arts class]. (Interview)

Students’ classifications can influence the types of activities in a lesson or the expectations a teacher has for those activities. Henry recognized the influence of DI theory and students’ readiness on his plans saying, “differentiated instruction is giving different instruction to the different levels of students” (Interview) prompting him to adjust the rigor and content of some of his learning centers. George provided another example of this kind of differentiation. He used a couple different sources of data to group students homogeneously by ability level for certain activities. At the beginning of the year, he determined the initial groups for his learning centers that each included three levels, or tiers, according to high-stakes testing data from the previous year. Throughout the year, he assessed students with “probes” (Interview) to gather data on the current concept, changing the groups as needed so that he can assign specific groups to a
particular tier. He talked about how students’ readiness is dynamic and can be influenced by different factors such as things going on in their personal lives (Interview). Elise led a KWL activity on cells to gauge her students’ readiness with that concept, stating in her interview, “By this I can tell who already knows a ton about cells and who doesn’t at all.” She used this kind of assessment, discussed in more detail in that phase of instruction, to modify parts of her lessons including questioning, scaffolding, and bellwork content. Henry explained that the data a teacher gathers on his or her students’ readiness levels influences the approach a teacher takes in delivering a particular lesson such as the depth of detail in a lecture-based lesson (Interview).

Learning at different levels. Teachers also implied that students learn at different rates. In other words, students begin at different starting points and progress towards the mastery of a learning objective at different rates. Diana expressed that this can be a challenging situation to plan for:

I always feel like I should be upping a little bit, upping the ante, but I don’t know quite how to get there. And I don’t know what’s too high and what’s too low, and I have a very broad mixture of students where I know I can ask a question that’s going to go over half of their heads and half of them are going to think ‘Sigh, really?’ (Interview)

Henry explained, “So if a student is low, I should be giving them a low level of instruction so that it’s simpler for them to understand. Medium should get your basic. High should get more than your basic” (Interview). He elaborated that he still plans the same activity for students, but his expectations of what students accomplished with the activity (such as a learning center based on writing) are more dynamic. During their interviews, George and Henry discussed how their expectations from class to class change based on that class’s average grades or progress towards mastery (Interviews).
Based on the belief that students learn at different rates, teachers demonstrated how they planned to provide instruction to match students’ progress towards mastery despite the challenges associated with teaching across the spectrum of students’ readiness levels. Diana planned to ask different levels of questions and directed those questions towards particular students (Interview), showing this technique when questioning students and groups during the presentation phase of their jigsaw activity (Observations #3-4). She also developed a partner-for-the-day system that provided an opportunity to pair a student moving slower towards mastery with a student who had already grasped the concept (Interview). Elise, like George, built the idea of students working at different paces into certain activities, such as her research-based cells foldable. She explained during the interview that the research phase of the activity includes three tiers. Students worked through one level at a time, progressing through the tiered information at their own pace so that some students would work through to the advanced level while others may not get that far (Interview). George abbreviated assignments for lower achieving students, pointing out an example during his interview of how he would move around the room during independent work time telling his ELL students in particular how far they should get on the current assignment. George made an interesting point during his interview, explaining how some students would simply do better, or learn faster, with certain kinds of activities. This sentiment underscores the idea that students would work at different rates and builds on it by considering factors that can influence that learning pace.

**Learning in different ways.** One of the most salient themes that emerged from this study’s data was teachers’ belief that students learn in different ways. Based on my analysis, this idea was the single most influential factor in determining how teachers planned to differentiate their instruction. Alice spoke the idea plainly, stating in her interview, “people learn
Elise explained that this belief develops with experience, saying, “you figure out that they don’t all learn the same way” (Interview). Fred implied the idea, expressing the importance of variety in his teaching “to address diverse learning styles by making my units approach the content from a variety of angles” (Interview). Brad stated, “Students learn best in a lot of different ways, through visual, you know, kinesthetic, so I try to do a lot of that in my teaching…I can incorporate the multiple intelligences,” (Interview). Likewise, Elise noted the same learning styles when talking about this idea, describing how most students like hands-on and visual lessons (Interview). Christine talked about gathering students’ input on their own learning styles at the beginning of the year and even at the end of some classes, asking students “How do you view this lesson worked for you?” (Interview). Similarly, George emphasized the importance of matching instruction to learning styles, describing his perspective:

Because I know that Katie (pseudonym), unless she’s moving, is not going to learn anything. The other kid over there, he doesn’t get anything at all visually, it’s all audio. And, after you know him a little bit, you start picking up on that. (Interview)

Teachers believe that students learn in different ways, or in different styles, and that belief influences pedagogy by guiding the types of instruction and activities teachers plan. One such example is how teachers planned for offering choices to their students on certain kinds of activities. The kinds of choices teachers offered ranged from a degree of open-endedness within an activity to offering a very flexible range, particularly on larger assignments like projects. Brad talked about creating a science fair at his school, where students “can pick whatever topic they want as long as they’ve got variables and controls and they’re using the scientific method to answer the question” (Interview). Christine described options students could choose from for a project on cells, including creating a poster of analogies, making an advertising catalog for cell
parts, or writing a song (Interview). Elise described how she has used choice boards to offer learning style-based options on projects. One example from Elise’s teaching, similar to what Christine described (Interview), was her unit on cells that included options for students to write poems or songs, create a model of a cell given some random materials like Legos and pipe cleaners, and even an option she called “free choice” (Interview) where students could propose any other type of project for teacher approval. Henry negotiated choice, developing a cell project where all students had to write a paper for the first half of the assignment but then offered choices similar to those offered by Christine and Elise for the second half of the assignment (Interview). However, because these assignments were generally larger and open-ended, several teachers explained that they used projects like this sparingly. Brad, Christine, Diana, and Elise all mentioned during their interviews that one project a unit, which typically corresponded to one major unit of their curricula, was an appropriate amount based on factors such as grading, parental involvement, and the breadth of the curriculum.

On a smaller scale, teachers could also differentiate their plans for activities by offering students a smaller degree of choice. Brad allowed his students to create their own illustrations for his notes (Observations #1-2). Christine asked students to develop a graphic organizer arranged according to students’ understanding of the terms about natural resources (Observation #4). Henry’s writing center, where students wrote a short story about cell division, provided for a degree of creativity and open-endedness for students to choose the point of view or to develop a narrative around the factual information about mitosis (Observations #3-4). Elise encouraged her students to record analogies about organelles that made the most sense to students and not necessarily the ones pointed out in her instructional story (Observation #2).
However, it is important to note that some teachers expressed that there were limits to the effect of learning differences on their plans. Fred voiced these limits:

You know we talk about the different learning styles and a certain degree of that is true and certain degree of that is complete bunk too. You know, you can be in a classroom environment and have an energetic teacher who’s just dedicated to getting it across to you and you’re willing to learn, it doesn’t matter what your learning style is, you can get it. Sometimes I think we put too much emphasis on that, oh Johnny’s a visual, I can’t you know, they can’t talk to him, that’s nonsense. That just means he’s probably going to do better with the visual stuff. (Interview)

Similarly, Christine takes her students’ feedback with a grain of salt, explaining, “I know that there’s kids when I’m asking [about how the activity worked for students] that use all [preferred methods/learning styles]…and so I really try to use them all” (Interview).

While teachers recognized that students learn in different ways, the idea does not imply that students cannot learn from instruction or activities presented in a non-preferred modality. Rather, students may learn more efficiently when instruction matches their preference or at least when a unit includes a preferential option. This is an important distinction as teachers typically planned for a single set of activities in a unit that each included elements of differentiation rather than developing an elaborate system of differentiated lesson plans that featured students working on their own more individualized paths toward mastery every day. Even when teachers such as Elise, George, and Henry used tiered learning centers, the differentiating elements were limited to how much students accomplished, the teachers’ expectations for the quality of what students accomplished, or by offering different kinds of resources to complete the activity. All students
still completed the same types of activities towards the same goal of mastering the required content standard.

**Building student engagement.** Since teachers recognized that their students have different levels of readiness, learn at different paces, and learn in different ways, teachers developed engagement by considering those characteristics and adapting their classroom environments to meet students’ unique characteristics. The strategies by which teachers develop and nourish student engagement such as giving students roles to facilitate a lesson, creating an interesting learning environment, developing rapport with students, and interacting with students as they worked have already been discussed in the *planning* phase’s best practices section under the sub-heading maximizing instructional time in a safe learning environment, so this section focuses on how teachers differentiated those best practices for their specific set of students.

Teachers used their understanding of their students, such as recognizing their interests or readiness levels, to develop a learning environment that was not only engaging but also included specific elements in order to engage particular students or groups. The distinction between what constitutes best practices and differentiated instruction here may seem like splitting hairs, but it is important to consider the mindset by which teachers make these planning decisions. Though they designed their environment and instruction based on their beliefs of how students learn best, they also planned ways to adjust those things because of their knowledge of and relationship with specific students. Environmentally, for instance, Brad discussed how he considers students’ characteristics when changing his seating chart to pair an ELL student with “someone who can help them out” (Interview). His specific words seem important here, because he did not just pair an ELL student with a high achieving peer, but he considered who might be helpful specifically to that student, implying that he made choices based on personality in addition to academic data.
Henry made similar comments when talking about creating his groups as he designated a leader for each heterogeneous group, explaining that in the class period I observed, the higher achieving students he would like to take the role of group leaders did not fit that role well because they were too social (Interview). Likewise, Christine choose specific students, considering “who is somebody in here that really helps like if you’re struggling with getting the notes taken down” (Interview) to be that peer who will help his or her neighbor by answering questions and allowing his or her neighbor to copy from the helpful student’s notebook. The relational aspects of these adjustments are an important part of creating an engaging environment specific to some students’ unique traits.

The arrangement of students’ peers, however, was not the only relational aspect to adjustments made in the learning environment to keep students engaged. Teachers themselves took advantage of their knowledge and relationship with students to engage them. One dramatic example was the long and heartfelt speech Christine delivered during my second observation, exhorting and encouraging students that they matter to her despite whatever difficult circumstances students find themselves in. She explained to me later that a student from that particular class had dropped a note in her dropbox that described a conflict the student was experiencing at home. Though it was just one student who left a note in her dropbox, Christine responded to the whole class (perhaps with that specific student in mind), developing the relationships in her community that led to higher levels of engagement. George provided another example when preparing his class to sing the water cycle song at the school-wide pep rally (Observations #3-4). He communicated to some students that if they were not comfortable at first standing and singing, they could watch and learn it from their desks. Though he expected them to learn the song, he understood that some students would not be comfortable playing such
an extroverted role. In this way, George differentiated his environment to promote engagement by building trust with those shy students who knew George expected them to learn the material, but who could also gratefully accept his offer of an alternative way to participate. The shy students could focus on learning the song rather than their own feelings of self-consciousness about standing and singing it in front of their peers. Henry, responding to a student’s interest in the videogame *Minecraft*, allowed that student to complete an assignment during an Earth science unit by taping a session of gameplay where the student could explain the concepts he or she had been exploring in class (Interview). Elise kept a “brain board” (Interview) in her room where students could leave any kind of science question that interested them, and she would write a response to them within the next day or two. Similarly, Alice, Diana, Fred, George, and Henry either discussed in their interviews or demonstrated during my observations how they use specific students’ interests to illustrate their examples during direct instruction. Even something as small as watching Alice commiserate with a yawning student or Fred congratulate a student on a benchmark score demonstrated how teachers responded to their specific set of students.

**Offering a variety of resources.** Teachers differentiated their planning by gathering and developing a set of resources designed to meet students’ differing learning needs. The variety of resources and access to them teachers planned for were designed to support students’ differences by offering instructional materials at different levels, supporting students’ organizational efforts in order to facilitate the pace at which they learned, and incorporating resources more specifically geared towards different styles of learning.

**Differentiated instructional materials.** Teachers demonstrated that they planned to offer a variety of instructional materials, some of which were aimed for specific readiness levels. It is important to point out that teachers typically (but not always) offered or assigned students to
these resources for everyone in the same way, but with an understanding that certain materials may benefit some students more than others. For instance, Elise’s tiered research-based activity on cells required students to use the app iCell to gather information about parts of a cell. The app included three levels of information, and students were required to complete lower levels before moving on to the next. Elise did not assign or designate students to specific levels, but challenged all students to do their best (Observation #4). In this way, she offered the differentiated materials universally, leaving it up to a student’s sense of accomplishment to decide how far he or she would go with those materials. Similarly, Diana offered different levels of texts to students during the research phase of their jigsaw activity, allowing students in each group to decide which texts it would read from to gather information (Observations #1-2). Fred straddled the two strategies, offering a variety of resources universally on his website but also assigning specific students to those resources during class. He developed a comprehensive website that included a series of links, such as notes from class, digital assignments, and links to instructional videos on sites like YouTube and Study Jams, organized according to each one of his required content standards. The website was always there to support students, but he also used it during remediation activities to assign students to specific resources. In two of my lessons with Fred, I observed students working on a track of digital activities that was determined according to recent assessment scores. For instance, if a student scored below an 80% on questions related to one content standard, then Fred would have that student work through a sequence of links on his website associated with that standard (Observations #2, 4). Alice and Elise also mentioned offering a variety of resources through their websites (Interviews), with Elise mentioning specifically how her site included links to a digital flash card website, Quizlet and instructional videos. Christine noted how she used her website to offer
recordings of her as she read a quiz to help ELL students in particular (Interview). George grouped his students for learning centers so that he could assign a specific tier to specific groups. He could offer resources at different levels of complexity, for instance, by offering various texts like articles from Scholastic and Highlights magazines and even science articles from The Wall Street Journal (Interview).

Several teachers even utilized their textbooks in different degrees to act as one of the differentiated resources. Alice primarily used the diagrams and illustrations in her textbook to support her own direct instruction (Interview). Christine and Henry used their texts as a guide for the development of their direct instruction, condensing and clarifying content to target students’ readiness levels (Interview). Elise mentioned her digital text’s audio feature as one of the supports she can offer to ELL students (Interview). By utilizing only selected elements of their classroom textbooks, teachers demonstrated how they had adapted this resource to suit the learning needs of their students.

Supporting students’ organization. Five teachers required students to use the resources of either a class science notebook or an agenda (and sometimes both) to support students’ organizational skills. I observed Christine, Diana, and Elise using science notebooks, a composition book organized specifically for their classes, to help students keep track of the activities and information they gathered during class. Their plans for how to organize the notebook and what to include in it reflected that they had considered the characteristics of middle school students; namely, that many need help keeping up with their materials. They designed these notebooks to provide a level of support to students deficient in that skill. Alice used weekly objective sheets, and Brad, Christine, Fred, and George all required students to write down an agenda either for the day or for the week. Not all students needed the support, but it
was offered (or required) to everyone as teachers planned with the general characteristics of middle school students in mind. While these routines could also benefit the teachers just as much (if not more) in facilitating their classroom management systems, notebooks and agendas were also intended to help students organize their classwork.

Different resources for different types of learning. Teachers planned to offer a variety of resources, some of which were intended to match a particular learning style. Sometimes, this included pooling resources with other teachers. Fred discussed his grade level’s “science alliance” (Interview) that included teachers from the around the school district that pool together resources. George and Henry discussed how they planned activities like learning centers and assessments with their grade level partners (Interviews), and I observed the same phenomenon with Christine and Diana who teach at the same school.

However they gathered the resources, teachers used a variety that included texts, audiovisual materials, classroom technologies, online resources, and physical objects to be used in demonstrations to account for different ways students might grasp a concept. Alice, for instance, created graphic organizers as notes for students to see the content and then also reinforce the idea by turning half of her classroom into a beach scene (Appendix J, Teaching Artifact #4), complete with a sea breeze simulated by a fan (Observation #4). In a similar fashion, Christine referred students to objects in her room like the lava lamps to demonstrate convection, making it so students could approach the same ideas about a concept in different ways (Interview). Christine and Diana’s jigsaw activities had students using texts from the library to find information and searching the web on student computers to find illustrations for their presentations (Observation #1 with Christine; Observations #1-2 with Diana). Elise utilized a number of resources during my observations, including a giant sticky note to record students’
prior knowledge on cells, an illustrated story the class read together, the school’s mobile lab with iPads and laptops, and paper and digital flash cards. Both George and Henry’s learning centers were designed so that students interact with content in different ways such as software on computers or iPads, articles, textbooks, teacher-generated notes or diagrams, and lab tools like microscopes (Interviews and Observations).

Here again, it is important to note that teachers typically used this variety of materials to teach all of their students while recognizing that, although students may have different learning needs, the materials may still benefit every student (though in different degrees). As Fred stated, an understanding of learning styles does not imply that there are modes of learning from which a student cannot learn (Interview). Rather, recognizing students’ preferred learning style means that a teacher can make the learning of a concept more efficient for that student if a preferred mode for learning is offered. In her interview, Elise discussed how much students enjoy learning activities that include talking. She emphasized that, though working in groups might be a preferred way of learning for her students, she believed they still needed to work on different kinds of activities that can improve areas students are weak in, like completing independent written work. So, while differentiating planning to include a variety of resources geared towards certain learning styles was an important consideration for teachers, they also typically utilized all of that variety in their instruction whether it was a student’s preference or not. In this way, teachers could ensure that they offered at least some instruction or activity in a learning modality a student preferred. They could also work towards developing well-rounded learners who were able to develop an understanding of a concept from a variety of instruction and accompanying resources.
Providing access. A critical component of developing certain types of resources was how teachers planned for students to access those resources. Most of the time teachers afforded students opportunities access to the resources in class, but teachers also arranged the resources so students could access them outside of regular class time, offering a loosely differentiated element by allowing students to voluntarily spend more time with the content. Teachers offered students access to the variety of resources in class, such as Elise’s tiered research-based cells activity (Observation #4) or Henry’s use of learning centers where students were required to utilize resources like the textbook, a graphic organizer, or Study Island software to complete various activities (Observations #3-4). Other times, teachers assigned students to specific materials, such as George’s tiered learning centers for homogenous groups (Interview) or Fred’s reteaching system (Observations #2 & 4).

Teachers supported students’ access to these resources by making it as easy as possible for students to use them. Elise kept a folder for each clump of desks, stocking it daily with the printed resources and activity materials students would need (Observation #2). George kept the printed materials in specially designated folders at his learning centers (Interview). It also included more intensive preparation, such as a recording of a teacher reading a quiz to post on their websites for ELL students (Interview with Christine) or by creating digital copies of study guides or notes for students to access from teachers’ websites (Interviews with Elise, Fred, George, and Henry).

Outside of regular classroom time, teachers primarily used their websites to offer their different resources. A couple teachers also noted how students could access their textbook online. Christine, Elise, Fred, George, and Henry all mentioned the variety of resources available on their website, including things like YouTube clips, online assignments, links to
informational websites, teacher-generated sets of digital flashcards, instructional videos, and school-purchased software like Study Island and BrainPop. Elise and Christine both mentioned the supplementary materials included with their textbook that have digital elements they can offer or assign to students such as online activities, audio files of the text being read, or extending information on a topic. Taking advantage of these constantly available digital resources, teachers recognized that regular classroom instruction might not be sufficient for all their students, so, in response, they developed an array of readily accessible resources to support their students.

**Scope of differentiation.** An interesting theme that emerged from the data was that as teachers planned ways to differentiate their instruction and activities, they typically expressed their plans for differentiation in terms of their students as a whole group as opposed to speaking of developing plans for specific students. Christine provided the initial in vivo code for this idea, responding to a question on how students’ characteristics influence how she teaches, explaining:

Well, I would get the characteristics of seventh graders as a whole. I really know what seventh graders are about. I make it my job to know what they're about. I don’t really look so much individually at their characteristics. For my teaching as a whole, I’ll look at them as seventh graders. You know, what are their maturity levels? What do they typically like? What do they do? Now, I certainly care about their individual thoughts too, but as far as my teaching as a whole, I try and look at the overall characteristics of a seventh grader. (Interview)

Elise shared the same sentiment, “But I know just in general this age, they’re so visual or they like hearing stories. They love video clips, and they learn well off of them” (Interview). Elise went on to include characteristics like middle school students’ increasingly social tendencies as
being a factor that influenced her plans, encouraging her to include activities where students could interact with each other but within reasonable limits. She explained, “I think they’re so worried about what their peers think, and that’s all they think about and so they miss half of what I say because that’s all they care about” (Interview). Elise also talked about how much her male students benefited from kinesthetic activities, comparing them to her female students that she described as being more easily engaged (Interview).

Teachers included students’ generational characteristics as well when considering how to adapt their plans to best meet the learning needs of their students. Fred described the idea, sharing that students’ proclivity for technology was a motivator for using technologies like YouTube in class (Interview). Elise echoed the idea, stating, “They’re just entertainment type kids you know, and I just tend to incorporate it because I know what this generation tends to be like” (Interview).

Many times teachers explained their ideas of how to adapt their plans for their students based on their perceptions of middle school students’ readiness levels. Brad described why he generally refrains from very open-ended inquiry-based activities sharing, “Give them a sentence basically and say, prove that density doesn’t change no matter how [many] objects you have. Most of my kids are going to be like, ‘What the heck are you talking about, I don’t understand’” (Interview). Similarly, Elise commented that the majority of her students preferred hands-on or visual modalities (Interview). Brad also expressed how the length of his eighth grade students’ attention spans affects how he plans (Interview). His response was to break his direct instruction into smaller segments to incorporate short activity-driven breaks (Observations #1-2). George talked about recognizing the difficulty his sixth grade students have in moving ideas from the brain to paper (Interview). He discussed how his experience teaching sixth grade has developed
his ability to read the textbook and predict how well his students would comprehend the information, anticipating how students’ levels of prior knowledge would influence their understanding of certain analogies or illustrations in the text (Interview).

**Contextual factors influencing planning.** Several conditions and contextual factors influenced teachers’ use of elements of best practices and how those elements were differentiated. During the planning phase, teachers were most influenced by the larger contexts, the macro level conditions, surrounding their classroom environment and instruction. These macro level conditions included the content standards mandated by the state’s department of education, the curriculum map of the local school district, teachers’ perceptions of the general characteristics of their set of middle school students, the influence of the concepts themselves on instructional planning, and their schools’ resources.

**The content standards.** The content standards required by the state and assessed by its high-stakes test, the largest of the macro conditions, provided the starting point for teachers’ planning. Alice talked about how she has focused her content as she has gained experience teaching science, relying on the item samplers the state’s Department of Education provides and the district-provided coach books that are arranged according to content standard (Interview). These resources became the foundation for her plans, describing the required content standards by providing examples of how they will be assessed, Likewise Fred, described that a “laser focus” (Interview) on the standards was the basis for his curricular alignment. In particular, he regarded how the standards were portrayed on the two sets of item samplers the state had provided through the company that actually writes the high-stakes test as critical to understanding the intended knowledge of the standards. Everything he teaches should be
aligned, he contended, to those content standards, providing the basis for his comprehensive website developed according to the state’s wording of the content standards (Interview).

**The curriculum map.** Having based the focus of planning on a particular required content standard, teachers then arranged to teach the corresponding concepts in line with the school district’s curriculum map, with some influence on following its chronology lying with grade level departmental teams. Alice, Christine, Diana, Elise, Fred, and Henry all discussed during their interviews how they followed the district’s scope and sequence for the curriculum. Though Brad did not mention the scope and sequence, he did reference following the textbook that in itself provides a guide for teaching the concepts required by the content standards (although chapters may not be chronological to the district map). Christine and Diana, who were a grade level team, provided a unique example of how science departments generally keep the same pace and follow the sequence of the district map. My first observation with Christine included students finishing a jigsaw activity on natural resources that Diana’s class was just starting (though different in its implementation) that same day.

**The characteristics of middle school students.** Knowing what to teach and generally when to teach it, teachers then considered the characteristics of their set of middle school students, relating these characteristics to teaching methods they felt would best suit those students. This includes a recognition that students begin at different levels of readiness, learn at different places, and learn in different ways. These differences led teachers to developing engaging learning environments for those students and planning for ways to offer a variety of resources aimed at providing instruction at different paces and through different modalities of learning. Teachers generally planned instruction and activities while thinking of their students as a whole group, including their preferred methods of learning that involved social aspects
(Interview with Elise), visual elements (Interviews with Alice, Brad, Elise, Fred, and Henry), and opportunities for kinesthetic learning (Interviews with Elise, George, and Henry). Students’ generational traits such as a proclivity towards technology (Interviews with Elise and Fred) and typical readiness levels (Interviews with Brad, Elise, and George) were also factors that influenced how teachers planned for the instruction of the concepts in the required content.

**Determining the best way to communicate a concept.** With this understanding of how best to teach their set of middle school students a required content standard, teachers then considered how the concepts in that content standard were best presented. Teachers provided several examples of how particular concepts lent themselves more naturally to certain types of activities. Brad mentioned that students learned some concepts best through experience as they practiced skills like interpreting dichotomous keys and calculating density (Interview). Diana and Elise discussed how visual activities helped students better grasp concepts like the Earth science topic on the layers of the Earth (Interviews). Henry talked about having designed some kinesthetic activities specifically for topics like cell division and diffusion (Interview & Observation #1).

**Connecting concepts.** While designing activities specifically for certain content standards was important, teachers also considered how to connect related concepts across their curricula. They planned ways to support students’ learning of a content standard by connecting past and future concepts with the current one. Teachers connected both backwards to previously learned content, such as when Brad reiterated the concepts of mass and density during several related units (Interview), and forwards as well, like when Alice previewed to students the concept of biomes by showing leaves blown from deciduous trees in a recent thunderstorm (Observation #3).
The availability of resources. Lastly, teachers’ plans for teaching the required content standards were influenced to some degree by the availability of resources in their respective schools. The available resources sometimes limited teachers, such as Henry lamenting deficiencies in class sets of certain lab equipment (Interview) and others stating a desire to have more technology like student computers to provide more research-based activities (Interviews with Alice and Diana). Other times, teachers demonstrated ways to take advantage of the number of resources that were provided by their schools to enhance their instructional plans. For instance, each teacher used a projector running through their teacher computer for things like displaying notes, delivering assessments with CPS clickers, showing video clips, or posting bellwork and/or the daily agenda. George and Henry talked about ways they used their iPads to connect to their projectors through an AppleTV to show students examples of content with apps or to simply encourage students to find relevant apps outside of class (Interview). Diana made use of the handful of student computers she had by using a timer for one member from each resource jigsaw group to spend some time researching his or her natural resource for their group’s presentation (Observation #2). She also had gathered relevant books from her school’s library that students could use for research (Observation #1-2). Elise, Fred, and Henry were all observed using their schools’ mobile labs that included either laptops, iPads, or a combination of both. Alice used a document camera to facilitate how students took notes in her class (Observations #3-4) while Christine and Diana talked about using interwrite boards for a similar purpose (Interviews). Elise even expressed some anxiety about not having access to the iPads in her school’s mobile lab, humorously telling me:

Yeah, I just got an email about iPads. We’re trying to update iPads, and we’re having issues, and I don’t know if they’ll be ready by Thursday [for the research-based cells}
foldable], and I’m like ‘eeee!’ so you better have a plan B. And I’m like, I don’t want to have a plan B, I want plan A. (Interview)

Several teachers discussed the variety of resources available through their websites, illustrating how they could universally provide students with opportunities for instruction and practice outside of regular class time (Interviews with Elise, Fred, George, and Henry).

**Teaching**

Effective middle school science teachers demonstrated a wide collection of teaching strategies, providing strong examples of dynamic teaching. The major themes that arose from the data related to best practices science teaching included using multiple forms of inputs, providing a variety of activities designed to move students through simpler concepts before more complex ones, and modeling thinking skills (see Figure 5). Teachers differentiated those best practices by designing the variety of activities they used with their students’ characteristics in mind, targeting instruction to students’ levels of readiness, and scaffolding students as they learned concepts. During the *teaching* phase of instruction, teachers differentiated instruction based on their perceptions of the general characteristics of middle school students as well as more specific characteristics such as the patterns of interaction they developed with specific class periods. Because teachers used such a wide variety of differentiating strategies during the *teaching* phase, I considered this to be the second most differentiated phase of instruction.
Figure 5. The teaching phase of instruction. This figure represents the key themes that emerged from the data accounting for teachers’ use of best practices (blue box) while delivering activities and instruction in addition the primary ways in which those practices were differentiated (green box) and the scope of the factors influencing how teachers chose to differentiated (size of the blue ring).

**Teaching with best practices.** Effective middle school science teachers demonstrated a number of teaching strategies considered to be best practices. First, they utilized multiple inputs to deliver instruction. This included a variety of strategies when using direct instruction, such as lectures with guiding materials and classroom technologies to enhance the instruction. Teachers also used demonstrations, student presentations, and a selection of different texts to present new content. Then, teachers implemented an array of sense-making activities, progressing students from simple concepts to more complex ones and integrating independent and cooperative elements in the activities. Teachers also communicated to students the purpose of the activity, creating a shared vision towards achieving the common goal of achievement. Finally, teachers opportunistically modeled thinking skills for students to support their understanding of concepts.

**Using multiple inputs.** One very salient theme that emerged was that each teacher used multiple types of inputs when presenting content. Typically, teachers relied on direct instruction
(though with elements to guide students during the instruction) as their primary mode of delivering content, but teachers also incorporated demonstrations, student presentations, and purposefully selected texts to give instruction. Teachers not only presented new information in different ways, but they also presented it repeatedly and/or sequentially, providing multiple exposures to a concept.

Direct instruction. Contrary to my expectations, I observed teachers relying on direct instructional methods, though they nearly always included some support to supplement the direct instruction in a majority of the 32 lessons; so much so in fact, that in my analysis, I consider a teacher’s skill in direct instruction to be a critical component of their effectiveness as a middle school science teacher. For example, Alice used direct instruction in all four lessons, devoting time in two lessons to lectures and time for instructional videos in the other two lessons. I observed versions of lectures on new content in Brad (Observations #1-2), George (Observations #3-4), and Henry’s (Observations #1-2) classes as well. Fred relied on direct instruction as a crucial part of communicating and remediating content, requiring students who made below a certain percentage to visit links on his website that led to instructional videos or notes from previous lectures (Observations #2 & 4). I observed Christine delivering a lecture as a review prior to a test (Observation #3). Elise used a whole class guided reading activity to provide opportunities for creating and explaining analogies to a cell’s organelles (Observation #2). Diana’s unit on natural resources included two lessons for students to present content (Observations #1-4). Teachers used direct instruction in differing degrees and for different purposes, but each teacher relied on it as an integral part of presenting or reviewing content.

The strategic use of direct instruction. The prevalence of direct instruction does not imply that all teachers utilized the strategy the same way and for the same reasons. For instance,
one such strategy was using direct instruction at the beginning of a new unit or new concept to introduce ideas and connect them to previously learned information or students’ prior experiences (as described in the best practices section of the planning phase). Henry described himself saying, “A lot of my style is I’m going to tell you exactly what I want you to know, and then we’re going to work on that” (Interview). Brad also introduced his new unit on adaptations using direct instruction, using most of his first two lessons for lecturing. When George started a new content standard on weather during my third observation, he began by explaining new vocabulary terms with key phrases to remember them by along with a corresponding motion to represent the term. By introducing students to the concepts included with a new content standard through direct instruction, teachers were developing background knowledge so that as students worked on later sense-making activities, they could refer back to their learning experiences during the direct instruction.

Additionally, it is important to point out that teachers rarely used direct instruction apart from other instructional strategies or elements. The supports a teacher provided to their forms of direct instruction were a recurring theme throughout the study, highlighting a key element of how effective middle school science teachers teach. Fill-in-the-blank notes on one side of a piece of paper and a corresponding graphic organizer on the other side (Appendix J, Teaching Artifact #2) supported Alice’s direct instruction (Observations #3 & 4). Brad also used a guided outline, having students illustrate certain sections of his notes (sometimes with the help of diagrams or illustrations in the textbook) to visually represent certain concepts or terms (Observations #1 & 2). Students in Henry’s class took notes from a PowerPoint presentation as he underscored important ideas with stories and illustrations (Observations #1 & 2). Christine relied on students to copy the notes she wrote down on the whiteboard as she reviewed key terms
and ideas about natural resources (Observation #3). Elise’s students recorded analogies (Appendix J, Teaching Artifact #5) about cell parts as she read a story out loud to the class comparing the organelles in a cell to the parts of a school (Observation #2). In Diana’s jigsaw activity, the listening students filled out a listening guide (Appendix J, Teaching Artifact #6) noting specific aspects for each group’s presentation of a natural resource (Observations #3 & 4). Fred’s instruction was supported by notes taken from a PowerPoint presentation, and these presentations had also been posted on his website. George’s supports for direct instruction were the only ones that did not include some sort of student writing, instead relying on kinesthetic elements as he taught students motions to go with new vocabulary terms to support his explanations of the terms (Observation #3). He reinforced these consistently, devoting time in all four lessons I observed to at least reviewing the key words of vocabulary terms with their corresponding movements if not also talking through the terms in more detail. Though teachers relied on direct instruction to present aspects of the content (either to introduce it or reinforce it), they never seemed to expect students to master a concept from that direct instruction by itself, consistently including visual, written, or kinesthetic supports to accompany the instruction.

Another strategy was how teachers used direct instruction to reinforce previously covered concepts. Christine, for example, used a whiteboard-based lecture as a method for reviewing important vocabulary terms (Observation #3). Diana closed her jigsaw activity by telling students that the next class period would be used to “clear things up” (Observation #4) referring to teacher-led instruction on the big ideas students had just presented on. While Alice used videos and a demonstration to introduce convection, she walked students through the creation of two sets of notes with graphic organizers to more precisely explain the concept (Observations #3 & 4). Fred used the direct instructional materials available via his website, such as BrainPop
videos or YouTube clips, to help remediate students (Observations #2 & 4). This strategy provided students with multiple exposures to concepts, often in a slightly different method than the original instruction.

**Multimedia.** Teachers also used other formats for direct instruction such as instructional videos or engaging brief video clips to present or reinforce content. Alice used a Bill Nye video to introduce convection (Observation #1) and then a brief YouTube video clip of students performing a demonstration of convection using different temperatures of water and food coloring to reinforce the concept the next day (Observation #2). Both Christine and Diana used the same YouTube video on biomass, though Christine used it as an engaging way to refresh students on renewable resources (Observation #2) and Diana as a way to communicate to students that they had not studied all the different types of natural resources and that resources may come from unexpected places (Observation #4). Brad even used the recently viral YouTube clip “How Animals Eat Their Food” as a way to engage students in thinking about how animals are uniquely adapted to their environments (Observation #4). Fred’s robust set of online resources on his website provided a number of links to multimedia, including short instructional videos from BrainPop, YouTube or TeacherTube video clips, and even musically-based explanations of concepts from Study Jams (Interview).

**Student presentations.** Another method of direct instruction teachers utilized was asking the students to take on the role of the teacher and present content to the class. Christine and Diana both used this strategy as an introduction their units on natural resources, having students complete a jigsaw activity on natural resources. Individual students (Christine Observation #1) or groups (Diana, Observations #3-4) researched their assigned resource and then presented their findings to the class with the help of a research guide to focus their presentations. George’s
students were the first to present new terms to the class, using previously completed definitions to play the ‘I have, who has?’ vocabulary game (Observations # 3-4). Brad used students to present content on a smaller scale as a way to review previously covered content. After he had used notes to communicate the concept of organisms’ adaptations to their environment (Observations #1-2) and assigned students to develop a small poster on an imaginary animal adapted to its ecosystem (Observation #3), Brad spent the beginning of the fourth lesson having students explain the posters they developed as he asked clarifying questions. While teachers never relied on students to be the sole presenters of content, some teachers gave students a significant role in delivering or reviewing information.

Selected texts. Another method of direct instruction used by some teachers was relying on selected texts to deliver new content or reinforce recently covered information. For instance, Diana’s jigsaw activity on natural resources was designed so that students selected from among a handful of texts, chosen by Diana from the school’s library, to find the information required on their research guide (Observations #1-2). The information in the texts had not yet been covered in class, so students had to read through the texts to gather information about their assigned resource before delivering their presentations. Relying somewhat less on students’ ability to be instructed independently from a text, both Elise and Brad had strategies for using selected texts to supplement other forms of instruction at the beginning of a unit. Elise read through a story on cells aloud to the class, stopping with each organelle and describing in more detail how a cell part was analogous to a part of a school (Observation #2). So, while the text did present new information, Elise was able to supplement it with her own way of communicating the same ideas. Brad required students to find information in the textbook on an as-needed basis, supplementing
the notes on adaptations he had previously covered (Observation #2). After finishing the notes, students used them in conjunction with the textbook to complete review questions from the book.

Demonstrations. Teachers also demonstrated the content, talking through an experiment or illustration to present a concept orally and visually. Henry provided a unique example of this teaching strategy, introducing the concept of diffusion by having his students participate in a class-wide demonstration. Without explaining diffusion or even mentioning the term, Henry instructed his students to put their hands on one specific wall of his classroom. Students gathered at the wall, crowding against it to get their hands on the wall. He then introduced the concept of high concentration by relating it to how crowded students were in this small section of the room. Then, he broadened the boundaries a little, telling students they could stand anywhere in this one half of the room. Naturally, students spread out in their new space. Henry ended the demonstration by telling students they could stand anywhere in the room, pointing out how students spread out to all corners of the room. Only at this point did Henry use the term diffusion, explaining to students that they had just demonstrated how particles move from areas of high concentration to areas of lower concentration (Observation #1). George and Alice also used demonstrations to instruct students about concepts, though they both used the strategy to reinforce previously covered information. After a popcorn reading of a textbook section on weather, George paused the reading activity to illustrate the idea of humidity. Using a classroom sink to wet a rag, he let water drip from the rag to explain to how air could become so full of water that new water would not evaporate easily (Observation #3). Likewise, Alice, having already shown and discussed with students a Bill Nye video on convection during my first observation, showed a second silent video clip from YouTube featuring a similarly aged class conducting an experiment. Students in the silent video filled a two-partition clear container with
water, filling each side from a different jug (one cold and one hot). Each side was then colored with food dye, one side being red and the other blue, before students removed the partition to mix the two containers of water. After a time lapse, students in Alice’s class noted how the red water moved from the side of the container to the top and how the blue moved from the other side to the bottom. She then asked students to describe what happened before revealing that the class would do the same experiment together, setting it up that day and analyzing the results the next (Observation #2). By conducting the actual demonstration in class, Alice gave her students the opportunity to feel the differences in temperature for themselves, observe how it affected the movement of water particles, and, over subsequent days, notice how the colors would blend as the two sides moved towards room temperature.

**Modeling thinking.** As teachers delivered instruction, they modeled thinking strategies for their students. As discussed during the best practices planning phase of instruction, teachers planned for ways to connect previous content and to illustrate concepts with real world or personal examples. Since that type of modeling was integrally tied to how teachers organized and presented the concepts in their curricula, I included it in that previous section. However, the thinking strategies teachers modeled during instruction like focusing on vocabulary and test-taking skills seemed more organic and concentrated on the lesson at hand rather than being an engaging strategy aimed at connecting concepts across the curriculum or to students’ experiences. During the teaching phase, teachers walked students through their trains of thought to describe the specific cognitive processes involved with understanding the big idea of a concept during the current lesson.

**Modeling vocabulary.** One common form of modeling during instruction was how teachers helped students master new vocabulary terms. Alice and George demonstrated
kinesthetic methods, teaching students a physical motion to represent a term. For instance, Alice taught her students a two-hand rolling motion to simulate the movement of particles during convection and then integrated it into an on-going game of Simon Says her students play with leftover time at the end of lessons (Observation #2). Similarly, after students had played a round of the ‘I have, who has’ game, George described the word *front* in more detail, giving students a double-handed squeezing motion to go along with his key words of “boundary of two air masses” (Observation #2). He modeled for students how to visualize the concept by acting out its motion. Elise modeled the recognition and understanding of new vocabulary terms as she read the analogy-based cell story, pausing with each new cell part to further explain and illustrate the analogy. The analogy served as a model for how students could remember the function of specific organelles (Observation #2).

Christine and Henry used more general modeling strategies related to vocabulary, demonstrating for students how to break down new and unfamiliar terms. During a whole class question-and-answer review session, Christine went over some of the technical vocabulary like the word alternative by focusing on the root *alternate* and giving students examples of how that word was used around school such as in the spelling bee or on sports teams. She also walked students through the word *geothermal* asking students about the prefix *geo-* and what the root *thermal* meant (Observation #4). Henry broke vocabulary terms down in a similar fashion, appealing to students’ prior knowledge of words like *passive* and *active* when teaching about how molecules move across a cell membrane in passive or active transport (Observation #1). He sometimes also added a visual cue, sketching a concept next to corresponding key words on the whiteboard for students to put into their science notebooks during his PowerPoint-based direct instruction (Observation #2).
**Modeling test-taking skills.** Teachers also modeled test-taking skills for students, preparing them especially for the high-stakes test at the end of the year. Alice provided one of the strongest examples of this kind of modeling, emphasizing at the outset of her unit on convection how students should approach diagram-based test questions. She began the unit by encouraging students to look for the diagram’s energy source, the concept taught during the last unit (Observation #1). As students took notes on the graphic organizer showing the movement of hot and cold air particles that create wind currents, she modeled for students how to answer questions on convection by referencing the drawing on the organizer, noting the placement of the energy source as the starting point (Observations #3-4). She reinforced this skill during each of my four observations to the extent that by the end-of-the-day quiz on my fourth observation, she asked students, “What should you find first?” to which students chorally responded, “The energy source!” In more general ways, Brad and Fred also modeled test-taking skills for students. They frequently used sample questions from the state’s provided sampler and USA test prep, integrating them into sense-making activities and assessment so that they could walk through questions like what students would see on the end of the year test. Though I did not observe Brad model test-taking skills using these specific resources, I did observe how he reviewed students’ homework at the beginning of my third observation, watching how he asked clarifying questions to guide students’ thinking on how best to answer that particular question. Similarly, Fred integrated questions like those on the high-stakes test throughout the year, explaining during his interview, “I’m trying to prepare the kids for the appropriate alignment and rigor level.” By integrating these questions into the normal flow of instruction, Fred provided himself with the opportunity to model the specific skills and/or testing strategies students should apply.
Providing a variety of progressively more complex sense-making activities. Along with presenting content in multiple formats, how teachers utilized a variety of activities was one of the most significant themes in the data. Teachers designed the activities to help students process information in different ways and to provide multiple exposures to concepts. Teachers offered several ways for students to make sense of a single learning objective and generally arranged the tasks so that students would move from simpler activities to more complex ones. Often times, this included communicating the purpose of the sense-making activity so that students would understand why they were being asked to complete a certain activity in a particular manner.

Types of activities. Similar to teachers’ use of multiple and varied instructional inputs, teachers also intentionally designed a variety of activities to make sense of new ideas. Alice summed up this theme well, explaining that it was important to her to allow students to “do more than just come in, sit down, and listening to me all the time” (Interview). She described how she incorporated variety saying, “For each skill [I do] three to five different things,” elaborating “But I have about 20 things I do throughout the year” (Interview). Put another way, she typically uses about 20 different kinds of sense-making activities that she adapts for particular concepts. Other teachers reinforced this idea, describing the lists of types of activities they typically choose from when developing sense-making activities. Brad identified different activities he routinely uses such as group projects, students working through questions in the text, drawings, roleplaying or debates, creating songs or stories, and labs (Interview). Fred also had students work through questions in the text, and he added hands-on activities, foldables, and the learning tracks provided by the resources on his website (Interview). Henry continued the theme, emphasizing the importance of creative writing and describing center activities based around flash cards, drawings, and labs (Interview). Christine mentioned hands-on activities and group
work to back up her strategies for direct instruction (Interview). Diana talked about hands-on activities as “mini labs” (Interview) and foldables students created in their science composition books. Elise emphasized hands-on and visual activities (Interview). These general strategies were expressed during the observations with specific activities like Brad’s (Observations #3-4) adaptations poster (Appendix J, Teaching Artifact #7), Christine’s natural resource graphic organizer (Observation #4), Elise’s cell drawing (Observation #2-3) and research-based foldable (Observation #4), Fred’s website-based learning tracks (Observations #1 & 3), George’s cloud graphic organizers (Appendix J, Teaching Artifact #8) to build a wall of student-created work on the different types of clouds (Observation #4), and Henry’s centers that included creative writing, chapter outline, and flash cards (Observations #3-4).

Teachers incorporated their variety of sense-making activities in a couple different ways. Based on the lists of activities teachers demonstrated or talked about, they could either provide variations on just one of those strategies for students work through a concept or string together foundationally different kinds of activities. For instance, though Alice relied heavily on using multiple forms of direct instruction, I observed how Alice could take a strategy like discussion and put different spins on the activity to make it feel like students were doing something new each time. Students participated in class-wide talks about videos they had just watched (Observations #1-2), volunteered verbal predictions of the outcome of a demonstration (Observation #2), and discussed in pairs how to fill out class notes, racing against a timer, before Alice began her instruction (Observation #3). In contrast, Elise had foundationally different kinds of activities each day. During the first observation, the class created a KWL chart for their upcoming unit on cells before some direct instruction via notes and an analogy-based story. The next day they moved on to a detailed foldable chart to organize what they had learned as Elise
showed students her digital flash cards on cell parts. During the third lesson, Elise added another element as she pulled individuals back to lab tables to practice with hard copies of flash cards while the rest of the class continued the foldable. By the fourth lesson, students were moving on to their research project for cells.

**Blending independent and cooperative elements.** As teachers assigned students to work through their variety of sense-making activities, they incorporated both independent and cooperative work. Many times, this theme showed itself as individuals responding to direct instruction and working through sense-making activities in cooperative groups. Alice had students watching videos (Observations #1-2) and individually taking notes (Observations #3-4) to instruct them on a concept while building in the cooperative elements of class-wide discussion (Observations #1-2) and student pairs’ predictions (Observations #3-4). Brad demonstrated a similar method, having students complete notes individually (Observations #1-2) before having students compare their works in progress (Observation #3) and share the completed adaptations posters (Observation #4). Henry likewise showed a similar rhythm, requiring students to complete notes individually during his presentations in the first two lessons before students worked cooperatively in centers, like quizzing each other on flash cards and sharing creative writing ideas, during the third and fourth lessons.

Other teachers showed variation to this theme, switching between independent and cooperative instruction and activities through the progression of the unit. Christine’s students finished their collaborative jigsaw activity during my first lesson, received direct instruction that required them to respond individually during the next two lessons, and then individually developed a graphic organizer at the beginning of the fourth lesson before participating in a team review game. Diana’s resource jigsaw required students to work collaboratively to research their
resources (Observations #1-2) but also required individual elements as individual students in a group took responsibility for presenting certain parts of the research guide and listening students to complete the listening guide (Observations #3-4). Elise’s students completed their cell drawings independently (Observations #2-3) but were arranged in groups (though each individual was responsible for his or her own work) during the creation of their cell foldables (Observation #4). In George’s class, students defined key terms individually (Observation #2) but practiced their motions as a group (Observations #3-4). Students were allowed to work in groups for the first day of their ‘I have, who has?’ game (Observation #4) but then were told they were expected to recognize the terms individually for the next lesson.

Scheduling tasks so that the complexity gradually increases. As teachers delivered content and provided sense-making opportunities, students progressed from simpler tasks to more complex ones. Henry and Diana expressed this thought process similarly, beginning instruction with basic and clear expectations on what students should know before adding more complexity (Interviews). Diana talked about finding a starting point for instruction saying, “I do try to start pretty basic and talk about something they may learned in the second grade and build up from there” (Interview). George voiced a similar idea, describing how he used repetition (such as with the key words and motions for vocabulary terms) to build a basic understanding before asking students to take those ideas to paper. In Alice’s class, she provided time for students to reflect on progressively more complex ideas during brief oral quizzes. Some questions only required students to recognize concepts, but Alice asked questions that increased in complexity each day requiring more cognitively demanding thinking skills like the ability to apply the concept (Interview and Observations #1-4). Elise and Fred demonstrated building the level of complexity by showing how their expectations grew for students over the course of a
unit. Elise tiered her organelle research activity so students could work through increasingly complex texts to find more detailed information (Interview and Observation #4). In his interview, Fred talked about how he sometimes offered constructed response activities to students who show mastery of the concepts via a multiple-choice test. Brad’s students were introduced to the general idea of adaptations during the first lesson, writing down and illustrating notes as he described the concepts (Observation #1-2). He then had students apply the information by assigning them to design the camouflage of a small cutout of a butterfly (Appendix J, Teaching Artifact #9) to tape somewhere in the room for a guest to search for later that day. If students decorated their butterfly so that it could not be found—proving the effectiveness of its adaptation to the classroom ecosystem—they would receive extra credit (Observation #1).

Communicating the purpose. Teachers sometimes took a moment to explain to students the purpose of the activity and how it related to the lesson’s learning objective. For example, Elise began her explanation of students’ research-based cells foldable by making it clear to students that her goal was for her students to understand the functions of different organelles (Observation #4). George communicated the purpose of a review activity to reinforce the unit’s guiding question, reminding students how air currents affect weather (Observation #1). Christine varied on the theme, introducing a graphic organizer activity on natural resources by asking her students the purpose of the activity. Students responded with answers about studying for the next day’s quiz and adding to their notebooks before arriving at the answer Christine seemed to be looking for: to organize what they had learned about natural resources (Observation #4). Fred took a broader view, giving students an overall picture of the upcoming set of lessons to build his students’ perspective on the purpose of his review. As students marked their incorrect answers
on an answer sheet that was separated according to content standard, Fred explained how students could use this information to know exactly what concepts they needed more practice with before the next day’s benchmark assessment (Observation #2).

**Differentiated teaching.** Effective middle school science teachers showed a number of ways that the teaching phase could be differentiated by adapting instruction and/or activities to enhance students’ understanding of a concept. In particular, teachers’ explanations of their beliefs about students’ learning confirmed why they offered a variety of activities and revealed similarities to the philosophy behind DI. Teachers also thought of ways to target their instruction to students’ specific levels of readiness even as students’ readiness varied significantly among students in a single class. Finally, but perhaps most powerfully, teachers consistently offered cognitive scaffolding by interacting with their students constantly to support smaller groups of students and individuals as they learned about a concept.

**Different kinds of activities for different kinds of learners.** While the variety of activities teachers offered was covered in the best practices section of this phase of instruction, it is significant to consider why teachers decided to include such a diversity of activities and why particular activities were chosen. Teachers utilized a variety of presentation techniques and sense-making activities for the specific purpose of supporting the different ways that students could build knowledge about a concept with special consideration of how the majority of students would best understand the concept. As teachers described and demonstrated a variety of activities for different kinds of learners, visual methods for presenting content and developing sense-making activities stood out as a focal point. Teachers also included elements of choice to allow students to pursue activities in preferential ways.
Variety and beliefs about student learning. One very significant theme was teachers’ explanations of how students learned in different ways. As a result of this foundational idea, teachers presented concepts in several different ways and designed activities to teach in a range of modalities. It is important to point out here that this diversity did not necessarily mean that individual students were presented with different instructional inputs or completed different kinds of activities compared to their peers in a single lesson. Rather, as teachers taught multiple lessons on the same concept, they were intentional about including a range of instructional methods and activities based on the different ways a student might understand the concept. For instance, George described the majority of his students as visual and kinesthetic learners, leading to his reliance on those methodologies. Students in his class learned kinesthetic motions for vocabulary terms (Observations #1-4), watched and listened as George demonstrated humidity with a wet towel (Observation #3) and drew the different types of clouds (Observation #4). Though he explained in his interview that he recognized the need to incorporate a variety of learning modalities since students learn in different ways, his understanding of how the majority of his students seemed to prefer visual and kinesthetic modalities translated into teaching practices aimed specifically to those perceived strengths and preferences. Brad provided another strong example, expressing that “students learn best in a lot of different ways” and therefore he “[tries] to hit it from a lot of different angles so different learners can understand the material” (Interview). He went on to describe his instructional style as a “wave” (Interview) that incorporates different kinds of instruction and activities for each concept. He talked about developing group projects, drawings, role-play, debate, songs, and stories to communicate his content (Interview). During my observations, students in his class listened to his lecture and took notes, illustrated those notes, watched a YouTube clip, colored a butterfly’s camouflage
adaptation to hide in the room, answered questions from the textbook, and created a poster describing an imaginary animal and how it was adapted to its environment. Teaching with variety on a single concept over the course of several lessons was one of the most significant themes of the teaching phase.

Teachers demonstrated the philosophic idea that students learn in different ways by building a base set of activities that are then adapted more specifically according to particular concepts. Having a base set means that teachers have a series of instructional activities that they adapt for each concept. Based on comments like Fred’s, saying, “You need to approach your content from a variety of angles” (Interview), and “I try to address all modalities in a unit plan” (Interview) along with the variety of teaching strategies I observed, teachers based instructional activities on different ways to learn: auditorily, kinesthetically, musically, linguistically, interpersonally, intrapersonally, and, the most salient of these modalities, visually. Teachers were intentional to include a range of these modalities for each concept so that their set of students, each with unique strengths and preferential ways to learn, would have the most success as a group. The average base set would include some kind of direct instruction presentation that required active student participation such as through notes or kinesthetic elements, a visual activity like completing a drawing or graphic organizer, a cooperative activity, independent work that involves answering questions from a text, and, sometimes, a writing assignment. Henry’s instruction and activities typified this theme. Henry’s base set was founded upon multifaceted direct instruction to present the concept (capitalizing on auditory and visual learning styles) before adapting a variety of sense-making activities, delivered via his learning centers, that were tailored for the specific concept. I observed centers based on students outlining the concept from the textbook, practicing test-like questions with Study Island, reviewing important
vocabulary terms by quizzing each other with flash cards, writing a creative story, and drawing a graphic organizer (Observations #3-4). Outlining the textbook and writing creatively might appeal to intrapersonal and linguistic-type learners, flash cards for visual and interpersonal learners, a graphic organizer for visual learners, and practice questions to help develop patterns or strategies to use when answering questions for intrapersonal and/or logical learners. Alice touched on this theme as well, explaining that she did not really consider how students would prefer to learn “because I figure I do for each skill three to five different things so I feel like I'm trying to cover it” (Interview). So, rather than try to match individuals to their preference each lesson, she addressed the concept in several different ways over the course of multiple lessons, working from the belief that at least one of those ways would be meaningful to every student. She emphasized that variety was important so she would be “letting them do more than just come in, sit down and listen to me all the time” (Interview).

Other teachers confirmed the significant theme of adhering to an idea that students learn in different ways, leading to teaching practices that incorporate this base set variety in instruction and activities for each concept. For example, Christine discussed using variety in her teaching because she believed that her students represented a spectrum of different kinds of learners. If a student did not grasp the material well from one modality, say a lecture aimed at auditory learners, then perhaps the next lesson that might utilize more visual elements like graphic organizers and concrete visual aids will be a better fit for that student (Interview). Diana explained that “Everyone has a different way of comprehending a concept” (Interview), and therefore she teaches using a variety of activities like the jigsaw I observed in addition to strategies like students writing about a concept, watching video clips, and “mini-labs” (Interview) so that students can hear about the concept, see it, and get their hands on it. Elise
described that as she has gained experience teaching science, “You figure out that they don’t all learn the same way” (Interview), leading her to develop instruction and activities including stories, drawings, flash cards, research, lecture, hands-on labs, video clips, and collaborative student work. In the four lessons I observed, students contributed to a KWL chart, listened to an analogy-based story on cells while stopping to discuss it and take notes, drew and labeled the parts of a cell, organized flash cards of organelles, and began a research-based foldable using the school’s mobile lab.

*Middle school students and visual learning.* The teachers in this study proved that incorporating visuals was a critical part of instructional variety. Of all the ways for presenting content, designing activities, and concentrating on learning styles teachers mentioned, visual ones were brought up or demonstrated most often. Elise summed up teachers’ views on visuals simply, saying, “A lot of [middle school students] are all about visuals” (Interview). Teachers used visuals as a focal point for how students made sense of concepts, supplement and enhancing their instruction.

Teachers consistently enhanced their methods of instruction by incorporating multiple visuals. For instance, Alice and Brad both relied on visual elements to be a foundation for students’ notes during instruction. Alice’s class notes were taken on graphic organizers (Appendix J, Teaching Artifact #2) so that students could easily visually reference how the concept of convection worked. As Alice explained convection, students filled in portions of the graphic organizer, at once seeing how details fit into the overall idea of how hot and cold particles led to wind currents. Brad paused at points during his lecture on adaptations to have students illustrate certain important ideas (Appendix J, Teaching Artifact #10) like an adaptation used for finding or eating food (Observation #1). Fred and Henry’s PowerPoint presentations
included illustrations on every slide so that students could relate what was being explained to the displayed figure (Interview with Fred; Observations #1-2 with Henry). Diana asked that student jigsaw groups include images in their presentations (Observations #3-4). George described his strategy for providing visuals by saying “Everything I try to say, I try to have some format visually in the room somewhere” (Interview). He went on to point out how he referenced illustrated posters of key terms scattered throughout his room during direct instruction. Every teacher in the study mentioned using some type of video clip, usually from YouTube, as a supplement or illustration to his or her instruction.

Once instruction had been delivered, teachers based some sense-making activities around pictures, diagrams, and illustrations to build students’ visual understanding of the concept. Henry talked about basing one of his centers (for any concept) on this visual element, describing his teaching as “big, big on drawings” (Interview). I also observed he and Elise assigning students to organize illustrated flash cards (Appendix J, Teaching Artifact #11) so that students could practice recognizing important vocabulary terms (Observations #3-4 with Henry; Observation #3 with Elise). Similarly, George had his students creating index cards on the types of clouds to form a kind of word wall (Appendix J, Teaching Artifact #8) as students began their study of how air currents influence weather (Observation #4). Henry and Christine’s students created graphic organizers with Henry’s students completing this near the beginning of a unit to build understanding (Observations #3-4) while Christine’s students used it as a review (Observation #4). Alice explained how she sometimes has students complete a nutshell (Interview) activity where students recreate diagrams from their text and then write descriptions of the details the diagram illustrates. Brad and Elise used multiple visual sense-making activities to teach one concept. Brad’s students decorated butterflies for their problem-based activity on
camouflage adaptations and illustrated a poster of a fictional animal adapted to its environment. Elise’s students not only worked with the illustrated flashcards, but they also drew and labeled the parts of a cell in preparation for their research-based foldable that itself included graphic organizer portions.

**Targeting instruction to students’ readiness levels.** Another way that teachers differentiated their teaching was to give instruction or assign activities that were developed specifically with students’ different levels of readiness in mind. As discussed during the planning phase, teachers planned with a recognition that students learn in different ways, at different paces, and at different starting points. Teachers applied that philosophic idea by offering different levels of instruction and activities, creating opportunities for homogenously ability-grouped cooperative work, and by focusing classroom time on the aspects of the concept they perceived students to be most cognitively prepared for, either focusing on the concept’s vocabulary or building a more critical understanding of the concept.

**Different levels of instruction and activities.** Teachers explained that they use different levels of instruction and activities in order to target their instruction to students’ different levels of readiness. This process generally involved two stages: first, recognize what students do know about the concept, and then secondly, modify or adapt classroom time according to that understanding of students. Teachers showed several ways that they might find out what students know. Alice and Fred both used traditional pretesting. Alice recommended the use of a pretest for each concept because of the variety in students’ readiness levels, stating, “I do a pretest on everything, and then I go back and look and see, and what I think is so funny, because every year, every group is different” (Interview). I observed Fred using a pretest to determine what activities students would use to review (or skip over) specific learning objectives (Observation
#1. Diana had her own type of pretest that she called an anticipation guide where students recorded their agreement or disagreement to a series of statements at the beginning of a unit. She did not review with students the correct response until the end of the unit, giving students a chance then to revise their initial answer. She explained the idea behind this two-part activity, explaining that, “In the beginning, I got my assessment, and I got what I really need to cover and what I can kind of skim on and move past. If there were a lot of kids agreeing with [an incorrect statement], then I really try to hit that hard” (Interview). Elise used the common KWL chart to find out what students knew (Observation #1).

However, not all teachers utilized this type of pre-assessment. Brad and George both communicated that these kinds of pre-learning activities were not particularly useful, instead relying on their own teaching experience to inform them of what students would (or should) already know. When asked how his teaching had evolved as he had gained experience, George explained:

The more you do it, the more you know what you need to focus on and what you don’t need to focus on. And, it seems too that…you get to know what the kids coming up are already going to know. You know when they come in, they know the planets. They know the order of the planets. They don’t know certain other parts of it though. That’s the kind of stuff you can already know because just the experience of doing it for a while. (Interview)

Brad related a similar idea, stating, “All I care about is where they end, not where they start” (Interview). Brad seemed to suggest that readiness had less meaning in the knowledge-based focus of the science standards as compared to more skill-based subjects like language arts, saying “Just because they’re gifted doesn’t mean they’re gifted in science” (Interview).
Teachers used their understanding of students’ various readiness levels, typically perceived at a classroom level, to adapt instruction and activities. Several teachers expressed that they adapted instruction in and between classes as they discovered how much a particular class understood the concept or how quickly they were grasping it. Between classes, Alice, George, and Henry all mentioned changing the pace of instruction or modifying activities based on class characteristics (Interviews). Henry explained the idea, saying:

So 6th period, as a class, their average is like a 62. So they are really low compared to the rest of my classes so I’ll approach that in a completely different manner…So for them, it’ll be like here's what you need to know, and we’ll drill that over and over and over and we won’t go into a lot of the side notes and the things that may get confusing. We’ll just go here, here’s what the standard says, here’s what you need to know, [and] when we get that, we’ll move on.

Brad and Diana discussed how they ask questions of varying complexity to gauge student understanding and then adapt instruction on the fly to focus on what students are not understanding about a particular concept (Interviews). Elise demonstrated how teachers used questions to gather informal data on students’ understanding that can lead to adaptations as she discussed during her interview how she noticed some students during the KWL activity simply repeated factoids about cells from posters in her classroom. However, she recognized that those student responses mimicking something on the walls reflected that those students did not have much understanding of cells but rather those students wanted to contribute “just so they’d have something to say” (Interview) so as to not be judged by their peers. Brad explained that this information a teacher gathers on students’ grasps of a concept can lead to an alteration to instruction or activities but does not change the learning objective. During our interview, he
clarified, “I don’t change the content. It’s just how I present it…I make sure it’s at their ability level.” Like Elise, he gathers the information about students’ readiness levels in order to decide how best to “build them up” (Interview with Brad) to an understanding of the learning objective.

**Homogeneous cooperative work.** One way that two teachers demonstrated targeting instruction to students’ specific levels of readiness was to create opportunities for homogeneously grouped cooperative work. For these activities, teachers grouped together students they perceived or measured as being of similar readiness to complete an activity that contained different levels of complexity for different groups. George explained that he often uses this strategy for centers, a major component of his sense-making activities. He explained that he used testing data from the previous year to initially group students and then uses formative and summative assessments to modify groups as often as every three weeks. He described that he used a random color-coding system so that students do not necessarily recognize their group’s level, and, since groups constantly change, students are not pigeon-holed at a particular level. For each center, he created different folders with activities requiring products of tiered complexity that he handed to each group. The learning objective did not change from group to group, but the activity or materials did. For instance, one center might have had students responding to a particular article, and so George had articles at different reading levels. Another example of George’s centers might have had a group of students with lower levels of readiness reviewing vocabulary while a higher tiered group might have been creating a graphic organizer of the vocabulary terms (Interview). Elise’s research-based cell foldable was structured somewhat similarly, as students worked through tiers of complexity at their own pace while being grouped next to similarly achieving peers for the activity so they might be able to help one another. Elise did not assign students to a particular tier but instead
allowed them to direct their own pace, mastering lower level tiers before moving on to ones of higher complexity (Observation #4).

*Critical thinking and vocabulary.* Teachers sometimes differentiated instruction to students’ readiness levels by focusing instructional time on the aspects of a concept the teacher perceived might be most beneficial and appropriate for the readiness level of his or her students. This was often expressed in terms of a teacher emphasizing vocabulary for students of lower levels of readiness or critical thinking for students of higher readiness levels. George provided a powerful example of this phenomenon. George, who wrote his master’s thesis on the correlation of vocabulary attainment and achievement, explained that, “Especially with science, it’s its own world, its own language, [so] that once they know the language, they can start filling in the pieces and getting the concepts” (Interview). He went on to say, “That’s the building block for the kids, the lowest kids is . . .knowing the vocabulary,” (Interview) describing how essential an understanding of vocabulary is to mastering a concept. When describing the demographics of his students in his interview, George stated:

> I wish they would all be at the same preparedness but the hardest part about, especially with the demographics of this school is that I have in most periods, I have about 10% that are ready if not over-prepared every day. So, about 40% that have done nothing. And I’ve got to find some common goal in that.

Henry, who taught at the same school, voiced a similar perception, pointing out that he had noticed students struggling with reading comprehension more than in previous years and lamented the lack of parental support his students as a whole received (Interview). Then, consistent with that perception, both teachers emphasized vocabulary heavily, especially with their ELL students. During each observation, George reviewed important vocabulary, drilling
students so that they could respond chorally with key words that described the term and demonstrated the motion associated with it. Henry opened the unit I observed on what cells do by telling students that if they could understand the unit’s vocabulary, “You win” (Observation #1). Diana also placed an emphasis on vocabulary, explaining, “The more I push that vocabulary, the higher my test scores go” (Interview). Using vocabulary as the first step towards an understanding of a concept, teachers utilized a number of strategies to emphasize vocabulary including giving terms kinesthetic motions (Observations #2-3 with Alice, Observations #1-4 with George, & Observation #2 with Henry), drawings (Observations #3-4 with Alice, Observations #1-3 with Brad, Observations #2-3 with Elise, Observation #4 with George, & Observations #3-4 with Henry), flash cards (Observations #2-3 with Elise & Observations #3-4 with Henry), and modeling how to break down complex words (Observation #3 with Christine & Observation #1 with Henry).

Once students had mastered some aspects of a concept (especially its vocabulary), some teachers moved forward to emphasize students’ critical thinking ability or higher order thinking skills to apply the concept as a way to demonstrate a higher degree of mastery. This stage of instruction seemed to represent the end of the sense-making process, and one that not all students would achieve. Elise and George both mentioned offering higher level texts with corresponding higher order tasks at their own initiative to students who had already mastered less complex tasks (Interviews). Elise described the higher order critical thinking or application-based tasks, saying students “have to find evidence in the text but at the same time…I want them to be able to kind of relate what’s going on…to talk about their lives” (Interview). Similarly, Fred talked about developing activities for students who demonstrated mastery on his standards-based review
exercises that would involve written explanations to questions rather than typical multiple choice responses (Interview).

Some teachers, like Diana and Henry, provided time for students to critically think in the back and forth flow from instruction to sense-making. When describing the variety of teaching strategies she used, Diana mentioned how she liked to incorporate elements of debate that require students to apply reason (Interview). To a small degree, I observed her asking debate-like questions to her jigsaw groups when they had finished their presentations on a natural resource such as “What do you see in the future for [the natural resource]” (Observations #3-4), requiring students to defend a position after having worked on that concept for several lessons. During his interview, Henry described incorporating a similar strategy into his writing center, sometimes assigning students the task of arguing a particular position, such as what organelle is most important to a cell. However, it is important to note that Henry tempered his expectations of the level of some students’ work, explaining that he accepted the work of some of his students of lower readiness levels that essentially defined important vocabulary terms on his Constructed Response Assessments (CRAs) instead of the assigned prompt that required higher order thinking skills (Interview).

**Scaffolding.** As teachers delivered a variety of instruction and activities that were sometimes targeted towards a specific level of readiness, they were constantly involved in students’ sense-making process, scaffolding individuals and small groups as needed to build them towards mastery by helping them reach what, individually, a student was not able to on his or her own. Teachers scaffolded students’ learning passively by anticipating students’ difficulties with a concept and building in supports to the instruction or activity specifically to address the expected area of difficulty. Because the supports did not require the teacher’s presence for
students to benefit from, I considered these as passive supports. They also scaffolded actively by working directly with a student or group to help them understand a concept. Teachers moved through the class as they worked on sense-making activities, spending time with individuals or small groups and using questions to discover any difficulties students were having and to address those difficulties specifically. Or, in some cases, teachers relied on students’ peers to perform a similar job, creating activities where students were heterogeneously grouped according to their readiness levels so as to develop opportunities for students to help each other.

_Supports during whole class instruction or activities._ During whole class instruction or activities, teachers built in passive supports to help scaffold students’ understanding and organization of the content to alleviate possible classroom management difficulties that would be associated with trying to respond to individuals. For instance, while all teachers used various types and lengths of lecture to deliver content, most of them also gave students some sort of guide by which to take notes. Alice (Observations #3-4), Brad (Observations #1-2), and Elise (Observations #1-2) gave students a fill-in-the-blank template for their notes, using the blanks strategically to reinforce important details or vocabulary terms. Christine (Observation #3) and Henry (Observations #1-2) had developed systems where students knew notes to take from the teachers’ presentations (Christine relying on the whiteboard and Henry on textual features from a PowerPoint presentation). Fred even posted his PowerPoint slides for a lecture on his website for his students to view, download, and/or print at any time (Observations #1 & 3). Diana’s class had a listening guide to fill in as student groups presented their portion of the natural resource jigsaw (Observations #3-4). Often times, the notes as a passive support incorporated visual elements to coach students’ visualization and organization of the concept, such as Alice’s
graphic organizer notes (Appendix J, Teaching Artifact #2) or Brad’s illustrated notes (Appendix J, Teaching Artifact #10).

Another passive support teachers provided was supplementary references available at students’ own initiatives. For example, several teachers made students aware of certain pages or diagrams in their textbooks that students could reference to help them during certain types of instruction and activities. During some of Brad’s pauses during direct instruction, he encouraged students to reference a particular section or diagram in their text to help them determine what or how to illustrate a point (Observation #1). Diana, Elise, and George made students aware of portions of their text that students could use to help them complete activities. Elise asked students to use an illustration in the text as a template for their own cell drawings (Observation #2), and Diana encouraged students to use their texts as a resource to help groups prepare for their resource presentations (Observations #1-2). Diana took it one step further, asking her presenting group to write the textbook page number where their resource could be found on the whiteboard so that listening students could reference it during their presentation and locate any information they missed from the presentation (Observations #3-4). George suggested students reference the textbook during a jeopardy review game (Observation #1). Christine (Observation #3) and Henry (Observations #1-2) used the structure and illustrations in the text to build their lecture presentations so that students could review a section of the text to supplement the direct instruction.

Teachers sometimes also referred students to resources on their website (discussed in more detail in the variety of resources section of the differentiated planning phase) to provide another kind of passive scaffolding. Fred had the most comprehensive of the teachers’ websites, including his presentations, supplementary instructional materials, and digital assignments
arranged according to content standard on his webpage (Observations #1 & 3). Elise included links to a digital version of her organelle flash cards (Observation # 2) and resources similar to those students used during class for the research-based cell foldable (Observation #4). George referenced a study guide posted on his website for an upcoming quiz (Observation #1), and Henry mentioned posting his PowerPoint presentations accompanying his lectures online (Interview).

Teacher proximity. The key element to teachers’ active scaffolding was their proximity to students during the sense-making process. This proximity contained two facets: teachers’ involvement in students’ work as they completed it and providing prompts to keep students engaged in that work. With the exception of Alice’s class where I did not observe any significant time where students completed individual sense-making work, every teacher was active, circulating among students and groups as they worked to check over students’ work and provide guidance to students who needed it. Brad and Diana both emphasized during their interviews the importance of arranging their classrooms so that they could move among students as they worked, and both demonstrated the idea during individual or group work (Observations #1 & 3 with Brad; Observations #1-2 with Diana). Christine’s seating arrangement during the first observed lesson had students sitting in large groups to complete the jigsaw activity on natural resources, and she had selected the groups such that she could scaffold one group in particular that had a higher proportion of students receiving special education services (Observation #1). George checked on student groups as they prepared their answers to jeopardy questions on whiteboards, sometimes stopping to ask questions or discuss an answer (Observation #1). Elise also took advantage of independent work time to check on students’ work and provide feedback and/or guidance as her students completed their cell drawings
(Observations #2-3), organelle flash cards (Observation #3), and research-based cell foldable (Observation #4). Christine and Henry actively scaffolded during independent work time, with Christine working with some students on re-arranging or developing their open-ended graphic organizers (Observation #4) and Henry providing feedback to students on their cell stories during the writing learning center (Observations #3-4). Even while sitting at his computer, Fred interacted with students as he received emails from students as they completed digital assignments, giving them feedback or direction based on the results (Observations #1 & 3).

Additionally, teachers actively scaffolded students’ engagement on a task by providing prompts to coach students’ time management. Brad (Observation #2) and Fred (Observation #1) encouraged students to remain on task when the volume got above acceptable levels and also provided time prompts to help students know when to expect the closing of the current activity. Henry (Observations #3-4) used a strike system during center activities to keep students working. George (Observation #1) used a dog training clicker to prompt student groups for their jeopardy answers. Similarly, Diana turned the lights out after students had a chance to review their listening guides between groups’ presentations, signaling the frequent changes from individual/small group work to the whole class activity. She even tied a small bell to her dry erase markers so that, as presenting students wrote the page numbers for their resource on the board, the listening students would be prompted to look up at the sound and find the reference (Observations #3-4).

**Questioning.** As teachers circulated, staying in close proximity with working students, they most often used questioning techniques to check students’ understanding, lead students through the cognitive process to correct a misunderstanding, and/or to guide students towards a more complete knowledge of the concept. It is difficult to generalize this kind of questioning
since it is so student-specific according to their individual work on one specific assignment, though it is significant that each teacher that demonstrated the code for proximity during sense-making time relied on questions as an integral part of their active scaffolding with students. During her interview, Alice described how she would work with struggling students by continuing to ask questions, “Just [picking] it apart and [backing] up” (Interview), until she discovered where a student’s disconnect with the content was. As Brad’s students worked on their adaptation posters, I observed him asking students for more depth on the poster, answering individual students’ questions about how to complete the assignment or if a specific aspect of their work was acceptable, and clarifying the directions for the assignment. He sometimes took individual’s questions or responses as an opportunity to address the group about a difficulty he perceived other students might also be experiencing (Observation #3). Christine used questions to guide a student’s thinking as this student mistakenly used coal as the top heading on the resource graphic organizer (Observation #4). Christine, noticing the work as she circulated among students, stopped at this student’s desk, pointed out the coal heading, and then asked if all of the other terms would fit under or describe coal, modeling the student’s thinking back to him or her so that the student would notice the mistake. George used his jeopardy review game questions as an opportunity to scaffold students, reiterating the important details of the correct answer and pointing out what made some groups’ incorrect answers wrong.

_Scaffolding vocabulary._ Teachers’ scaffolding was especially evident as they taught new vocabulary terms (also discussed in the targeting instruction to students’ readiness levels section of the differentiated teaching phase). One such strategy was using flash cards to coach students on the key ideas, or images that defined a term. Henry included a flash card center so students could quiz each other on those key ideas of a definition. The index-sized cards had very limited
descriptions on them, focusing students on only the most important aspects of the term (Observations #3-4). Elise’s in-class organelle flash cards (as opposed to the digital set on her website) included images of parts of a school (Appendix J, Teaching Artifact #11), scaffolding students’ understanding of how organelles performed specialized functions (Observation #3). Alice (Observation #2), George (Observations #1-4), and Henry (Observation #2) all used motions to scaffold students’ understanding of new terms. Each also had corresponding games based on the motions to reinforce the appropriate motion for the terms so that, if students performed the motion, they would visually represent how the term is defined or applied. Similarly, Alice (Observations #3-4), Brad (Observations #1-2), Elise (Observations #2-3), and George (Observation #4) developed visual elements to activities specifically so that students could see how and where certain vocabulary terms would be applied. Christine (Observation #3) and Henry (Observation #1) scaffolded students’ ability to break down vocabulary terms, modeling for them how to use prefixes or similar, more familiar words to uncover the new term’s meaning.

*Heterogeneous cooperative work to provide support.* The last significant element of teachers’ scaffolding was their use of heterogeneous groupings by readiness so that students could provide support to their peers. Teachers provided for this type of scaffolding either by seating students of mixed ability near each other or by assigning groups for specific activities. All teachers in this study noted on their surveys that they purposefully arrange students’ seating to support students’ learning. One aspect of that support was putting lower achieving students near higher achieving peers. During their interviews, Brad, Christine, George, and Henry all mentioned that students’ assigned daily seating took into account placing lower achieving students next to helpful, higher achieving peers. Christine gave a specific example, describing in
her interview a situation where she had planned to rearrange students’ desks but first privately approached one struggling student to ask who this student thought was helpful. She explained that when students take notes, and the struggling student falls behind, the helpful student would slide the notes over to help the struggling student keep up. Diana explained a similar strategy in her interview, assigning students whom she anticipated might struggle with a concept a partner for the day to help them through that lesson.

Teachers also created mixed ability groups to create situations where students could scaffold their peers on specific types of assignments. Seven of the study’s eight teachers responded on their surveys that they take into account students’ ability when grouping them for cooperative work (see Figure 6).
Figure 6. Criteria for determining student groups. This figure shows participants’ responses to a survey item about the formation of their student groups.

For example, Diana randomly grouped students for the jigsaw activity on natural resources (Observation #1) but then rearranged some individuals to better mix the groups based on personality and readiness (Interview). Elise and Henry created their daily seating arrangements so that students of different levels of readiness were grouped together and then used those same groups for cooperative work. Elise sat her lab groups together in adjacent desk pairs “so they can learn from each other,” (Interview) in both daily instruction and lab activities. Henry changed groups occasionally, but tried to keep “like three medium kids, a high, and low” (Interview) together. He usually found this to be an effective kind of peer scaffolding because
“the high kids are a lot of times good leaders” (Interview), but he also noted how his highest achieving students in one class could be too social, detracting from his purpose in mixed ability groups. George blended these two strategies together, arranging their normal seating so that students of different levels of readiness were at the same table to help each other with certain activities, such as his jeopardy review game (Observation #1) and also mixed those table groups for other kinds of activities like his homogeneously grouped centers (Interview).

Scope of differentiation. During the teaching phase of instruction, teachers expressed and demonstrated the scope of their differentiation in terms of their set of students as whole (similar to the planning phase), narrowing down to the classroom level and even including elements of some lessons geared specifically for smaller groups within a class. The teaching phase showed the application of the participants’ teaching philosophies, revealing certain universally offered differentiated elements. For instance, teachers implemented their plans for different kinds of activities for the different kinds of learners in their classes. Teachers offered instruction and activities in a variety of modalities (though heavily drawing on visual elements), relying on their base set of activities to provide at least one kind of activity that would play to the strength and/or preference of the different types of learners they perceived in their classes. Christine described this application of teachers’ learning philosophy:

They all learn differently…I’ll quiz them at the end you know, get feedback: ‘Ok, how do you view this lesson worked for you?’ And you may have only six people raise their hands, but that was six that I reached with that, [so] I will do everything from, you know, ‘I’m writing notes on the board, some of you learn that way, and some of you [do] not. So, here’s a video. We’re going to watch this video, ok. Some of you aren’t going to get
it that way. Now, we’re going to do an activity. We’re going to do some hands-on stuff…we’re going to go to our groups. (Interview)

Alice agreed with the idea, explaining in her interview that “People learn differently, so I’ve got to vary how I teach it,” going on to justify the variety by saying, “I figure I do for each skill three to five things, so I feel like I’m trying to cover it. Hopefully, within those things, each child will get it”. Brad summarized the idea, saying, “You can still hit all the students with just one thing, one thing at a time” (Interview). Teachers taught with recognition that their students learn in different ways, and so they provide different types of instruction and activities to accommodate those differences.

However, the scope of differentiation began to narrow in this phase, as several teachers expressed how they adapt lessons to fit the personalities and readiness levels of specific classes. In discussing the teaching phase, Alice, Diana, Fred, George, and Henry all made comments alluding to or directly about adaptations they made to a lesson based on their perceptions of the personalities and readiness levels of different class periods. In Alice and Fred’s cases, they described how classes’ behaviors can present a challenge and how the implementation of activities might change between classes in response to that challenge (Interviews). Alice stated, “I can’t imagine a teacher teaching the same thing, the same way every period. If my class is loud, we’re not going to do the get up activities because I can’t rein them in as quickly…If the class is quiet, then we’ll get up and move more and do more of the silly stuff” (Interview).

Diana and Henry both talked about changing the complexity of instruction, as Diana would vary the complexity of the questions she asked to target different levels of readiness and Henry would narrow instruction to focus only on what was essential for understanding the required content
standard for classes he perceived as being at a lower level of readiness (Interviews). Similarly, George discussed changing the pace of his content, explaining:

My last class is a good example of this. I can go real fast with them. They pick up a lot of stuff real quick. They already have a really strong basis, the class as a whole does. So, they may end up getting completely different lessons than most of my other classes, especially this last period we just had. Those are two polar opposites there. (Interview)

Narrowing the scope of differentiation further, a few teachers incorporated tiered elements to provide instruction and/or activities for groups of students at different levels of readiness within the same class. Elise and George demonstrated and discussed these kinds of activities at different levels. Recognizing that students come to class with different degrees of readiness for a concept and will learn at different paces, Elise’s research-based cell foldable included beginner, intermediate, and advanced stages that students would progressively work through. Though she offered the tiers to all students, she identified several students during her interview that she believed were ready for more than the beginning level, and so she expected them to move quickly through it to the upper tiers (Interview). However, she explained she required students to work through the tiers so that less ready students would not immediately “get in over their heads” (Interview). George’s centers typically involved him assigning specific groups to specific tiers, using sets of folders at each center to adjust to the readiness level of the group rotating into the activity (Interview).

Even when teachers did not necessarily prepare different kinds of activities for student groups at different readiness levels, they adapted their level of expectation rather than the level of difficulty. Henry explained, “Every kid gets the same work, but they have to accomplish a different goal with it” (Interview). He illustrated the idea, describing how he has different
expectations for students of different readiness levels during writing activities. He accepted CRA responses from students of lower readiness levels that essentially defined the concept’s vocabulary while he expected more descriptive and applicative writing from students of higher readiness levels (Interview).

**Contextual factors influencing teaching.** During the teaching phase of instruction, teachers’ use of best practices and elements of DI was influenced by increasingly more specific contextual factors. First, however, it is important to point out the significance of the connection between planning and teaching and how the contextual factors of one affect the other. During the planning phase, teachers’ instructional plans were influenced by the macro-level conditions including the required content standards, the school district’s curriculum map, the characteristics of middle school students, the influence of how best to communicate a particular concept, and the school’s resources. Since the teaching phase is in many ways an extension and application of planning, those same factors influenced teaching. Though, once a teacher has his or her plans in place, the implementation of those plans was influenced by more specific and narrow contextual factors such as the characteristics of middle school students as a whole, the characteristics of individual class periods, and even groups within a class.

Teachers’ instruction and activities were influenced by their perceptions of how students learned best, particularly the characteristic learning preferences of middle school students. Like the planning phase, teachers implemented their plans with the recognition that middle school students learn in different ways. This led to teachers using multiple types of inputs and providing a variety of activities since different kinds of instruction will benefit the different types of learners. While explaining the significance of this variety, teachers said things like, “students learn best in a lot of different ways” (Interview with Brad), leading to teaching practices where
teachers “try to hit it from a lot of different angles so different learners can understand the material” (Interview with Brad) and “try to address diverse learning styles by making my units approach the content from a variety of angles” (Interview with Fred). From this philosophic starting point on how middle school students learn best, teachers were influenced to use a base set that includes multiple instructional inputs and activities of different types to reach the different kinds of learners. Examples of the base set were George and Henry’s centers (Interview with George and Observations #3-4 with Henry), Brad’s “wave” (Interview) of instruction, and Alice’s “three to five different things” for each learning objective (Interview). Visual elements were especially critical to each teacher’s base set. Elise summarized the importance of visuals, saying, “A lot of them are all about visuals” (Interview).

As teachers implemented their planned lessons, they were sometimes influenced by the characteristics of the current class period, leading to modifications of how the teacher delivered the lesson. Teachers discussed ways in which a class’s personality or overall level of readiness could influence how a teacher delivered a lesson. Alice, Diana, and Fred talked about the challenges associated with a class’s behavior, with Alice describing how this behavior directly influenceed the kind of activities she chooses to use during a lesson (Interview). Brad, Diana, George, and Henry explained how they might adapt the complexity or depth of a lesson according to their perceptions of students’ readiness. Brad and Diana described how they changed the complexity of their questions according to different classes (Interviews). George talked about changing the pace of his content (Interview) and Henry the depth of his instruction (Interview), both influenced by a class’s overall level of achievement.

In some cases, the implementations of teachers’ plans were also influenced by smaller groups of students with similar readiness levels within a single class. In response to having to
teach students with different levels of readiness in a single class, some teachers tiered lessons, planning in advance with specific groups of students in mind. Both Elise and George demonstrated ways that the mixed levels of readiness in one class influenced their instruction as they offered students instruction and activities at different levels of complexity. Elise’s research-based cells foldable included three levels of complexity that students, of their own initiative, could choose to work through to demonstrate their understanding of the concept (Observation #4). George described how he used separate folders at some of his centers to provide the most appropriate level of work to his homogeneous groups (Interview). To some degree, Henry’s admission that he had a “different goal” (Interview) for some students in mind when they completed certain kinds of activities also underscored the idea that teachers’ instruction can be influenced by groups of students of different readiness levels in one class.

**Assessing**

Effective middle school science teachers strategically assessed their students, using different types of assessments as an opportunity to gather grades, gauge student learning, and as a means to improve their instruction. The themes that arose from the data related to best practices in science included the frequent use of formative assessments, gathering data from those assessments on their students’ understanding, and using that data to inform future instruction (see Figure 7). Teachers differentiated those best practices by offering alternative types of assessments to students and modifying the assessments to more authentically measure the learning of some students. During the assessment phase of instruction, teachers differentiated their assessments primarily with small unique groups of students in mind. Since assessments did not always include modifications or adaptations for specific students and were
grounded in the state-mandated content standards, varying so little in comparison with the teaching phase, I considered this to be the least differentiated phase of instruction.

**Figure 7.** The *assessment* phase of instruction. This figure represents the key themes that emerged from the data showing teachers’ use of best practices related to assessment (blue box), inclusion differentiated elements during assessment (green box), and the intended scope of teachers’ differentiation (size of the blue ring).

**Best practices assessment.** Teachers demonstrated best practices principles related to assessment as they gave frequent formative assessments to gather data on student understanding and then used that data to inform instructional decisions. Teachers’ formative assessments included both informal and formal aspects, providing occasions for teachers to offer feedback to their students on their progress towards mastering the learning objective. Teachers gathered data on students’ understanding during these frequent assessments, using the data cyclically throughout the sense-making process to inform their instruction, focusing it and revealing what aspects of a concept to emphasize, based on students’ demonstrated understanding of the concept.

**Frequent formative assessments.** Teachers took advantage of a number of opportunities during class to assess their students: class discussion, questioning students, a variety of sense-making activities, and more traditional types of formative assessments like oral, multiple choice, and short constructed response quizzes. Teachers’ assessments can be categorized as informal, where teachers simply look over a student’s progress on an activity or listen to students’
responses in class, or formal, such as a quiz or assignment students turn in so that teachers can take a grade. In either case, the assessments allowed teachers to provide students with critical and meaningful feedback as a kind of scaffold to help guide students towards mastery of a concept.

Informal assessment. Teachers frequently informally assessed their students, building in opportunities to check students’ understanding during instruction and being active during students’ sense-making. Teachers created an opportunity to emphasize specific parts of instruction by discussing certain points with the whole class, using questions to guide students’ thinking as a form of scaffolding. For example, while showing a Bill Nye video on convection, Alice paused the video twice to ask students questions about the section they had just watched (Observation #1). During the first pause, she reminded students of the video’s relationship to the learning objective, asking, “What did I ask you to look for?” (Observation #1). The second time, she paused to ask students if they had heard the point the video had just made. Similarly, during Christine’s lecture on natural resources, she wove in numerous questions, asking both the class and individuals about certain aspects of points she had just made (Observation #3). Other teachers used similar strategies, such as Brad asking extending or clarifying questions about students’ answers to a homework assignment from the textbook (Observation #3). Diana also asked clarifying questions, giving her jigsaw groups an opportunity to explain in more detail to the class about what they had found during their research and to give them an opportunity for providing a more complete answer according to the rubric Diana was grading them by (Observations #3-4). Henry reviewed the key points of his lecture by asking the class to respond chorally to identify the words he was describing (Observation #1).
Teachers used similar strategies for individuals, looking over students’ efforts during independent work time to check on their progress and understanding of the assignment at hand. It is significant to point out that this type of informal assessment was made possible because teachers were active during students’ independent work time (see the scaffolding section of the differentiated teaching phase). If a teacher remained at his or her desk as students worked, the teacher would have missed the opportunity to quickly measure students’ learning in this way. By staying active and involved in students’ sense-making work time, teachers could use their observations as a step towards providing scaffolding to help a student better understand the concept. For instance, Brad tasked students with decorating a butterfly to be camouflaged with some part of his room. As students worked, he circulated among students, checking their progress and asking questions about why students chose specific colorations or where a butterfly might blend in most (Observation #1). Likewise, Christine monitored students’ progress on completing their graphic organizers on natural resources, moving among students to observe what they had completed and sometimes asking questions to guide students’ thinking (Observation #4). George used his team jeopardy game as an opportunity to listen to student groups discuss possible answers to questions (Observation #1). Elise built in a more structured version of this strategy, assigning students to move to a lab table to work on organelle flash cards she could review with the student while the rest of the class remained working on their cell drawings (Observation #3). By including this quick, informal assessment, Elise intentionally gave herself the opportunity to check on specific students’ understanding of the content that had been covered in recent class periods and provided feedback if necessary.

An opportunity for informal and immediate feedback. Informal assessments gave teachers a way to provide immediate feedback to students. The feedback a teacher gave could be
considered a kind of scaffolding since, during these informal assessments, students would have a chance to rework or focus their answers to better meet the teacher’s expectations. For example, Henry positioned himself by the writing center where students worked to create a story about cell division so that, as students finished or had a question about their progress, they could hand him their papers so Henry could scan through and look for the big ideas that describe cell division. (Observations #3-4). During these instances, he would often tell students of strengths in their writing and, if applicable, point out areas in which a particular phase was not completely described. Elise’s organelle flash card check was designed so that students at lab tables would signal Elise when finished so she could check over their work, pointing out any mistakes before giving a student an informal check in the gradebook for completing the assignment correctly (Observation #3). Brad seemed to place significant value on this feedback, explaining that he thinks “teachers’ biggest downfall is they talk too much…But you try to minimize how much you talk and maximize the students’ work on the task” (Interview). He proved this viewpoint during our third observation when he gave students most of the class period to work on developing their imaginary animal that was adapted to its environment rather than assigning it for homework. By providing this activity during class time, he was able to remain involved with students’ work as it developed. Often times, he would point out aspects of his directions to students, helping them to earn full credit and guiding their thinking with his feedback to a better understanding of the learning objective (Observation #3).

**Formal assessment.** Teachers used formal assessments as another way to check students’ progress towards mastering the concepts in a unit. Formal assessments, in contrast to informal ones, required students to turn in an assignment that teachers used for recording grades. These kinds of assignments included sense-making activities, daily checks, or quizzes. During several
classroom visits, I observed how teachers used sense-making activities as a formal assessment leading up to a more comprehensive assessment on a concept. For instance, Brad’s adaptation poster (Observation #3) served as both a sense-making activity where students received feedback and scaffolding from Brad and also as a formal assessment that students turned in for closer scrutiny at the beginning of the following class period as homework. Diana’s listening guide for her jigsaw groups’ presentations on natural resources was intended to scaffold what information students were to be listening for during the presentations and as a way for Diana to assess students’ attentiveness during the instruction (Observations #3-4). Elise’s students’ cell drawings were added to their science notebooks that were kept in the room so they could be periodically checked by Elise to measure students’ progress (Observation #3). Fred’s students’ online checklist of assignments, directed by their scores on a pretest and benchmark assessment, often included digital work that was emailed to Fred as soon as students submitted the assignment.

Some teachers also used specific kinds of daily formal assessments to ensure students were keeping up with instruction. Daily checks allowed teachers to keep track of students’ progress on a regular basis and giving structure to lessons. Alice’s system provided the strongest example of this strategy as each class began with students writing down the daily objective and then ended with an oral quiz, both recorded on the same sheet that students turned in weekly (Observations #1-4). This system of formal assessment was kept filed in the classroom so that Alice could check them as often as necessary to stay updated on students’ progress and current level of understanding with the concept. She described the importance of daily assessments to students’ retention of a concept saying, “Giving them a quiz the next day is not as effective as doing it that day” (Interview). In Brad’s class, students were required to write the daily agenda
in their student handbooks each day, and Brad circulated through the students during this time to ensure that students were working on it, also checking homework at the same time (Observations #1-4). Though it was not necessarily content-related, Brad’s system required students to know exactly what was expected of them during that class period. Elise used daily bellwork questions consisting of test-like questions from the state’s test preparation samplers or assessment questions students struggled with during the previous lesson (Observations #1-4). Students recorded their answers in their science notebooks, and Elise would randomly select students’ names using Popsicle sticks to receive an answer to these questions after students had several minutes to work. It may not be the most significant type of assessment Elise gave her students, but it was one that kept students accountable for starting class each day while also providing time to emphasize an aspect of the day’s learning objective.

Teachers also used traditional quizzes as formative assessments, typically assessing according to specific content standards. Because I only observed each teacher four times, I did not have a chance to observe how every teacher delivered these formal quizzes. However, I did observe Fred’s class taking a summative benchmark (Observation #3) and George’s class taking a formative quiz (Observation #2). Each of these formal assessments was recorded as a grade and was explicitly tied to particular content standards. Fred’s students prepared an answer sheet that categorized questions according to the content standard, making it easy for teacher and student alike to measure a student’s understanding of each specific concept (Observation #3). In George’s case, the quiz was built on the content standards covered in one chapter of the textbook as evidenced by his answer key’s designation of each question according to the specific content standard it assessed, allowing him to measure each student’s progress on each concept, much like Fred’s system (Observation #2).
An opportunity for formal feedback. Though not consistently as immediate as the feedback provided during informal assessments, formal assessments gave teachers another way to respond to students’ understanding of a concept. For instance, as students submitted digital assignments in Fred’s class, he sometimes gave students verbal feedback in the form of praise or by guiding students to another resource (Observations #2 & 4). Brad gave students verbal feedback as well, checking students’ completion of vocabulary notecards and responding with their grades and comments about the quality of their work (Observation #1). Diana’s formal feedback was less immediate, as she took notes on groups’ presentations according to a rubric that students would receive after their presentations (Observations #3-4).

Gathering data on student understanding. A major purpose of frequent informal and formal formative assessments was for teachers to gather data on students’ understanding of a concept. Using the informal and formal assessments described above, teachers gauged students’ understanding of a concept in different ways. Informally, teachers could quickly gather details about what parts of a concept students were grasping and what they were struggling with. Brad talked about this phenomenon, saying, “If I’m asking questions and it’s dead silent, and they can’t answer it, then I’m just going to over it more and more until they got it. I’m going to ask them questions until we are ready to go” (Interview). Students’ informal responses to his questioning strategies provided him data at the classroom level of how well students were grasping the concept. Likewise, Diana mentioned during her interview how she used exit tickets to find out what stood out to students from a particular lesson so she knew what she had covered well and what she needed to cover in more detail in future lessons. Formally, teachers typically gathered a broader kind of data, measuring students’ understanding of one or a set of content standards. Fred (Observations #1 & 3) and George (Observation #2) arranged their formal
assessments according to content standards,designating questions by the content standard they pertain to. Some teachers used pre-assessments to gather informal and formal data on students’ understanding of a concept, such as Alice’s formal pretests (Interview), Elise’s informal discussion based on a KWL activity (Observation #1), and Diana’s semi-formal anticipation guides that provided her with informal feedback at the start of a unit and more formal feedback for her and the students when they reviewed these at the end of a unit (Interview). A few teachers even mentioned using larger testing measures to gather data on students. George discussed using high-stakes testing data from the previous year to initially group his students according to their readiness levels (Interview). Henry mentioned his school’s piloting of the Response to Intervention (RTI) program that used a series of summative assessments to track data on student progress on specific concepts or skills, saying, “It’s really easy to see what kids are struggling in what areas which I like, and so it’s easier to determine what’s working and what’s not” (Interview). Looking at these strategies as a whole, effective middle school science teachers demonstrated the significance of gathering multiple forms of data on students’ understanding.

**Using data to inform instruction.** Once teachers have gathered the data from the informal and formal assessments, effective middle school science teachers applied their interpretation of that data to benefit both their students and their own teaching. Teachers used that data in several ways, first measuring students’ levels of understanding of the concept, then as a way to identify students that would benefit from reteaching or extending opportunities, and finally as a tool for reflecting on a lesson or activity.

**Data to measure students’ understanding.** First and foremost, teachers used their multiple means of assessment to measure students’ understanding to inform future instruction.
Frequent formative assessments, when designed to measure students’ understanding of a concept rather than their completion of some activity, proved to be the most effective way teachers gathered data on students’ learning. Elise described the strategy of using several kinds of assessment throughout a unit, explaining:

I use a variety of [assessments]. I mean, not every assessment is a test. Sometimes I pull small groups to just assess maybe, it could be matching manipulatives, it could be a model I’m having them build to show me what I just taught them. So it’s not just those…horrible assessments. And I tend to do them every couple weeks. I do checkpoints where I just check up on their learning to make sure that they understanding it. (Interview)

Her organelle flash card activity seemed to be just this type of checkpoint, allowing her to measure students’ grasp of organelles’ functions early on during the unit to determine which organelles students grasped and which they typically struggled with (Observation #3). Alice gathered data on student understanding through her daily quizzes, discussion questions woven into instruction time, and even her Simon Says vocabulary-based competitions (Observations #1-4). Brad gathered data from students’ completion of vocabulary notecards, their decoration of camouflaged butterflies, questions from students’ textbooks, and a poster displaying a fictional animal’s adaptations to an ecosystem (Observations #1-4). In Christine’s class, students completed packets describing natural resources from their jigsaw activity, answered questions during her lecture, created graphic organizers, and participated in a baseball-style review game (Observations #1-4). The variety and frequency of formative assessments was critical to gathering data on student understanding. However, the frequency of formative assessments alone may not be what made data on students’ understanding valuable. George described this
data gathering process’s effectiveness as hinging on the validity of the assessment itself, emphasizing:

I’ve got to grade it on mastery, not on did you do your homework or not. So I got to find that fine line of, ok, can I really justify grading this? And it be a mastery thing? Well yes, they’re mastering that they know the clouds and what happens in the clouds, [so] yes, this one I can [grade]. Doing your terms? No, I can’t really justify grading that as mastery. (Interview)

With a clear understanding of what students understood and what they did not from valid and frequent assessments, teachers can focus instruction on those aspects of a concept students are struggling with, providing students with instruction and activities that will benefit them most. Henry described instances of informal assessments informing his instruction, stating, “A lot of times, we’ll be in the middle of something, and if I’m like, ‘This isn’t working,’ we’ll change it. I’ve done that in the middle of class before. It really depends on what I see from it” (Interview). Fred used a review and benchmark assessment to identify specifically what skills students struggled most with and then used that data to determine what activities a student would complete next to remediate the concept (Observations #2 & 4). In theory, Elise could use her “checkpoint” of students’ progress on the organelle flash cards (Observation #3) to guide specific students to spend most of their time at the appropriate tier of complexity or on a specific organelle during their research-based foldable activity (Observation #4).

_Data as an identification tool for reteaching or extending._ Having measured students’ understanding in a number of formal and informal ways, teachers described how that set of data was used as a tool to identify students who would benefit from reteaching or extending activities, often times during their school’s designated tier two time. Tier two was an extra (but
abbreviated) class period where teachers had the opportunity to pull students back into their class specifically for reteaching or extending lessons. For example, Elise went on to say that she used her “checkpoints” (Interview) to identify when students were not understanding a concept, simply saying, “And if they’re not [understanding], then I remediate them during their study hall time” (Interview). Similarly, after Christine had described how her base of activities was intended to deliver content in students’ preferred ways, she explained, “Some of you [students] still aren’t going to get it that way so I’m going to sit down with you one-on-one during our [Remediation and Enrichment] time” (Interview). When describing how his teaching has evolved, Fred described a cyclical process of assessment and remediation, explaining, “It’s just natural now when I give a test, I understand for next three to five days after, we’re doing some remediation trying to bring up the deficit areas for each and every student” (Interview). He used assessments during the remediation time to identify students who still need additional help, inviting selected students to extended remediation on some half days and Saturdays. He later explained that when students did show a mastery of the material on that first formal assessment that he could identify students who may benefit from more challenging work, and so he was building a set of constructed response questions to increase the degree of complexity for these students during that “remediation” (Interview) time.

*Data as a reflection tool for teachers.* Teachers sometimes spoke about trying a new lesson or activity and then using its informal and/or formal assessments to gauge its value. Diana, for instance, discussed this process, explaining, “I take every lesson, and I change it. I’ve never done the same lesson twice in the exact same way. So I definitely make mental notes on, ok, they didn’t get that so well” (Interview). Other times, she also took feedback from her students, describing how she sometimes gave students sticky notes as exit tickets for lessons and
asked them to write down something they learned from the lesson. She explained, “Those exit tickets speak volumes because if…I’m pulling a bunch of cards that are off the wall, I feel like that’s my cue that I did something wrong, and I need to go back over it” (Interview). She went on to describe how that process of experimentation and reflection led to the development of her base set, helping her to recognize how different students learn in different ways so that now she incorporated lecture, visual elements, hands-on activities, writing activities, drawings, and short video clips into her instruction on a concept. While discussing the evolution of his instructional goals, George explained his students’ achievement history by noting that he helped the lowest achieving students produce the highest learning gains (according to the state’s effectiveness measure) but that his highest achieving students did not make the same level of gains. He had used that data as a reason to experiment with new lessons and activities, saying, “And every year, I try something new, and I have not found the golden ticket yet” (Interview). Henry, the least experienced teacher in the study, talked about how his activities and tests had changed each year he has taught, describing the process, “Something I’ve seen, you know some things will be gone like, this is successful, I’ll stick with that, but I’m definitely still in the experimenting stage. I’m trying to do, ‘I like this, I don’t like this, this works” (Interview). The most experienced teacher, Fred, has even formed a coalition of teachers across the district that develops and shares new resources that they find to be effective in their own classrooms. This way, one teacher’s data and reflection on a lesson or activity can benefit a number of other teachers as well.

**Differentiated assessment.** Though assessment appeared to be the least differentiated phase of instruction, teachers did demonstrate a couple significant ways that their assessments could be differentiated to accommodate students or groups with adaptations designed to clearly reveal what students knew and what they did not about a concept. Teachers differentiated
assessments in two primary ways: by offering alternative formats for informal or formal assessments or by modifying one assessment to ensure that it authentically assessed a student’s true knowledge on a concept rather than their ability, for example, to read or write at grade level.

**Alternative formats.** On some assessments, teachers provided students with the option to complete it in an alternative format as a response to a student’s or group of students’ characteristics. Sometimes, teachers differentiated the assessment by simply allowing students to choose from among different formats (see the choice section under the differentiated planning phase). Other times, teachers created specific alterations for students. For example, on some smaller types of drawing assessments, Alice brought up how she offered to one “messy” (Interview) student the option to type out or print his work rather than drawing it. She explained, “If a child really can’t do what I want them to do, I will find another way for them to do it and still make an A or a B—whatever I think they are at that time,” (Interview). Christine also had a specific student in mind when talking about alternative formats, describing how she might orally assess a student because “I’m not going to let a kid who, just because he can’t get it to the paper, you know, not be successful. He’s smart” (Interview). Another time, she referred more generally to offering alternatives, explaining how written reflections sometimes provided a better assessment than the one she had designed, saying:

Sometimes I find it better to let them write what they think about [a concept]. And, I’m always surprised, if I tell them to write a paper, they have a hard time with it, but if I say, just write what you think about that, they come up with some really good stuff. It’s like, ‘Wow, that was more than I really asked for.’ (Interview)

Henry explained that he thought his provision for alternative formats was built into his system of frequently assessing students with different types of activities, testing their knowledge with
drawing-based assessments, web-based online test questions, and constructed response assessments (Interview).

**Modifications for authentic assessment.** In addition to sometimes providing alternative formats, teachers made modifications to a single assessment for certain students in order to more authentically assess those students’ knowledge of the concept. These assessments typically seemed geared towards providing support to students who struggled with reading and writing at grade level but also included accommodations that allowed students to show what they knew in spite of challenges with deciphering a test question. Christine, Elise, and George all discussed accommodations they made for ELL students, making provisions for assessments to be read to those students to give them the best chance at demonstrating their knowledge of science rather than reading comprehension (Interviews). Christine recorded herself reading the quiz and posted it on her website so that ELL students can take the quiz on her classroom computers while other students take the same quiz at their desks (Interview). Elise had a similar technique as she took advantage of the textbook’s online companion that included a feature that would read the text in order to support ELL students as they worked on textbook-based assignments (Interview). In George’s class, I observed an Educational Assistant (EA) who routinely took a group of ELL students to a different classroom to read them larger formal assessments like quizzes (Observation #2).

With writing being an integral part to Henry’s center sense-making activities and his cycle of assessments, he discussed an accommodation he makes to his expectations to authentically assess individual students at their level of readiness. While discussing the influence of DI during his interview, Henry explained how “every kid gets the same work, but they have to accomplish a different goal with it” (Interview). One practical application of this
philosophy included how Henry graded students’ constructed response assessments (CRA’s) by having different expectations for different students. He did not describe how his expectations are reflected in students’ grades, but he gave the example:

I’ve got a couple kids that really struggle with material, and like if we do a CRA, they’ll bring it up to me and it’s basically definitions strung together with words, and I’ll accept that as a grade and be like, ‘Well, obviously you went out and found the material and you kind of understand it. You reworded it.’ (Interview)

He went on to say, “But if like a high student brought me that, it’d be like no. And they’d have to come back with full understanding and proof, you know, citing evidence and all that good stuff” (Interview). Because Henry frequently assessed his students in a variety of formal and informal ways, it seems he had an understanding of students’ readiness levels on a concept before giving them a larger formal assessment like a CRA. While his perception of those readiness levels did not necessarily mean he created different types of assessments, it did mean that his expectations of what constituted understanding and achievement were differentiated according to the student.

Additionally, one teacher made her students aware that they could choose to answer questions on an assessment in a way that best demonstrates their knowledge of a concept. In Christine’s class, she explained that she invited students to make their own accommodation where they may choose to simply write out what they do know or even draw their understanding in place of answering quiz questions (Interview). With her test on natural resources coming up just after my observations ended, she described how a student might draw next to one of her test questions a picture of coal burning to heat water, creating steam that turns a turbine. She explained, “I would know from looking at if they have [an] understanding of the concept, so if
they want a different route than I thought, that’s ok” (Interview). In this way, a student who did not understand or was confused by a question could opt to show his or her understanding in a different way rather than simply guessing at a multiple choice answer.

**Scope of differentiation.** Teachers used these differentiated elements to adapt assessments to the different kinds of learners in their classrooms. While the specific alterations teachers put in place typically were designed for the narrower scope of small groups of students or individuals, some teachers also mentioned making these kinds of accommodations universally available, leaving it up to students to choose what might be best for them. Teachers’ explanations or demonstrations of how they differentiated assessments included adapting them for particular groups of students, such as providing read aloud support for ELL students (Interviews with Christine and Elise, Observation #2 with George) and even raising or lowering a teacher’s standard of grading according to students’ readiness levels (Interviews with Alice and Henry). Teachers also adapted assessments for individual students, as Alice discussed offering alternative formats to one “messy” (Interview) student that she has been working with or Christine orally testing a student (Interview). Christine emphasized that these kinds of adaptations are founded on “just getting to know that person” (Interview) in order to find out how a student best demonstrates their understanding of a concept.

Though teachers’ adaptations were designed for small groups or individuals, several teachers mentioned how the accommodations were offered universally for any student to take advantage of. Christine made all her students aware of the opportunity to write or draw what they know about a concept next to a test question (Interview). Fred and George discussed how accommodations for one student could benefit others, so they offered it to all their students (Interviews). George explained the tactic in terms of Universal Design where “every
accommodation you would make for the kids that would need it for differentiated instruction, you make it for everybody” (Interview).

**Contextual factors influencing assessment.** Teachers’ assessments were influenced at several different levels, ranging from macro-level conditions such as state and building-level requirements to the unique characteristics of smaller groups of students and even individuals in a single class. First and foremost, teachers designed their assessments to be aligned to the content standards required by the state. Alice, Brad, Elise, and Fred specifically named or used test question samplers provided by the state in their assessments (Interviews with Alice, Brad, and Fred, Observations #1 & 4 with Elise). Brad and Fred supplemented those questions with similar ones developed by USA Test Prep (Interviews with Brad and Fred). Fred best summarized this practice saying, “I’m trying to prepare the kids for the appropriate alignment and rigor level” (Interview). Using these resources allowed teachers to create assessments founded on what students were required to learn. Though the other teachers did not necessarily mention assessment and these resources together, each teacher mentioned following the district’s scope and sequence, a general calendar for teaching the grade level’s content standards required by the state.

Next, building level policies sometimes influenced teachers’ assessments. In Fred’s class, I observed his class taking a benchmark test (Observation #3), a common assessment used by a school’s grade level department to track data on students’ achievement. Though Fred tied all of his assessments to specific content standards, measuring data on each (Interview), this particular type of assessment is one required by the district but organized according to school level policies. Additionally, it seemed that several teachers’ systems of assessment were influenced by their school’s policy of including a remediation and enrichment class period.
Brad, Christine, Diana, Elise, George, and Henry all brought up the designated tier two remediation and enrichment class period, noting its relationship to students’ assessment scores. Brad explained, “You can use [the remediation and enrichment class period] for students who are struggling with certain topics. Like, if I just gave out a test or a quiz on Friday, and I got the scores back, and [I could just] pull students who do poorly on that” (Interview). This statement reveals how classroom assessments were geared toward building students’ understanding rather than reflecting the high stakes like the year-end test since schools provide time for teachers to reteach concepts and for students to retake assessments. In this way, any of teachers’ frequent formative assessments could be used to identify students on a daily basis for inclusion in their tier two instruction. Because of the school’s scheduling, teachers were given the opportunity to use assessments strategically, constantly measuring, monitoring, and responding to students’ levels of understanding.

Finally, teachers could also be influenced by specific groups of students in their classes and sometimes even particular individuals. This last influential factor on assessment is rooted in teachers’ philosophies and applications related to DI, as teachers adapted assessments in response to the learning needs of their students. Teachers adapted assessments for ELL students, providing read aloud supports (Interviews with Christine and Elise, Observation #2 with George) to more authentically measure a student’s understanding of a concept rather than their ability to comprehend the reading required by the assessment. Henry talked about how his grading and expectations were influenced by his perceptions of students’ readiness so that he accepts different levels of work from students of different abilities (Interview). Fred and George described how they offered these adaptations universally, though they might have been initially developed for specific groups of students or individuals (Interviews). They talked in general
terms about offering accommodations (like using multiple choice formatting or offering read aloud tests) to all of their students so that those who think they might benefit from the accommodation could choose to take advantage of it (Interviews). Similarly, Christine allowed her students to opt for an accommodation of simply writing or drawing what they know about a concept when faced with a question they struggle to decipher (Interview).

**Reteaching/Extending**

Effective middle school science teachers used the data they gathered from frequent and varying assessments to drive their decisions on how to reteach and/or extend instruction. Teachers’ reteaching and extending contained two major facets: that which was done during normal class time (referred to as tier one) and that which was done outside of class time (tier two), either during the school’s remediation and enrichment class period or before or after school. The major themes that described how teachers retaught or extended their instruction related to best practices science teaching are that teachers reinforced their high expectations for learning, provided multiple exposures to content while remaining focused on a central learning objective, and focused their reteaching or extending instruction to students’ zones of proximal development (similar to the *teaching* phase of instruction) according to informal and formal assessment data. During this phase of instruction, teachers’ instruction revealed strongly differentiated elements as teachers adapted the reteaching/extendng activities specifically for small groups of students and individuals. This was especially evident as teachers provided different levels of support according to students’ needs during tier one instruction, flexibly grouped students during tier one and tier two instruction, and used specific data to target certain learning objectives for selected students (see Figure 8). Because teachers’ reteaching/extendng
instruction was tailored to the needs of specific groups of students or individuals, I considered this to be the most differentiated phase.

Figure 8. The reteaching/extending phase of instruction. This figure represents the key themes that emerged from the data accounting for how teachers implemented best practices teaching for science (blue box), differentiated those practices (green box), and their intended scope of those differentiated elements (size of the blue ring).

**Using best practices to reteach/extend.** Teacher’s best practices during this phase of instruction were emphasized in two key areas: reinforcing their high expectations for learning through multiple exposures to the content and, as a unit progressed, using assessment data to focus instruction on students’ zones of proximal development. Integrated with teachers’ implementation of a variety of increasingly complex sense-making activities (see those sections described in more detail in the best practices teaching phase of instruction), teachers used teachable moments to continually emphasize what students were expected to learn. Teachers reinforced those high expectations throughout a unit, describing what students should know by giving students multiple exposures to instruction and activities related to specific learning objectives. As teachers engaged in this back-and-forth process with the teaching and assessment
phases, they were able to target certain aspects of a learning objective based on how students progressed through a unit.

**Reinforcing high expectations.** First, teachers reinforced their high expectations for student learning by re-emphasizing a learning objective(s) each lesson. This way, students knew exactly what teachers expected them to know and were given multiple opportunities for understanding and applying that learning objective. It is important to point out here this section’s close relationship (and even overlap) with the *teaching* phase of instruction, as teachers provided multiple inputs of instruction, used a variety of sense-making activities, and gradually increased the complexity of the instruction and activities throughout a unit. From an observer’s point of view, it can be difficult to distinguish between reteaching and normal instruction. For the purposes of this section, I categorized instances of reteaching as when a teacher focuses on the same learning objective through the course of multiple lessons, using different inputs or sense-making activities for the one learning objective. However, it should be noted that teachers typically planned units so that students would be exposed to the same learning objective in multiple ways (see the section on types of activities in the differentiated *teaching* phase of instruction). I considered this to be an example of how teachers planned to reteach/extend a concept based on an understanding that not all students will grasp a topic the same way, at the same rate, and so it is necessary to plan to reteach the concept, reinforcing their expectations for mastery and providing multiple opportunities for students to build the capacity for mastery.

As a result of teachers’ philosophies of learning (particularly that students learn in different ways and at different rates), they took advantage of teachable moments throughout the sense-making process to reinforce their expectations for students’ understanding. Sometimes, teachers’ utilized elements of reteaching/ extending during a single lesson. Elise demonstrated
this strategy, randomly calling on one student to give an answer to the bellwork question and then calling on a second to explain why that was a correct answer (Observation #2) or even to explain why the first student may have thought the incorrect answer they gave was the right one (Observation #3). Brad used a similar tactic, taking time to review homework (Observation #3). While some teachers might simply have taken the assignment up, graded it, and handed it back to students, Brad took class time to ask several students their answers for each question on the homework, often following up with clarifying statements and/or questions. In this way, Brad highlighted the big ideas contained in each answer, reinforcing his expectations for how students should understand and communicate the concept. George reviewed the correct answers during his jeopardy game, often asking a group who got the correct answer to explain why they chose that answer, to clarify it or give more explanation (Observation #1). Diana took opportunities to piggyback on groups’ presentations, reteaching about a natural resource in her own way. For instance, after a group’s presentation on nuclear power, she asked questions to the group to emphasize important details like what classifies a resource as non-renewable that were intended as instruction for the whole class (Observation #3). Her questions to the group became questions for the class, explaining that if uranium were mined more quickly than it is naturally formed, it could be classified as non-renewable and even become scarce. She also paused between groups’ presentations to cover the same material but in a new way and with a fresh perspective, showing short clips on fuel cells (Observation #3) and biomass (Observation #4) after those groups’ presentations.

Teachers’ reteaching strategies were not always so immediate though, also acting as bridge between lessons. For example, when asked how students learned best, Alice emphasized, “Slowing down and stopping and then reteaching the next day and not waiting until a test has
been given”, (Interview). In her view, it was essential to continually shape students’ understanding throughout a unit, using frequent formative assessments instead of waiting until the end of a unit to identify struggling students and reteach them. She explained how she used her daily oral assessments (Observations #1-4) to gauge student understanding and to note what aspects of a concept she might need to review during the next lesson (Interview). Henry’s reteaching strategy involved summarizing the key points of instruction at the end of that lesson and again at the beginning of the next (Observations #1-2). After emphasizing his expectation that students should focus on the vocabulary during his lecture at the beginning of class, Henry ended the lesson by asking students to chorally identify the terms he described (Observation #1). Before stating his learning objective at the beginning of the next lesson, Henry made sure to review with students the six important terms from the previous lesson, reinforcing what he expected his students to know about the words (Observation #2). Christine followed her students’ jigsaw cooperative work on natural resources that I observed during my first visit with her own teacher-led instruction, delivering the same information but communicating it in her own way, with her own media (Observations #2-3).

Teachers’ reteaching strategies also led to teaching about the same concept multiple times throughout the year. Alice used this strategy comprehensively and specifically, taking appropriate moments to simply remind students about something they had already learned (see also the section of connecting to past and future content in the best practices planning phase). For instance, she built teachable moments into simple classroom routines, expecting students to call out ‘Open circuit!’ when she turned out the lights (Observations #2-3) and rotate their desks in the same counter-clockwise direction as the Earth rotates when students moved to face the projector screen (Observation #1). She also consistently reinforced significant vocabulary terms,
continuously adding in more terms and their motions with each unit to her on-going Simon Says games (Observations # 2-3). Brad retaught concepts like density that he knew from experience that students struggle with. In his interview, he explained how he taught about density during the opening lessons of the school year when he taught measurement tools, again later in the curriculum during the unit on the properties of matter, and once more when teaching the difference between mass and weight.

The repetition involved with reteaching (whether in a single lesson, over multiple lessons, or longer periods of time) was an important part of how teachers’ believed that their students would learn best. George explained the idea in terms of how students built knowledge, describing:

I do a lot of repetition. Repeat it back to me. Repeat it back to me, so they’re hearing it over and over again. And when I do this, I’m doing it on a very simple level. I don't try to get them to learn the in-depth knowledge of it, just to the basic parts so they can start building from that. (Interview)

With this strategy, George continued, students would be better prepared for more complex applications of the learning objective like writing assignments. He demonstrated this idea by consistently reteaching vocabulary terms, their key descriptives, and the kinesthetic motions that demonstrate them (Observations #1-4) Henry found success with the same kind of repetition. After explaining hand motions to demonstrate mitosis, he laughingly described to his class how he sometimes sneaks up on former students and yells a phase of mitosis at them fully expecting that they respond with appropriate “hand dance” (Observation #2). Not all repetition necessarily needs to be exactly the same though, as Fred described how he often reteaches students using presentations and resources similar to those he used during the initial instruction but
incorporating new slides of notes, illustrations, and any other resources he might have gathered since his initial instruction. He explained that these reteaching resources focus on exactly the same learning objectives but with the intended goal of exposing students to that content multiple times, communicating it slightly differently each time (Interview). The comprehensive website he has developed with those resources helps him reteach content at the end of a unit, a grading period, and just before high-stakes testing time.

Henry also emphasized the importance of repetition particularly before the high-stakes test by explaining how his grade level science team organized their curriculum so that “we’re going a little bit faster this year, and the idea is we’ll have more time for review at the end” (Interview). Saving time to reteach concepts to students so they will be fresh for the end-of-the-year high-stakes test was a critical component, Henry admitted, to the achievement gains he helps his students produce. Similarly, Christine, Diana, and Elise all developed systems for students’ creation of a science notebook, storing notes and other work in composition books so that students could refer back to concepts throughout the year and especially during review for testing (Interviews).

**Focusing instruction in students’ zones of proximal development (ZPD).** An important part of how teachers reteach or extend instruction is the narrowing of the learning objective to what students still should learn about the concept, fitting instruction and activities to students’ ZPD. While there is some apparent overlap here with how teachers target instruction to students’ readiness levels in the differentiated section of the teaching phase, in this section I focus specifically on those instances where a teacher uses the same learning objective for consecutive lessons, teaching the same content but in a novel way. Fred provided the most obvious and objective example of this kind of best practices reteaching. After students had taken a kind of
review test (Observation #1) and the actual benchmark assessment that the review covered (Observation #3), Fred assigned his students to specific instruction and activities based solely on their scores. Students began with whatever learning objective they scored lowest in, subsequently working through a series of predetermined activities beginning with reviewing instruction from Fred’s notes and study guides before moving on to application activities like online assignments and BrainPop quizzes (Observations #2, 4).

Without that degree of specificity, other teachers demonstrated similar ideas about designing reteaching for specific levels of readiness, implementing strategies according to their own style and perceptions of their students (see also the section on critical thinking and vocabulary in the differentiated teaching phase). Henry, for instance, described how he reteaches concepts for his lowest achieving class by repeatedly teaching concepts, and particularly their vocabulary, in a single lesson and over consecutive lessons. Thinking primarily of his ELL students, Henry utilized this kind of reteaching through repetition until he recognizes students mastering the content. He explained focusing on the most essential parts of the learning objective, saying about his lowest achieving class, “We won’t go into a lot of the side notes and the things that may get confusing. We’ll just go here’s what the standard says. Here’s what you need to know. When we get that, we’ll move on” (Interview). George, teaching at the same school, seemed to have a similar philosophy, describing in his interview how he perceives only about 10% of his students as being truly ready and prepared every day. During my observations and our interview, George often demonstrated the value he places on multiple exposures to a learning objective by repeatedly reviewing vocabulary terms and their associated kinesthetic motions (Observations #3-4). He also displayed posters for significant vocabulary terms (Interview) and had students chorally respond to instruction as the first step in building
knowledge (Interview). He did move on from this kind of repetition, using his centers to provide students even more exposures to a learning objective through a variety of sense-making activities. He mentioned constantly rearranging his homogeneous center groups to match students to the appropriate skill level (Interview). Then, he also extended on previously taught concepts for homogeneous groups that received his highest tier of instruction. Likewise, Elise’s research-based cells foldable (Observation #4) was designed so that, as students progressed through each tier of the activity, they were exposed to extensions of the same learning objective. Students were being retaught how organelles contributed to the health of a cell (the learning objective) during each tier but at higher levels of complexity as each tier provided more detailed information.

Beyond normal classroom instruction, teachers also used tier two, organized slightly differently among the schools I observed, to pull in particular students to reteach or extend instruction. George used tier two to pull in students he noted as struggling, describing how he would continue his emphasis on vocabulary and work with students in smaller groups to identify and fill the gaps in their learning. The gaps, he explained, are not typically with rote memorization of terms but in the application of new terms. So, he uncovered what students did not understand about a term’s application and then built on their knowledge of what the term means to try and find a real world connection that was meaningful to that student. In this way, he was identifying where students were not able to independently explain the learning objective and then helping them to connect to the word so they could explain it on their own. Henry and George used this time as an immediate remediation strategy in response to students’ grades, pulling students in to make up and retake certain assignments. Christine used tier two for extending on previously taught concepts, mentioning that she caters the pace of instruction
during that period to those students that are “My high levels learners, we may do things…[to] meet their needs in a private situation like during [tier two],” (Interview).

However, it is important to point out that the effective middle school science teachers in this study did not all emphasize tier two instruction equally. For instance, while Alice’s school did have a system for tier two, she did not mention it during the interview or anytime during one of my four observations. Given how she reviewed the end-of-class oral quizzes with her students (Observations #1-4) and so frequently connected her learning objectives, it was possible that those strategies compensated for the apparent de-emphasis on tier two. Similarly, Fred’s system of immediate reteaching using the school’s mobile laptop lab to plot tracks of instruction using his website might make tier two less relevant. He did mention pulling students for reteaching and extending during his interview, explaining the occasional use of Saturday’s and half days to work with struggling students (sometimes with the help of peer tutors), but he did not emphasize the daily tier two time during the interview or mention it during my classroom observations. Elise’s school organized tier two with an adaptable rotation system so that she did not always handpick her students. Like Fred though, she put numerous resources online for students to access on their own at any time. However Elise did take advantage to the extent she could of the rotation system, discussing how she used the time to reteach a concept in a new way for students still struggling to master it (Interview). In contrast, Christine, Diana, and George seemed to place more emphasis on tier two. Diana devoted a section of her whiteboard to listing students’ names that should visit her during tier two that day (Observations #1-4). Christine spoke about using the time to provide extending activities for her highest achieving students (Interview) and mentioned to her class during my fourth observation that they could come to her that day to
review for the next day’s test. George used tier two time to help students master and apply important vocabulary (Interview).

**Differentiated reteaching/extension.** Reteaching, when done as a response built from teachers’ informal and formal assessments, is differentiating. In this section, I focus on how a teacher talked about or demonstrated ways of adapting his or her reteaching or extension instruction for specific students in contrast to more general reteaching strategies delivered to the whole class. The *reteaching/extension* phase of instruction appeared to be the most differentiated as most teachers targeted and/or selected specific students and then developed instruction and activities with their learning needs in mind. As teachers retaught or extended a concept by focusing on a single learning objective and repeating it throughout a single class, over multiple lessons, and/or connecting it with other content throughout the year, they provided different levels of support according to students’ diverse learning needs. As a part of that support, teachers grouped students flexibly, configuring the groups in several ways to provide different kinds of support. Finally, teachers used assessment data to target specific objectives for specific students, particularly as a part of their tier two instruction. Because teachers tended to focus on small groups organized by similar data points or individual students, teachers’ differentiating strategies were the narrowest and most focused at this stage of instruction.

**Different levels of support according to students’ needs.** One way that effective middle school science teachers differentiated during the *reteaching/extension* phase was to provide different levels of support according to students’ needs. Teachers provided this support during both tier one and tier two instruction, though in different degrees according to teachers’ pedagogical styles. This section shares some similarities with scaffolding in the differentiated *teaching* phase as both relate to how teachers support students during the learning process;
though, here, the focus is on how teachers scaffold after having made informal and/or formal assessment(s) on a learning objective that has been the focus of multiple lessons.

*Tier one supports.* First, teachers retaught a concept during normal class time by using scaffolding strategies to review one learning objective or to teach it in a novel way so that students have an opportunity to show a greater degree of understanding and mastery. Alice described the support she gives to students during this differentiated reteaching time very simply, saying:

“I see somebody struggling. I walk over, and I figure out a different way, or a different trick behind it, or analogy or a different, you know, common sense about it. It’s not like I give them a separate assignment to do or anything like that. (Interview)

She went on to describe in more detail how she asked the student questions about the concept to find where the student’s disconnect or misunderstanding was before taking another approach to fill that gap. Henry voiced a similar strategy, explaining, “I won’t ever lower the curriculum. I’ll just add additional help to those who need it” (Interview). I observed Elise working one-on-one with students she had assigned to the organelle flash cards at the lab tables, reteaching the functions of organelles by using questions to guide a student’s thinking and when that student did not match the flash cards with 100% accuracy (Observation #3). With this strategy, Elise could handpick students she may have had concerns with about their current level of understanding, check just how much the student did understand about the concept with the informal assessment afforded by the activity, and then adapt her reteaching methods accordingly to target the individual student’s gaps. Fred’s posttest remediating strategies could also fall into this category, as students progressing through his predetermined set of resources according to scores on each learning objective could send him their scores to digital assignments. Several
times I observed him checking his email to see students’ scores and then following up by telling the student to view a particular resource or move on to a specific activity (Observations #2 & 4). During his interview, Henry even described one example of reteaching where he tried to engage a student completely uninterested in learning about natural resources by assigning him to play a video game he enjoys and note certain aspects of the game’s relationship to the learning objectives the student had previously failed to complete. In that case, the student had not mastered the previously taught material not because of an inability to understand it, but because of his unwillingness to engage during class time. Henry described the student as one who “didn’t do anything with the earth science stuff” (Interview). By differentiating the reteaching process to support this student’s preferred way interacting with the content, the student who had not mastered the material as it was originally taught was now motivated to learn. On the extension side, Diana and Elise talked about targeting certain high achieving students as a unit progressed with more complex questions to give them an opportunity to learn more about the concept that the teachers did not necessarily expect of other students (Interviews).

Tier two supports. Teachers demonstrated ways to provide these different levels of support outside normal class time, opting to utilize tier two instruction to reteach and/or extend a concept for a smaller group of students. Teachers discussed how they used tier two to either reinforce content for lower achieving students, extend a concept for higher achieving students, or some combination of both. In any case, tier two was revealed to be instruction designed for the ends of the spectrum. Christine emphasized using her tier two for students struggling to keep up during normal instruction during her interview but went on to say, “I use my [tier two] for upper and lower [students]” (Interview). Diana shared this dualistic mindset, explaining, “The ones that are struggling, the ones I feel need the differentiation, that’s what [tier two] is for” later
adding, “Sometimes I pull in only advanced students. Sometimes I pull in only basic students, and I work with them on their own level” (Interview). Diana explained that her normal instruction time is aimed at students reaching the advanced/proficient mark for the year-end high stakes test, which is considered to be equivalent to an “A” or “B” grade respectively. Elise described her reteaching strategies during tier two:

Sometimes, if I just sit with them one on one, or within a small group, they understand it better. I think they’re so worried about what their peers think, and that’s all they think about, and so they miss half of what I say because that’s all they care about. (Interview)

Based on responses like these, tier two might best be described as time to provide extra and personalized scaffolding, as an extension for instruction and sense-making activities, designed for specific students on specific learning objectives.

Some teachers, however, gave special emphasis to the lowest achieving or struggling students during tier two. George consistently emphasized working with his lowest achieving students during tier two, talking in general terms about working with them in smaller groups to teach to students’ learning gaps. He helped these students when it came to memorizing and applying new vocabulary words (Interview). He mentioned informally after one observation that he had planned to pull in a group of students to review his cooperatively grouped jeopardy game (Observation #1) in more detail. Similarly, Christine and Henry offered the time to students struggling to master the material, with Christine inviting students to study for an upcoming test (Observation #4) and Henry explaining how he offered extra printed or online resources to supplement his normal instruction (Interview). When asked how she differentiated instruction outside of the accommodations required by Individualized Education Plans (IEP’s), Elise described, “A lot of times that happens during their [tier two] time just because it’s so hard in the
regular classroom, but I do a lot of remediation with these kids” (Interview). Focusing on the students needing remediation, she described, “I just need to stop and slow down…and then I’ll just have to find a different way for them to get it” (Interview).

**Flexible student groups.** When asked on their surveys how teachers grouped their students, each participant in this study responded that their groups changed. During the *reteaching/extending* phase of instruction, teachers discussed grouping students according to ability so that instruction could be targeted for students with similar learning needs or, in contrast, grouping students of mixed abilities so that students could provide support to each other. Flexibly grouping students allowed teachers to provide an appropriate amount of support, either as a single same-ability group directed by the teacher or as several mixed ability groups where high achieving students could offer support to their peers.

Teachers used homogeneous groups during the *reteaching/extending* phase to deliver teacher-directed support to students with similar learning needs. During tier two in particular, teachers like Christine and Diana sometimes pulled only low or only high achieving students (Interviews). Teachers like Elise and George only discussed pulling their lowest students, working with those students to master the current concept they had shown difficulty grasping during tier one instruction (Interviews). Grouping students like this for tier two meant that a teacher could come up with a single reteaching strategy or reinforcing activity to benefit a group of students without necessarily having to individualize the level of support they could provide during that time. During normal classroom instruction, Elise and George grouped students homogeneously for similar reasons. Elise used same ability partners for the research-based cells foldable (Observation #4), partly for practical reasons since students had to share the laptop or iPad to do the research (meaning they needed to work at similar paces) and so that the high
achieving students “can push themselves a little bit more” (Interview). As these groups researched about organelles’ functions, a concept that had already been covered during the two previous lessons, Elise then moved from pair to pair to give student groups the kind of support that most benefits that particular group according to their progress (Observation #4). George used the strategy to not only prepare assignments for students’ readiness levels but also so that he might be able to scaffold particular groups as they worked on certain assignments during his centers (Interview). Especially if the center activities followed the pattern of instruction I observed that emphasized a concept’s vocabulary (Observations #3-4), George could focus his reteaching efforts to the appropriate level of support for each group, helping them to apply the words in the context of the activity they were currently working on.

Other times, teachers grouped students heterogeneously. Part of teachers’ systems for reteaching and/or extending a concept was delegating some of the responsibility for scaffolding to cooperative groups of students. During tier two, only Fred mentioned using heterogeneous groups. He utilized that grouping strategy specifically to create peer tutoring situations, helping his lowest achieving students receive the maximum amount of support by enlisting higher achieving peers to help him in the scaffolding process (Interview). However, typically, teachers used heterogeneous groups during tier one as a routine type of support where higher achieving students could reinforce directions or parts of instruction to their lower achieving peers. Brad, Christine, Diana, Elise, George, and Henry all talked about creating seating arrangements for activities that could be used to group students of different abilities so that higher achieving students could help lower achieving ones (Interviews). Brad, Christine, and George mentioned the strategy’s benefits for the kind of reteaching done with repetition in a single class period, as the higher achieving student could prompt the lower one during the normal flow of daily
instruction. Henry arranged his table groups heterogeneously, relying on the high achiever(s) in the group to lead especially during the center activities that reinforced the already delivered instruction (Interview). Elise used her heterogeneously arranged desk clumps as her lab groups, with students sitting in pairs and sharing resources for classroom activities between two sets of pairs (Interview). If her lab activities followed instruction in the way that George and Henry’s did, then the high achieving student(s) in the group could provide the initiative for applying the previously taught concept to the current lab sense-making activity. Based on Diana’s modified random grouping system that I observed, she also could make sure that each group had a student able to lead cooperative activities and to provide support to the group (Interview and Observation #1). While heterogeneous groupings during tier two time were rare, that type of group was common for tier one as both create the opportunity for higher achieving students to reinforce directions and instruction to support their lower achieving peers.

*Using data to target specific learning objectives for specific students.* Other than the actual strategies and scaffolding used to reteach or extend a concept, the next most critical element of how effective middle school science teachers used this phase of instruction was that they used specific data to set learning goals for specific sets of students. Though teachers made many informal observations throughout the sense-making process (see the gathering data section under best practices assessment phase), teachers seemed to make special use of formal observations to select and target students for reteaching and extending. Fred’s digitally based remediation used testing data to target specific students for specific learning objectives since he had organized his assessments and corresponding website resources (Appendix J, Teaching Artifact #12) according to content standard (Observations #1-4). Teachers like Brad and George discussed targeting students for reteaching on specific learning objectives using data gathered
from recent quizzes or tests. Brad in particular made explicit mention of how test scores influence what students he selects for tier two, reteaching students before having them retake the assessment. Brad explained the process:

I gave them their answer sheet back, and I gave them the quiz, and I had them correct it. But am I going to give you points for it? No. I want you to see first of all what you did wrong, but I’ll give you the quiz retake form if you want to retake another quiz or test. But you got to study first and prove to me you’ve actually put forth the effort in studying, and you have to answer some reflection questions. But then I’ll give them full credit for that quiz that they retake. (Interview)

I found Brad’s attitude towards reteaching closely matched George’s, who explained that his grading system was based solely on mastery rather than a system that gave credit for completion (Interview). By requiring his students to correct the assessment they did poorly on and reflect on it, proving to Brad they were more prepared, he ensured that students are mastering the concept through this process of reteaching rather than simply memorizing answers.

Beyond the most formal assessments like quizzes and tests, teachers also used other assessment data to select students for reteaching. Elise talked about her “checkpoint” (Interview) data she gathers by pulling students away from one activity to complete another with her so she can clearly identify their level of understanding, like she did with students as they sorted flash cards related to organelles and their functions (Observation #3). She explained the checkpoints, “And I tend to do them every couple weeks. I do checkpoints where I can just check up on their learning to make sure that they are understanding it, and if they’re not, then I remediate during their [tier two] time” (Interview). Christine spoke in general terms about the data she used to select students, explaining that she had developed her instructional goals to include a “focus on
where kids are missing learning, like standards they didn’t understand and identifying those kids and pulling particular kids to work on those particular items with them” (Interview). Though without the reflective element that Brad’s system had, Henry’s grade recovery center provided the opportunity for him to glance through his gradebook, noting any failing or missing grades, and immediately give students time to work on those particular assignments (Observations #3-4). This was a proactive approach to working with students who could be expected to develop a learning gap if not given another opportunity at the instruction and/or activity. Whatever assessment data teachers chose to use, teachers were especially efficient during this phase as they identified specific learning objectives to reteach to selected students.

**Scope of differentiation.** In the reteaching/extending phase of instruction, most teachers generally targeted specific individuals and small groups of students organized according to their shared learning needs. Alice stood out as a disconfirming case, relying instead on a system of reteaching for the whole class through the delivery and review of her daily oral quizzes. Teachers arranged this phase this way in order to reteach/extend certain learning objectives for a concept for specific students.

**Small groups.** Teachers differentiated the reteaching/extending phase of instruction by grouping students heterogeneously and homogeneously to either provide a degree of support from students’ peers in the heterogeneous arrangement or to gather students of similar readiness levels to target particular learning objectives. Diana, Elise, George, and Henry grouped students heterogeneously during tier one (Interviews) so that high achieving students could act as leaders for mixed ability groups, reinforcing directions and instruction as cooperative groups worked through sense-making activities or labs. Fred invited high achieving students for his own specially designed tier two, taking the opportunity of half days and some Saturdays to work with
lower achieving students while providing his own scaffolding along with that provided by students’ peers (Interview).

Other times, teachers focused on homogeneous groups (typically during tier two) to reteach a concept using a single method designed for a group of similar learning needs. Christine and Diana mentioned pulling in only their highest achieving students to extend on concepts (Interviews), and, along with Elise and George, brought in students struggling to master a concept to reteach it with another type of input or a different sense-making activity (Interviews). Elise explained that she even sometimes pulled in an entire class when, based on her informal and/or formal assessments, the students did not demonstrate that they had reached the learning goal. She explained, “I’ll say I need to see my fifth period because they just didn’t get this,” (Interview).

Individualization. Teachers also differentiated the reteaching/extending phase according to the needs of specific individual students. Teachers like Brad, Christine, and Diana arranged their tier one class time so that some specific students who struggled to keep up with the normal flow of instruction could have a higher achieving partner for the day to relay directions and bits of instruction to help them keep up (Interviews). This kind of immediate repetition or reinforcement made possible by a helpful peer could also help a teacher maintain a degree of instructional rhythm rather than frequently pausing to check with an individual student. As Diana pointed out, “when they’re working with someone, they would choose to ask that person rather than ask me for help. Whereas, if they’re working by themselves, it’d be constant hand up, ‘I don’t get it. I don’t get it’” (Interview). The method is discreet and might even be preferable for some students who might be embarrassed to ask the teacher frequent questions (Interview with Elise).
Fred’s system of differentiating reteaching for individuals was unique. How a student was retaught a concept was dependent on their test scores (Observations #1 & 3), and so the instruction and activities Fred assigned to them could be individualized as students progressed through predetermined tracks on his website. At certain junctions during those tracks, students would receive feedback from Fred after sending him digital activities like BrainPop quizzes or completing his own online assignments (Observations #2-4). Fred used some of his tier one time to provide this kind of remediation, possible because of the immediacy of his use of classroom technology.

Teachers also used tier two to pull in handpicked students. Brad, George, and Henry all talked about selecting individual students according to scores on recent assessments or classwork grades. Henry mentioned pulling in certain students for make-up work (Interviews). Diana devoted a section of her board to listing the names of students she expected to see during her school’s tier two (Observations #1-4).

**Contextual factors influencing reteaching/extending.** The primary factor influencing how effective middle school science teachers retaught or extended on a concept appeared to be the organization of their schools’ tier two programs. Though, since teachers differentiated this reteaching/extending phase so thoroughly by selecting students for certain learning objectives, it was also in some degree influenced by the students themselves.

**Tier two organization.** How a school organized tier two influenced how teachers utilized that instructional time to reteach and/or extend a concept. It is important to point out that not all teachers relied on tier two instruction equally. From the interviews with Brad, Christine, Diana, George, and Henry, I gathered that each used the daily tier two instructional period to pull specifically identified students. This kind of flexibility is possible when a school organizes tier
two in such a way that teachers are able to select small groups from a larger pool of students. Students could be designated for smaller tier two groups by being given a pass for that day to report to a specific teacher or by being included in a rotational system. Brad, Christine, and Diana’s school seemed to fit that description, as each made mention of pulling specific groups of kids (Interviews with Brad and Christine, Observations #1-4 with Diana). Diana explained about her pull-list, “We each get our priority day, so that helps a lot with [tier two] to make sure they’re not falling behind” (Interview). Deductively, this reveals that each of the five core subjects was given a day to be the top priority class, allowing teachers from all subjects to see the students they most needed to reteach and/or extend at least once a week on their “priority day.” Christine made an open invitation to one class period I observed, welcoming any students who wanted extra study time for the upcoming test (Observation #4), possibly revealing that all teachers could pull students on any day unless a student had already been selected by the priority subject. Elise’s school appeared to be organized so that students could be selected out of rotating study halls (Interview). George and Henry explained that their school was piloting the school district’s RTI program that includes identifying students for remediation on particular learning objectives, though neither specifically addressed how that program influenced the students they saw during that class period. George only mentioned that he worked with a smaller group during RTI to fill in learning gaps for selected students (Interview). Henry did not emphasize the program during the observations and interview, but that could be due to his use of a grade recovery center that allowed him to regularly check students’ grades and help them stay current with learning objectives (Interview). Similarly, Alice and Fred developed systems of reteaching during tier one that made tier two somewhat less relevant, such as Fred’s website-based remediation determined by assessments organized according to content standard (Observations
#2 & 4) and Alice’s habit of reinforcing her learning objectives at the end of that class period and connecting them to subsequent lessons (Observations #1-4).

**The influence of the students.** Students influenced how teachers retaught according to their level of achievement on a learning objective. Therefore, individual students, sometimes grouped according to similar learning needs, made up the micro level conditions that affect how teachers utilize this phase of instruction. As this was the most differentiated phase, much of what teachers did in terms of providing reinforcing instruction and activities (in addition to different levels of support to coach students through that process) was dependent on the data teachers gathered informally and formally during normal class time. Teachers used testing data from the previous year (Interview with George), recent grades (Interviews with Brad and Henry, Observations #2 & 4 with Fred), formative assessment data gathering in a single class (Interviews with Alice and Elise), and even informal observations (Interview with Elise) as determining factors to identify students for reteaching as well as what kind of instruction and/or activities might benefit them (see also the using data section in the differentiated section of the reteaching/extending phase). For example, Henry created a grade recovery center as a direct response to his students’ levels of achievement (Observations #3-4). Alice reviewed her daily learning objective by going over the answers to a brief oral quiz at the end of each class period and then restated that objective during the next lesson to tie concepts together within a unit (Observations #1-4). In this way, she could proactively scaffold how a student builds knowledge about a concept rather than waiting until that student proved that he or she does not understand a concept by failing a test. Though only certain students may truly need that reteaching time to master a concept, she provided it to everyone, showing similarities with Fred and George’s views on offering instructional accommodations to all students even though they may have been
originally designed for specific individuals (Interviews). Reteaching, as demonstrated by the teachers in this study, is by its very nature defined according to students’ progress toward a learning goal. Though each teacher had a somewhat unique system of reteaching, each teacher utilized it in such a way as to support his or her systems and styles of pedagogy as he or she gathered data about student learning and responded to it.

Summary

In this chapter, I have described how effective middle school science teachers differentiated the best teaching practices they employed according to the four phases of instruction: planning, teaching, assessing, and reteaching/extending. Not all phases are differentiated equally, with reteaching/extending standing out as the most differentiated according to this study’s data and assessing the least differentiated. As teachers progressed through this back-and-forth flow of instruction, they generally narrowed the intended scope of their differentiating strategies from the characteristics of middle school students as a whole during the planning phase to adapting instruction and activities for reteaching/extending based on assessment data for individual students.

Research Aim

The aim of this research was to develop a model describing how and to what degree effective middle school science teachers differentiate their best practices teaching. To that end, I conducted a grounded theory qualitative study to develop that model from data collected from observing, interviewing, surveying, and collecting teaching artifacts from eight science teachers in a suburban school district in the Southern United States who have scored the highest rating on the teacher effectiveness, or value-added, measure of their evaluations at least once in the past three years. The model that emerged from that data (see Figure 9) was organized according to
four phases of instruction, *planning, teaching, assessing,* and *reteaching/extending,* and showed the major themes from both teachers’ best teaching practices and elements of differentiation at each phase. The model was developed from the synthesis of the study’s research questions.
Figure 9. Model of differentiating best teaching practices in science. This figure represents how and to what degree effective middle school science teachers differentiate their instruction. The more transparent the blue best practices box, the more differentiated that phase of teaching appeared to be. The blue rings represent teachers’ intended scope for differentiation.
Research Question 1

This study’s first research question asked what best teaching practices do effective middle school science teachers employ. The major themes of those practices appear in the blue boxes in Figure 9 above. The most obvious and significant of these themes was that teachers focused on specific content standards, designing a variety of instructional inputs and sense-making activities to communicate those standards.

During planning, teachers started with a big idea, the learning objective contained within the state-mandated standard, and then focused on the best ways to present that idea. This included finding ways to connect the idea with others that had already been taught or ones that would be taught later. Teachers’ plans for instruction were delivered efficiently because of the purposeful setup of the learning environment, including seating arrangements conducive to teachers’ involvement so that they were able to provide immediate and constructive support to students. Also, teachers developed their own unique classroom management systems that engaged students and used well-established routines to maximize instructional time. While teaching, teachers consciously used multiple inputs for presenting the big idea and then followed with a blend of individual and cooperative activities designed to help students make sense of the idea. These activities were arranged so as to move from simple ideas to more complex understandings and applications as the teacher modeled how to think through the concept. Throughout these activities, teachers constantly were involved with students’ work, using every interaction as a formative assessment (informal ones like conversations with students and more formal ones like students turning in an assignment) to gauge student understanding that could influence the next step in walking students through the big idea. Finally, teachers reinforced their high expectations by repetitively communicating to students what they should know and
how they would be expected to show it. Reteaching and/or extending time either built into the school schedule or inherent within a teacher’s pedagogical style gave them an opportunity to focus instruction on small groups or individual students after the initial round of teaching to either help students achieve mastery or to extend on other applications of the big idea.

**Research Question 2**

The study’s second research question asked how effective middle school science teachers’ best practices reflected DI principles. The major elements of teachers’ differentiation can be found in the green boxes of Figure 9 above. Each teacher in this study showed some degree of influence from the model of DI, particularly in creating different kinds of learning activities (see Figure 10) designed to accommodate different ways to understand a concept.

While planning, teachers took into account the diversity of students’ readiness levels and preferred methods for learning to offer a variety of resources. Building student engagement by connecting with students through relating content to personal experiences was important to draw students into the learning process. In the *teaching* phase, teachers explained that they used different kinds of activities based on different learning styles or preferences to account for the different ways students might think through the concept. Teachers would sometimes modify these activities for groups or individuals so that they would work at a level the teachers perceived as within reach but complex enough to push students beyond their current level of understanding.
Figure 10. Differentiated teaching strategies. This figure shows participants’ responses to the major differentiated teaching strategies identified in the literature.
Teachers were very involved with students during learning activities so as to scaffold students’ understanding and to take advantage of brief one-on-one teaching moments. During assessment, teachers would sometimes plan alternative or modified assessments for a specific group or individual to ensure that the assessment accurately measured student understanding. Finally, teachers used assessment data to select specific students or groups of students for remediation/extension class periods. During this time, teachers could reteach very specific aspects of the content to selected students, finding the best way to reteach the ideas based on teachers’ understandings of the learning needs of the student.

**Research Question 3**

The third research question asked how teachers’ beliefs about the ways students learn can influence how and to what degree they implement DI. Each teacher expressed that students learn in different ways. Therefore, they developed multiple ways to teach a single learning objective. This basic ideology leads to significant adaptations in how teachers presented content and developed activities for students to master it. Teachers spoke of having a base set of activities that they used for each content standard so that students could typically see, hear, and physically interact with every important idea. Once content had been presented and students had completed learning activities, teachers used assessment data (both informal and formal) to guide the last steps towards students mastering the content. At times, this meant specific pieces of information were reviewed as a whole class, and other times, it meant spending time after a formal assessment to reteach material to specific students.
Research Question 4

The fourth research question focused on the influential factors on effective middle school science teachers’ implementations of DI, including students’ socioeconomic status and the availability of resources at a teacher’s school. There was a direct connection between teachers’ articulation of how their students learned best and how they planned for/delivered lessons. Teachers viewed students both in terms of the general characteristics of young adolescents and of specific characteristics teachers learned about their set of students. For example, teachers in the lower socioeconomic schools explained how much they emphasized vocabulary (Interview with Diana, Interview with George, Observation #1 with Henry). In Diana and George’s case, they explained how they had led lower achieving students to high gains but found less gains in the higher achieving students (Interviews). In contrast, teachers in the relatively higher socioeconomic schools spoke of the importance of critical thinking and showed scores reflecting that they led higher achieving students to high gains (Interviews with Fred and Elise).

Teachers often reflected that the personal experiences of their students were an avenue to communicate content in a meaningful way (Interviews with Alice, Christine, Elise, George, and Henry), revealing that a teacher’s understanding of his or her students is a critical component of adapting teaching to maximize learning. Teachers were generally satisfied with the level of resources they had, completely utilizing the variety that was available to them such as mobile computer labs, online resources, and classroom presentation tools to present content in multiple ways and deliver a variety of activities. However, two teachers stated they could increase that variety with more resources like computers for research-based activities and lab equipment (Interviews with Alice and Henry).
Research Question 5

The last research question asked about any other factors that might influence how an effective middle school science teacher implements DI. The most obvious influence from a factor outside the context of the students or the resources in a teacher’s classroom came from how a teacher’s school implemented the American Co. policy of a remediation/enrichment class period, commonly referred to as tier two (as the district prepares for a full implementation of RTI the next year). Each school had a somewhat different system for that period’s schedule, and therefore teachers’ strategies for selecting students and providing instruction differed. In some cases, such as Alice and Fred, teachers did not seem to rely heavily on tier two for reteaching and/or extending instruction, instead developing their own system for building that phase of instruction into normal class time. Other teachers like Christine, Diana, Elise, George, and Henry discussed specific strategies for selecting students for enrichment or remediation on specific learning objectives. In every case, teachers retaught and/or extended instruction to provide targeted instruction on specific learning objectives. This support proved to be one of teachers’ most significant strategies for differentiating instruction.

Synthesis of the Research Questions

I constructed a multifaceted model of effective middle school science teaching from the data gathered during this study. During the planning phase, teachers focus on the big idea contained in a content standard, consider how best to communicate that idea, and connect it to other related concepts in their curriculum all within classroom management systems that maximize instructional time. Teachers differentiated those best practices by recognizing that different students will learn the big idea in different ways and therefore plan for a variety of resources to meet those learning needs while also engaging students with the content and with
supports built in to the learning environment. Teachers’ differentiating strategies during the
*planning* phase took into account broad student characteristics to help teachers “because you’re trying to reach as many kids as you can at one time” (Interview with George).

During the *teaching* phase, teachers delivered instruction using multiple inputs like lecture, video clips, different types of texts, and demonstrations to give students the information necessary to make sense of the content through a variety of activities that build in complexity. During instruction and activities, teachers often modeled thinking skills to guide students through the learning process. Teachers differentiated those best practices by targeting instruction to students’ readiness levels and intentionally including different kinds of activities to reach the different ways students understand content. As students received instruction and complete the sense-making activities, effective middle school science teachers are constantly active to scaffold students’ learning. The scope of differentiation started similarly to the *planning* phase as teachers considered the learning needs of their middle school students as a whole but began to narrow as teachers adapted their teaching as a response to their specific set of students and individual classes.

During the *assessment* phase, frequent informal and formal assessments provided teachers with data that they used to inform future instructional decisions. Teachers sometimes differentiated the format of those assessments, or modified the assessment all together, as a response to some students’ unique learning needs. Though this was the least differentiated phase of instruction, teachers still gave some consideration to groups of students with similar learning needs and even sometimes individuals as they adapted assessments to be as authentic as possible, measuring students’ understanding in a way that reflected what a student understood about the concept rather than his or her ability to take a certain type of test.
The last stage of instruction, *re-teaching/extending*, revealed how effective middle school science teachers reinforced their expectations for learning, using repetition to emphasize the details of a concept as the instruction become increasingly more specific to students’ zones of proximal development. Teachers uncovered the most appropriate level of instruction through their frequent formative assessments during the previous phase of instruction. Differentiation in this phase was very strategic. Effective middle school science teachers offered different levels of support according to their understanding of students’ needs. Teachers grouped students heterogeneously to provide opportunities for higher achieving students to scaffold their lower achieving peers and also grouped students homogeneously to deliver the most appropriate level of work for students with similar readiness levels. As teachers provided different levels of support during individual and cooperative re-teaching/extending, they used assessment data to target specific learning objectives for specific sets of students. Teachers used systems of support during normal classroom time or by taking advantage of their schools’ system of a remediation or enrichment class period.

Collectively, the data from the study provided the pieces from which I developed a picture of the complex, organic process of teaching middle school students using elements of differentiated instruction to strengthen and reinforce best teaching practices for science. No single strategy or idea encapsulated the entire process, but effective middle school science teachers do share many philosophical and pedagogical similarities, capitalizing on their own personal strengths within some general principles of effective instruction.
CHAPTER FIVE: DISCUSSION

In this chapter, I summarize the findings of the study’s data and how I analyzed it to develop the model that describes how and to what degree effective middle school science teachers differentiate their instruction. Then, I examine this study’s findings in relationship to relevant literature before suggesting the implications of the model. Finally, I discuss the study’s limitations and recommend avenues for further research.

Summary of the Findings

The purpose of this study was to develop a model describing how and to what degree effective middle school science teachers differentiated their best teaching practices (see Figure 11). The model was built from observational, interview, survey, and teaching artifact data from eight teachers who have scored at the highest level on the teaching effectiveness, or value-added, measure of their teaching evaluations at least once in the past three years. Through the course of data collection and its analysis, the findings suggest that teachers demonstrated a number of best teaching practices, differentiating particular elements to adapt those methods for their specific set of students. To describe teachers’ instructional practices, I broke instruction down into four parts—planning, teaching, assessing, and reteaching/extending. Each phase was distinct according to the themes of best practices and differentiation that the eight participants utilized, the degree to which the phase was differentiated, and with respect to the scope of factors that influenced how the phase was differentiated. The model reveals that effective middle school science teachers reflect selected portions of the ideology and strategies of the DI model.
Figure 11. Model of differentiating best teaching practices in science. This figure represents how and to what degree effective middle school science teachers differentiate their instruction. The more transparent the blue best practices box, the more differentiated that phase of teaching appeared to be. The blue rings represent teachers’ intended scope for differentiation.
In particular, the study’s participants expressed that students learn in different ways and therefore offered a variety of ways to access and receive instruction, provided different ways of processing new information through a blend of independent and cooperative sense-making activities, and used informal and formal assessment data to inform future instructional decisions.

**Discussion**

The findings of this study suggest an overlap with elements of the best teaching practices for science and portions of the DI model. However, there were aspects of each that were conspicuously absent from this study’s data bringing into question their value in light of an evaluation system that relies on a value-added score measured from one high-stakes multiple choice test. The model developed in this study extended the research on the best teaching practices in science and examined the value of differentiating those practices to help teachers achieve the highest marks on the teacher effectiveness component of their evaluations.

**Best Practices**

The study’s participants confirmed many of the tenets of best teaching practices for science advanced by the literature. Teachers’ philosophies of learning and the pedagogy that resulted showed evidence of the constructivist-natured best practices literature. They also developed learning environments that confirmed specific elements of the type of classroom, including qualities of the teacher most conducive to efficient and highly motivated learning (Banilower et al., 2010; Miller, 2011). Finally, they discussed and demonstrated a number of instructional strategies recommended by the literature of best practices for science.

**Evidence of constructivism.** The learning philosophies and teaching strategies teachers demonstrated through the course of this study revealed some match with a constructivist view of learning. The literature emphasizes how learners should be active during the learning process.
(Miller, 2011) as students take new information and apply it to the world they know (Kellough & Kellough, 2008). In order to actively engage students in the learning process, teachers bridge students’ prior knowledge with the new information, creating a temporary state of disequilibrium where students then are motivated to pursue the connections between what they already know and the new piece of knowledge (Lederman, 1999; NRC, 2005; Staver, 2005).

The planning phase of instruction revealed how the teachers in this study reflected those ideas as they planned for ways to connect students’ experiences, the teacher’s own experiences, and real world examples to a concept as the starting point for instruction. Teachers used strategies like traditional pretests, anticipation guides, KWL charts, and even simply questions during interactive lectures (Herrenkohl et al., 2011) to begin connecting students to the concept by tapping into their prior knowledge. This helped establish the relevance of the learning objective (Parkay et al., 2010) especially in the context of how it applies to “real life” (NSTA, 2003a). It also helped teachers identify students’ misconceptions (Banilower et al., 2010). These connections, a hallmark of constructivist learning theory, were the starting point for teachers’ initial instruction.

**Sense-making.** While the specific activities teachers used during the teaching phase are discussed in a following section, the chronology of instruction teachers used in this study revealed how, once the connections were made with students and the content, sense-making activities were used to provide ample time for students to interact with new information to establish it into their existing knowledge, consistent with constructivism. As students completed a number of sense-making activities related to a single concept, they were able to reflect on what they had learned and revise their preconceptions (NRC, 2005; Staver, 2005). Teachers in this study showed how the ebb and flow of this process worked, delivering instruction, providing
activities for students to organize their understanding of the instruction, and then repeating this process as necessary depending on the complexity of the topic and if they retaught/extended on the concept.

**Zone of proximal development (ZPD).** Though teachers planned with a central focus on the required content standard and the best way to communicate that content, teachers did consider the varying readiness levels, or zones of proximal development, of their students when planning instruction and activities. Staver (2005) recommended pretests, questions of varying degrees of complexity, and concrete learning experiences to ensure that teaching is developmentally appropriate, and teachers in this study certainly used those strategies. Teachers demonstrated several ways to preassess students such as formal pretests, anticipation guides, KWL charts, and informal questioning during instruction. Several teachers explicitly mentioned using questions of different difficulties both within a single class and among the various readiness levels of a teacher’s set of class periods. Concrete learning experiences included kinesthetic methods for teaching vocabulary or to introduce a concept along with a wealth of visual elements to support instruction and activities. Extending what has been said in the literature on best practices science teaching and the zone of proximal development, teachers stayed involved throughout the learning process. Teachers built in supports and scaffolded students as they worked through sense-making activities. Teachers offered a variety of resources (sometimes digitally) and arranged for peer tutoring sessions to ensure that students had access to help so they could complete work just beyond their individual capabilities (Shabni et al., 2010; Staver, 2005).

**Inquiry.** One of the most intriguing aspects of the data collected from this study was how insignificant a role inquiry, a decidedly constructivist strategy, played in effective middle
school science teachers’ pedagogies. Much of the best practices literature in science focuses on the importance of inquiry as a central mode for teaching new content (NRC, 2005), a way to demonstrate the dynamic nature of scientific knowledge (Banilower et al., 2010), to mimic the real world community of scientists (Herrenkohl et al., 2011), and to share and discuss evidence and alternate explanations to build scientific literacy (NRC, 2005). The NSTA (2003b) recommends that at least 80% of instructional time should be used in laboratory investigations. However, in 32 observations of eight teachers who scored the highest marks on their teaching effect scores, I did not observe a single lab investigation requiring students to gather data, analyze it, and draw a conclusion. Some teachers talked about the benefits of inquiry during their interviews, but the consensus of the eight teachers was that when they choose inquiry, it was typically as a large project delivered once every major unit, or once every quarter.

Effective middle school science teachers did not rely on inquiry, in contrast to the literature, as a significant way to engage students in learning about science for several reasons. First, several teachers expressed concerns over the amount of time it takes for students to complete an inquiry-based activity. This concern was amplified when teachers considered the scope and sequence of their curricula, worrying that open-ended activities were not specific enough to focus on the content standards they were required to teach or developmentally appropriate for their middle school students. Teachers began the planning stage of instruction by focusing on the big ideas of the concept included within the required content standards. With those learning objectives in mind and with the pressure of evaluation scores that measured how well students mastered those learning objectives, teachers developed pedagogies that were direct and focused on what students were required to know. Open-ended inquiry, however recommended (NSTA, 2003b) to build scientific literacy (NRC, 2005), may not lead students to
the knowledge of the content that will be on the high-stakes test. In this way, teachers in this study defined the limits of constructivist learning theory in light of teacher evaluation scores. It is good for students to actively engage in the learning process, asking questions and reflecting on what they are learning, but being too open-ended with instruction means there is less time to concentrate on required content standards. Teachers used inquiry-based lessons only when they can be designed to focus solely on the concepts of a content standard. Otherwise, teachers found more efficient ways to deliver instruction and create sense-making opportunities.

**Instructional strategies.** Participants’ instructional strategies were the product of their philosophy of learning (Parkay et al., 2010). Participants discussed and demonstrated several key elements delineated by the literature of what constitutes the best strategies for science such as using multiple and varied instructional inputs (Brophy, 2000; Kellough & Kellough, 2008; Palincsar et al, 2001), blending independent and cooperative work (NSTA, 2003b), modeling (Brophy, 2000; Radcliffe et al., 2004), and strategically assessing students (Brophy, 2000; NSTA, 2003b).

**Multiple and varied instructional inputs.** Teachers demonstrated consistency with the literature recommending a mixture of the modalities and types of instruction (Brophy, 2000; Kellough & Kellough, 2008; Palincsar et al., 2001) to provide multiple experiences leading to the same conceptual conclusions (Parkay et al., 2010). Teachers in this study delivered instruction directly with the help of multimedia, demonstrations, and student presentations. In particular, the observations in this study showed how effective middle school science teachers rely on direct instruction to communicate exactly what students should understand and be able to do with the new knowledge, thus setting clear expectations and eliminating confusion (Upadhyay & DeFranco, 2008). Teachers used the opportunity afforded by direct instruction to cognitively
model concepts, a strength of direct instruction (Kirschner et al., 2006) especially when teaching new vocabulary and test-taking skills. Teachers also built supports into direct instruction such as guided notes, graphic organizers, and illustrations proved to be ways that teachers could scaffold students’ understanding of a concept consistent with the recommendations of the NSTA for supporting students’ learning (2003b). The supported direct instruction used by teachers in this study often followed the structure of their textbooks and gave teachers the opportunity to model an understanding of the concept rather than relying on students to obtain it through reading alone that is consistent with the literature’s emphasis on the importance of modeling with reading (Radcliffe et al., 2004). Five teachers discussed or demonstrated how they included students reading from their books as one input for instruction, but each also used direct instruction to provide that modeling of how students should think through a concept. This explicit guidance has been shown to contribute to student learning (Kirschner et al., 2006; Parkay et al., 2010).

**Sense-making activities.** Teachers used a variety of increasingly complex sense-making activities. First, teachers planned activities with a clearly defined purpose (Thurlow et al., 2008). Teachers in this study demonstrated that importance, explaining the purpose of specific activities and even communicating the broader curricular goals of a particular concept.

**Variety.** With the purpose giving students a sort of frame for the activity, the literature recommends a variety of developmentally appropriate activities, blending independent and cooperative elements (NSTA, 2003b) designed for different learning needs (Brophy, 2000; Kellough & Kellough, 2008; Palincsar, 2001). One recommended strategy is the use of hands-on activities (NSTA, 2003b; Thurlow et al., 2008). Teachers confirmed this recommendation, demonstrating ways to incorporate hands-on elements to activities. The literature also recommends that teachers use several structures to organize cooperative activities (Kagan, 1989)
that also promote important social skills like individual accountability within a larger interdependent group (Kose et al., 2010). Teachers reflected these cooperative best practices as they grouped students for peer tutoring, to make predictions in upcoming instruction, to reflect on questions, to complete jigsaw activities, and to conduct research. Teachers also blended cooperative activities with independent ones, such as drawings, writing stories, developing graphic organizers, designing posters, and completing digital assignments, reflecting a mixture consistent with the NSTA’s (2003b) suggestion.

**Modeling sense-making.** As students work through sense-making activities, Brophy (2000) emphasizes the importance of leading questions to scaffold students’ understanding of a concept. Teachers in this study used passive and active methods of scaffolding to provide a model of how students should think about a concept. Passively, teachers modeled students’ understanding by using a number of supports during instruction such as note-taking guides, illustrations, and graphic organizers to help students structure and visualize the concept. Teachers also provided resources like references to the textbook or online media to act as models for instruction or activities. Actively, teachers modeled and scaffolded students’ learning by staying in proximity with students as they worked, moving among them to check on their progress, answer questions, and ask the leading questions Brophy (2000) recommends. Teachers also modeled thinking strategies for the whole class, especially as they showed students kinesthetic or visual ways to understand important vocabulary.

**Strategic assessment.** The literature suggests that assessment should be frequent and include informal and formal aspects (Brophy, 2000; NSTA, 2003b). In this way, teachers can identify weak points or details students are not understanding in order to make adjustments to their plans and learning objectives (Brophy, 2000). Informally, this study’s teachers took
advantage of their proximity to students during the sense-making progress to check frequently on students’ progress on an activity and their understanding of the concept the activity was designed for. These informal assessments could be measured individually as teachers walked among their students as they worked, asking questions along the way, and as a whole group such as when teachers reviewed activities or homework assignments with the whole class. Informal assessments also provided teachers an avenue for delivering immediate and constructive feedback, making larger adjustments to their plans unnecessary because of the on-the-spot scaffolding that brought students back on track to master a learning objective. Formally, I observed daily oral quizzes, short constructed response assessments, and longer multiple-choice tests all aimed at gathering data on students’ understanding of specific concepts and content standards. Teachers not only confirmed how significant making frequent informal and formal assessments are to student learning, but they also demonstrated a wealth of strategies for carrying out assessments.

Learning environment. The aforementioned instruction and activities contribute to student learning, but they are made efficient and most effective in a learning environment that is grounded on high expectations, facilitates students’ emotional well-being, is organized, and led by a teacher possessing certain critical qualities like content knowledge (Banilower et al., 2010), pedagogical content knowledge (Lee et al., 2007), and a degree of self-efficacy (Staver, 2005).

High expectations. The literature proposes that student achievement is in part affected by the teachers’ communication of high expectations (Brophy, 2000) supported by the idea that all students can learn (Staver, 2005). The teacher and the student both bear some responsibility, as the teacher provides support through scaffolding during developmentally appropriate tasks (Brophy, 2000; Staver, 2005). The teachers in this study showed strong examples of providing
that support to students during a variety of tasks, reinforcing their high expectations for learning by communicating what students should be able to complete and know by the end of an activity, lesson, and/or unit. Teachers confirmed that high expectations contribute to students’ achievement as they communicated high expectations when setting up activities so students know what they should gain from it or when reviewing assessments so students know what they are expected to understand about a concept. Teachers set their high expectations by designing remediation activities for students scoring below expectations and prompting students as they worked about what was expected of them.

**Emotional safety.** High expectations are best delivered in the context of an emotionally safe classroom environment. To meet students’ needs at the bottom of Maslow’s (1987) hierarchy like physical safety, feelings of belonging, and self-esteem, teachers should communicate to their students that they care by getting to know them and building rapport (Brophy, 2000). Participants provided examples of how these kinds of relationships are developed and then maintained according to a teacher’s unique personality. Teachers built rapport as they got to know their students, joking with them about mundane tasks, using students’ names in examples, and connecting content to students by showing them how a concept related to their interests. Other teachers took advantage of students’ interests and learned as a relationship with them was developed to provide examples or connections with a learning objective. Though unique to their personality, every teacher in the study reflected the idea that relationships built on caring and respect are a significant part of an effective middle school science learning environment.

**Classroom management.** With a caring and positive learning environment established, the best practices literature asserts that an efficient use of time and resources is indicative of
student achievement (Marzano & Marzano, 2003) as time spent progressing towards the learning objective is maximized (Brophy, 2000). Teachers displayed this level of efficiency in several ways. First, teachers used organizational routines to maximize instructional time. Next, teachers created fluidity in their curricula as they seamlessly transitioned between lessons to maintain students’ focus on learning objectives. Additionally, teachers sometimes gave students roles in managing certain aspects of class to make teaching more efficient, thereby creating a culture of shared responsibility and setting expectations for how to appropriately work together—both of which are recommended by the literature (Brophy, 2000; Kellough & Kellough, 2008; NRC, 2005).

**Qualities of an effective science teacher.** The teacher plays a critical role in creating and maintaining the kind of engaging, motivating learning environment that produces high levels of student achievement (Banilower et al., 2010). Specifically, teachers must be able to engage students intellectually (Brophy, 2000; Palincsar et al., 2001) and select the most appropriate resources for instruction and activities to best communicate a concept (Banilower et al., 2010). Content knowledge (Banilower et al., 2010) and pedagogical content knowledge (Lee et al., 2007) are also important qualities for a teacher to effectively communicate content as well as the self-efficacy he or she reflects to his or her students

**The ability to engage.** The best practices literature proposes that teachers need to be powerful communicators of the concepts they teach, possessing the ability to connect a concept to students’ lives and teaching them when and how the concept applies (Brophy, 2000; Palincsar et al., 2001) through a strategic use of instruction and activities selected specifically for how students will think through the concept as opposed to novel, extrinsically motivating methods for presenting new information (Banilower et al., 2010). This study’s teachers reflected these
qualities through their styles of supported direct instruction as they provided supports like note-taking guides and graphic organizers designed for helping students think through a particular concept and also giving real world examples or telling stories to relate a concept to students’ lives (Brophy, 2000; Palincsar et al., 2001). Participants engaged their students by constantly staying involved in their learning and scaffolding them through the series of sense-making activities they had developed for that unit (Banilower et al., 2010). Additionally, teachers developed engaging learning environments by including interesting elements like full-size skeletons, class pets, and relevant technology like iPads and laptops to use as reference tools and examples during applicable lessons matching the recommendation of the literature to connect concepts to students’ lives (Brophy, 2000; Palincsar et al., 2001). Teachers also found ways to excite students about showing what they have learned, using kinesthetic games and music to engage students through communication tools that are relevant for young adolescents (Brophy, 2000; Palincsar et al., 2001). This study’s teachers showed specific ways to engage students intellectually but also to get them interested and excited about their learning with methods that were suited especially to young adolescents.

Content knowledge and pedagogical content knowledge. In order to teach effectively, teachers must know what they are teaching and how best to teach it. The more a teacher understands the concept he or she is teaching, the more prepared he or she is for fielding questions, finding different ways to explain the concept, and posing questions to get students to think through the concept (Banilower et al., 2010). Moreover, helping students approach questions scientifically and yet still be able to apply them to their lives is a skill that can be difficult for new teachers but is an important part of pedagogical content knowledge that is built on communicating a concept in such a way that encourages inquiry and application (Lee et al.,
2007; NSTA, 2003b). Though the teachers in this study had a wide range of experience, even the least experienced teachers talked about how they reflect on their lessons, continually finding new strategies, examples, and assessments that best communicate a concept to their specific set of students. Emphasizing true scientific inquiry was not an integral component for participants, but each did encourage questions, especially those that made application to students’ own lives. Rather than encourage students to develop their own investigations to answer their questions, teachers preferred to simply answer students’ application questions. It may not encourage inquiry, but this strategy was efficient for maximizing instructional time.

Self-efficacy. A teacher’s self-efficacy is a model of high expectations, reflecting a teacher’s belief in his or her own effectiveness and holding him or herself accountable to be effective (Staver, 2005). Since this is an intensely personal quality that is not necessarily apparent through an observation of a teacher, it can be difficult to meaningfully measure a teacher’s self-efficacy. However, several teachers (interestingly, since they are all from the same school) expressed their track record of leading students to learning gains according to the teacher effect evaluation measure during their interviews with one even discussing how she told students and their parents about the score. These teachers held themselves accountable to that high standard of teaching. Even teachers who had seen their effectiveness scores recently decline discussed trying new teaching strategies and gathering new resources with the help other teachers also dedicated to the same goal of improving their students’ levels of achievement, demonstrating the level of effectiveness they are committed to and expect from themselves.

Differentiating the Best Practices

The study’s teachers demonstrated and discussed a number of ways their philosophies of learning and pedagogy reflect the model of DI. Though in different degrees, teachers
differentiated their best teaching practices or reflected the theory behind DI during the four phases of instruction. However, they did not always differentiate in a manner consistent with Tomlinson’s (1999, 2001) model, instead picking and choosing methods strategically and practically. The following sections compare teachers’ beliefs and differentiating strategies to Tomlinson’s (1999, 2001) four domains of DI: content, process, product, and learning environment. Then, I compare how teachers differentiated according to the three characteristics which Tomlinson (1999, 2001) suggests adaptations should be based on: readiness, interest, and learning profile. In this way, this study’s findings may be situated within the theoretical context of DI and evaluated according to the value of its application through the teaching strategies these effective middle school science teachers used.

**Beliefs about student learning.** Teachers’ beliefs about student learning shared similarities and differences with the model of DI. In common with DI, teachers discussed how they recognized that students learn concepts differently. Showing some contrast to DI, teachers showed some limitations to the effectiveness of differentiating instruction to specifically match individual students to instruction and activities as well as in their mindsets of student learning compared to the fluid mindset recommended in the literature (Sousa & Tomlinson, 2011).

**Students have different levels of readiness.** During the planning phase of instruction, teachers considered the readiness levels of their students, recognizing that not all students started with the same background knowledge or progressed towards mastery of a new concept at the same rate. Therefore, they planned activities and instruction with different degrees of complexity to help match students to the level of instruction. This reflected the emphasis on Vygotsky’s (1978) theoretical construct of the zone of proximal development in the model of DI. Additionally, teachers considered how middle school students in particular learned best, noting
the limits of students’ attention spans, struggles with reading comprehension, ability to respond orally more clearly than in writing, and proclivity for concrete learning experiences. This understanding reveals similarity with the DI model’s reliance on Piaget’s (1954) theory of cognitive stages as teachers planned for ways to deliver instruction and activities that are developmentally appropriate for young adolescents.

*Students learn in different ways.* One of the most obvious similarities between teachers’ beliefs about student learning and the model of DI was a recognition that students learn in different ways. Teachers planned to teach with a variety of instructional inputs and activities, revealing the ways in which they believed their students learn best. The axial code describing teachers’ base sets of activities revealed how teachers planned for different ways that students could understand a concept such as through lecture and discussion, reading, writing, kinesthetically, and visually. Sometimes, this led teachers to offer students choices in how to complete activities. The idea that students learn in different ways and through different types of instruction and activities is consistent with the DI model’s theoretical background that includes Sternberg and Zhang’s (2005) thinking styles and Gardner’s (2011) multiple intelligences (Tomlinson, 1999, 2001).

However, it is important to point out that this study provided contrasting examples of the practical limits of this differentiated belief. On one end of the spectrum, a teacher discussed how he has students that must hear information or turn an idea into a kinesthetic movement to retain it while, on the other end, several teachers expressed how they offer variety but expect students to learn to some degree in those different ways even if they were not a student’s strong area or preferential way of learning. Though participants recognized that learning might be more efficient when instruction or activities match a student’s strength or preference that does not
necessarily mean that a student cannot learn in a particular way. Teachers in this study revealed that this is a point of contention and that both beliefs are compatible with leading students to high achievement gains.

**Students learn at different paces.** Teachers in this study also talked about how students learn at different paces, progressing toward mastery at different rates. Tomlinson’s (2001) model includes the same idea, contending that individual students have different needs when it comes to the pace of instruction, and, therefore, that teachers should adjust the pace to match the needs of their students. Teachers demonstrated practical strategies for doing this as they asked questions of differing degrees of complexity to specific students and even adjusted their plans among their class periods to best meet the needs of that set of students. They also provided some peer supports to help struggling students keep up with the pace set in class.

**The teacher’s mindset.** Drawing on the work of Carl Dweck (2006), the DI model emphasizes the importance of a fluid mindset held by the teacher who believes that all students can learn as long as both teacher and student are willing to work hard enough toward that goal (Sousa & Tomlinson, 2011). Though teachers revealed their high expectations for students in a number of ways (such as reinforcing those learning expectations throughout a unit and setting certain standards for students’ level of achievement), they also revealed how their expectations might be tempered according to their understanding of their students’ capabilities. Teachers discussed how their expectations for students’ quality of work or level of mastery changed according to the student. Teachers reflected the idea that all students can learn, but the extent of mastery would change according to the student given that they completed basically the same set of instructional tasks during normal class time. Teachers also considered the most appropriate instruction and activities that would increase the level of mastery for their lower achieving
students by taking advantage of their school’s tier two intervention program to select specific students for remediation or extra instruction.

**The four domains of DI.** Tomlinson (1999, 2001) categorizes strategies for differentiating into four domains of instruction: content, process, product, and the learning environment. While the findings of this study could have been represented according to those domains, the four stages of planning, teaching, assessing, and reteaching/extending more accurately reflected the process of teaching demonstrated by the effective middle school science teachers in this study. However, for the purposes of comparing the literature on DI to the findings of this study, it is helpful to consider how teachers’ differentiated beliefs and strategies fit into Tomlinson’s (1999, 2001) model. The following sections examine the similarities and differences for each domain that between this study’s findings and Tomlinson’s (1999, 2001) model.

**Content.** Tomlinson’s model of DI includes adapting both the ‘what’ and ‘how’ of teaching. Though the general education teachers I observed did not differentiate the ‘what’, being restricted to the unmodified and required content standards according to the district’s scope and sequence, they showed they might offer class periods different amounts of information that was not strictly essential to an understanding of the required content depending on students’ readiness levels. Teachers expressed that they do not deviate from the required content but rather change the level of support and depth of their teaching according to students’ needs. Though not revealed during the observations or brought up during the interviews, most of this study’s teachers responded on their surveys that they used content-based ‘what’ differentiating strategies like curriculum compacting (75%), mini-lessons (100%), and concept-based teaching (88%).
Teachers revealed similarities to the DI model much more through a differentiation of the ‘how’. Working from a philosophy that students learn in different ways, teachers planned for different kinds of instructional inputs and a variety of activities to encompass several learning modalities just like the model Tomlinson (2001) advocates for, allowing students to approach the content in a preferential way. However, it is interesting to note that teachers did not design these activities with specific students in mind or in order to offer instruction only in ways that students preferred. Rather, teachers used a single approach to daily instruction, but they varied the modalities that would be represented over the course of several lessons in a unit. One simple reflection of this principle was that none of this study’s eight teachers marked on their survey that they used learning contracts where students decide on particular types of instruction and activities to complete during a unit (Tomlinson, 2001). While teachers did not differentiate the content according to specific students’ needs, they applied differentiated elements to the whole of their teaching so as to make the planning and teaching phases of instruction practical but still strategic for their different types of learners.

Teachers in this study confirmed and extended certain aspects of differentiating content, showing practical ways middle school teachers can adapt the ‘how’ of instruction to meet the needs of their students. Teachers used inputs like direct instruction, multimedia, student presentations, and demonstrations during a unit to teach a single concept or a string of related concepts, reflecting strategies recommended in DI literature (Hall et al., 2003; Park & Oliver, 2009). Extending on these varied inputs, teachers developed resources to reinforce them that allow students to access the resources outside the classroom by taking advantage of their teacher websites to post study guides, links to instructional websites, and other helpful or related links. Teachers offered their website resources in different ways, assigning students to particular
resources and/or providing them universally for students to reference on their own. Two teachers developed tiered learning centers that offered different texts depending on the group’s readiness level, a strategy also appearing in Bailey and Williams-Black’s (2008) qualitative study on differentiated teaching methods and organized in a fashion similar to several other studies (Hall et al., 2003; Mastropieri et al., 2006; Park & Oliver, 2009; van Hover et al., 2011). Two other teachers utilized jigsaw groups that included independent and cooperative elements so that students each provided a piece of the larger concept of natural resources similar to other DI research (van Hover et al., 2011).

**Process.** Teachers differentiated the process of instruction in several significant ways that correspond with the literature’s model of DI but also with some elements of contrast. Consistent with Tomlinson’s (2001) model, teachers used sense-making activities during the teaching phase of instruction to build students’ understanding of a concept, moving from simpler to more complex ideas. Like DI literature proposes, teachers showed a willingness to offer choices to students, offering a wide range of options on larger projects and also by including a degree of open-endedness on some activities (Dotger & Causton-Theoharis, 2010; Goodnough, 2010; Tomlinson, 2001) such as allowing students to create their own animals for an adaptations poster, choosing how to illustrate notes, developing their own graphic organizers, or choosing images for presentations. Sense-making activities blended independent and cooperative elements, flexibly grouping students according to the teacher’s purpose for the activity consistent with DI literature (Mastropieri et al., 2006; van Hover et al., 2011). Teachers confirmed DI literature by discussing and demonstrating things like problem-based activities (Park & Oliver, 2009) like a camouflaged butterfly assignment, graphic organizers (Tomlinson, 2001), jigsaw activities (Bailey & Williams-Black, 2008; Tomlinson, 2001; van Hover et al., 2011), and
learning centers that were sometimes tiered (Goodnough, 2010; Mastropieri et al., 2006; Simpkins et al., 2009). No matter the activity, teachers focused its purpose on the required content standard so that each lesson was grounded on a central concept or skill lesson (Bailey & Williams-Black, 2008; Tomlinson, 1999).

However, like the content domain, it is important to point out that teachers generally assigned the same activity to all students (except when they offered choice). Teachers’ process differentiation did not include the idea that each student would be working on a different set of tasks that lead them to mastery of a concept in an individualized, preferential way. In contrast to the model of DI (Tomlinson, 2001), teachers used a single approach for their sets of activities, offering a sequence of activities that varied by modality and complexity to the whole class through the course of a unit. They developed activities according to their understanding of the general characteristics of middle school students (e.g., cognitive readiness, a general preference for visual activities, a preference for cooperative work that allows them to be social), focusing the methods for instruction and activities based on the majority rather than the individual. This led to a heavy emphasis on visual methods, concrete learning experiences, and adding cooperative elements to break up independent work. In this way, the teaching phase of instruction seemed more consistent with the concept of Universal Design for Learning (UDL), which one teacher even explicitly referenced, where teachers make adjustments to the curriculum and learning environment to remove barriers to student learning (Hall et al., 2003) but in a more general and less individualized way. Then, teachers did differentiate the process of learning by offering activities that varied according to complexity and learning modality, even sometimes offering choices to allow students to approach activities in preferred ways, but they did so with
an eye towards the majority of students rather than specific individuals, again reflecting the practicality of their application of DI strategies.

**Product.** The product domain provided the most contrast between the DI literature and these teachers’ strategies for assessment. However, despite the lack of assessments that were structured as the model of DI suggests, teachers used assessments strategically to gather information about their students and inform instruction. Teachers differed significantly from Tomlinson’s (2001) differentiated model of assessment which encourages long-term assessments where students apply several ideas or skills through the development of an agreed-upon product. While some teachers mentioned long-term projects, these were typically offered once a unit. Teachers in this study primarily relied on multiple choice, brief oral quizzes, and/or short answer assessments as their products for instruction in addition to their informal and formal assessments during students’ sense-making activities. While the actual assessment product was less differentiated, this study’s teachers used their assessment data to identify students’ level of mastery with a skill or concept, using that information to target students for remediation as is suggested by DI literature (Ernest et al., 2011a; Tomlinson, 1999; Tomlinson, 2001). Through the course of the sense-making process, teachers consistently made their expectations for the essential criteria and expectations for quality known as they stayed involved in students’ independent and cooperative work, scaffolding them through the sense-making process (Park & Oliver, 2009; Tomlinson, 2001). Teachers also sometimes offered alternative formats (Ernest et al., 2011a; Hall et al., 2003; Park & Oliver, 2009; Tomlinson, 2001) such as read aloud tests either in person or digitally, including an option to draw rather than write their understanding of a concept, and in providing choices.
**Learning environment.** Similar to the best practices literature, Tomlinson (2001) emphasizes the emotional and social attitude of the learning environment as a critical factor of students’ success. To be properly motivated, students must feel safe to work independently and collaboratively towards learning goals (Eggen & Kauchak, 2007; Maslow, 1987; Tomlinson, 2001). Teachers cultivated these qualities of the learning environment by giving students roles in daily classroom routines, demonstrating and communicating care and respect, and managing students’ behavior in such a way as to value cooperation in the learning community. They also demonstrated other ways to help students feel safe and engaged by developing stimulating, interesting learning environments with lots of visual elements, sometimes classroom pets, content-related objects, attention-grabbing technology, and even by simply positioning materials in such a way that students had to cooperate and share to complete activities. Teachers adjusted their arrangement of the learning environment to put students who need help keeping up with the normal flow of instruction by helpful peers and organizing desks so that the teacher could easily move through students’ work area to monitor their work and provide scaffolding. They encouraged students’ participation in the learning environment by using classroom competitions, an impromptu performance during a pep rally, using their students’ names as examples in content-related stories, and incorporating kinesthetic elements to instruction. With these practical strategies, teachers applied the elements suggested by the DI model (Tomlinson, 2001) and even provided examples of more ways to help students feel safe and motivated in learning as a community.

**Differentiating by student characteristics.** Three student characteristics—readiness level, interest, and learning profile—serve as the basis for differentiating the following four domains (Tomlinson, 1999, 2001). Though in different degrees, teachers demonstrated ways that
these student characteristics led to adaptations and adjustments in the environment and instruction.

**Readiness level.** Teachers differentiated according to students’ readiness levels by asking questions of different difficulties during a class period, including sense-making activities that progressed from simpler applications of a concept to more complex ones, modifying their expectations of how much some specific students would do with a particular assignment, and by sometimes offering alternative assessment types. Teachers grouped students both heterogeneously and homogeneously to support students’ learning according to the purpose of the activity. Teachers used heterogeneous groups to create an opportunity for students to support their peers or homogeneously to tier a resource or activity for the readiness level of that specific group. Additionally, teachers expressed how the general characteristics of middle school students influenced their instructional plans as they developed inputs and sense-making activities to match students’ zones of proximal development, consistent with the suggestion of the model of DI (Tomlinson, 1999, 2001). This meant adjusting the length of instruction to match students’ attention spans, using pretests to gather information on students’ prior knowledge of a topic, and adjusting in-class or tier two support for struggling students or offering extension opportunities for high achieving students.

**Interest.** Teachers differentiated according to students’ interests by offering a variety of inputs for instruction, sometimes providing choices during the sense-making process or assessments, and including stimulating elements to the learning environment to engage their students. Interest differentiation provided a solid example of the contrast with Tomlinson’s (1999, 2001) DI model and the ideology and strategies demonstrated by the effective middle school science teachers in this study. The model for DI (Tomlinson, 1999, 2001) emphasizes the
availability of choice and offering preferential inputs and activities to a much more prevalent degree than the teachers of this study did not reflect. Teachers incorporated students’ interests by giving high interest examples, including types of activities that they perceived as beneficial for the majority of middle school students, and connecting students’ experiences to content, but they did not consistently offer interest modifications for every input or every sense-making activity. Teachers conveyed the idea that by offering their base set, a variety of instruction and activities, they could reach all of students’ preferential ways for learning within a unit rather than in a single lesson.

**Learning profile.** Tomlinson (2001) breaks down a student’s learning profile as a combination of how students prefer to be grouped, their cognitive style, preferred learning environment, and intelligence preference. Much like interest differentiation, teachers demonstrated a tension here between the more individualized nature of the DI model and what is practical for their middle school classrooms. Teachers included various elements among those four categories but did not offer them to all students for every lesson, instead opting to rely on different types of instructional inputs and activities to afford students the opportunity to interact with the content in a preferential way hopefully at some point during the progression of a unit. A variety of cognitive styles (Tomlinson, 2001) were included in teachers’ single approach to instruction and sense-making activities such as offering creative outlets like writing or drawing to respond to content, focusing on the essence or facts of a concept, including whole-to-part activities where students take the whole of direct instruction and then work on individual parts during sense-making, part-to-whole jigsaw activities, concrete hands-on, kinesthetic, or visual experiences with the content, and different types of collaborative work. In the learning environment, teachers demonstrated still and quiet work time along with noisy, kinesthetic
activities. Teachers offered instruction and activities according to several intelligence types (Tomlinson, 2001) but not all of them. It was interesting that during the interviews, when teachers referred to multiple intelligences or different learning styles, they only mentioned the visual, kinesthetic, and interpersonal styles along with an auditory style that neither Tomlinson (2001) nor Gardner (2011) directly reference. While teachers considered developing instruction and activities that cover a number of Tomlinson’s (2001) learning profile aspects, they did so with a single approach to daily instruction, progressing through a variety of inputs and sense-making work throughout a unit that was intended to cover a range of ways students might best interact with the content. In contrast to Tomlinson’s (1999, 2001) ideology on matching students’ work to their learning profiles, a couple teachers mentioned the value of students working in non-preferred ways to help students develop as well-rounded learners. Another teacher stated that the contemporary educational climate might make too much of learning styles (Curry, 1990; Spence, 2011), explaining that teaching to a student’s learning style might make learning more efficient but that a proclivity for one style does not mean that a student cannot learn in a different way. The teacher’s sentiment agrees with literature (Kavale & LeFever, 2007) that questions the value of matching students to preferential modalities of instruction for increasing achievement in light of other empirically demonstrated strategies like drill and practice, reinforcement, and feedback, though other research places more emphasis on matching modality to the learner (Lovelace, 2005) that seems more consistent with the recommendations of the DI model advocated by Tomlinson (1999, 2001).

**Implications**

This study has significant implications for middle school science teachers who want to be effective classroom leaders who consistently help students show gains in their achievement
according to evaluation measured tied to students’ high-stakes testing scores. Though the model developed from the data is extensive and multifaceted, it provides a template of how a middle school science teacher can structure and implement an organized, efficient, and engaging classroom by suggesting a number of best practices and methods for differentiating them that are proven to lead students to higher levels of achievement on summative standardized tests. In this section, I discuss the most significant themes in the data in order to describe the implications of this study’s findings for the consideration of what constitutes best practices science teaching and the value of the DI model for middle school science in this context.

First, teachers utilized a number of best teaching practices, though they did not emphasize perhaps the most critical element suggested by the literature—inquiry (NSTA, 2003b). Some of this study’s most obvious themes matched the literature on best practices science teaching, confirming these as essential elements to effective middle school teaching. In particular, each teacher focused instruction and activities on big ideas (Thurlow et al., 2008), connecting them to students’ experiences (Banilower et al., 2010; Parkay et al., 2011) and real-world examples (NSTA, 2003a). With this starting point for planning established, each teacher in this study demonstrated a wide variety of both instructional inputs and sense-making activities (Brophy, 2000; Kellough & Kellough, 2008; Palincsar, 2001; Parkay et al., 2010; Thurlow et al., 2008). The ebb and flow of instruction and activities created a number of opportunities for teachers to gather informal and formal data on students’ understanding of a concept (Herrenkohl et al., 2011; NSTA, 2003b) because of teachers’ willingness to constantly stay involved in students’ learning by frequently checking students’ progress and giving constructive feedback (Brophy, 2000). All of these instructional qualities were grounded in efficient, organized learning environments that valued caring and respect (Brophy, 2000) and where high
expectations were placed on students (Brophy, 2000; Staver, 2005). Teachers’ structural organization, arrangement of the learning environment, and use of routines ensured that instructional time would be maximized (Marzano & Marzano, 2003).

However, in stark contrast to the recommendation of the best practices literature (NRC, 2005; NSTA, 2003b), teachers in this study did not rely on inquiry to deliver content. The data from this study reveal the weighty implication that inquiry-based instruction is not a significant contributor to students’ achievement as measured by a high-stakes standardized test. It should be noted that the methods and design of scientific inquiry compromise one major unit of required content standards at each grade level in the setting for this research, so students are being taught this critical component of best practices science teaching. Effective middle school science teachers, as defined by the criterion of the teaching effect evaluation measure, simply may not use inquiry-based instruction to communicate content standards that focus on foundational scientific knowledge such as causes of weather systems, the structure and function of cells, and how an animal’s adaptations are a response to its environment. While this implication could be perceived to point out a potential tension between required content standards and the best preparation for work in the field of science, it is important to consider the goals of middle school science curricula. The NRC (2005) identifies a familiarity with the models or theories related to a concept as one of the components of scientific literacy (and perhaps the most basic level of it). While understanding and applying inquiry skills are crucial to scientific literacy, they do not constitute the whole of it. In other words, for a student to have the ability to conduct a novel inquiry on the mechanics of a tectonic plate, he or she must first have a working knowledge of what a tectonic plate is, why it moves, and how we have come to an understanding of those ideas. Those pieces of working knowledge make up one of the required content standards for
seventh grade science in the research setting. It could be that curriculum-makers believe the ability to develop a valid and well-constructed inquiry on a tectonic plate may be more a more advanced skill more appropriately left to higher levels of education, instead focusing the younger middle school student on the foundational knowledge. Or, this implication might speak to the need to resolve a tension between the required content standards and the necessary skills to advance scientific knowledge. The relationship of required content standards and standardized testing may in fact jeopardize the functional scientific literacy of aspiring scientists so that a rethinking of authentic assessment in science might be worth considering. In any case, the data from this study imply that the role of inquiry-based instruction in middle school science, at least on content standards not dedicated specifically to scientific inquiry, is minimal for helping students demonstrate learning gains according to scores on a standardized, multiple choice high-stakes test.

Next, teachers showed a number of similarities in the ideology and application of teaching strategies from the DI model, but they also implied some practical limits to how far the model extends into effective middle school science pedagogy. Ideologically, teachers planned with an understanding that students learn differently, and so different types of inputs and sense-making activities were significant for connecting students to the content and making learning efficient. Though they did not express all of the differences among learners accounted for in Tomlinson’s (2001) description of DI, teachers did recognize the most critical methods for teaching middle school students—primarily visual, kinesthetic, and interpersonal strategies that sometimes included a degree of creativity and choice. Teachers also recognized that students start the learning process at different levels of readiness and progress towards mastery at different rates, leading to a range of whole class, small group, and individual scaffolding.
Teachers anticipated ways to make instruction more accessible to students, offering a variety of resources (sometimes posting them online), incorporating supports like note-taking guides and graphic organizers to go along with direct instruction, and working with small groups and individuals throughout the sense-making process. Through a constant involvement during the teaching phase, teachers were able to use their informal and formal assessments (offering some accommodations or modifications) to adjust the level of support students received and the complexity of instruction accordingly. Teachers used assessment data to flexibly group students, sometimes homogeneously to scaffold students with similar learning needs and sometimes heterogeneously to provide an opportunity for peer support. Teachers also used assessment data to determine what students would benefit from reteaching or extending opportunities during tier two instruction. All of these strategies are elements of the DI model, though they do not make up the entirety of the model.

The participants did not demonstrate what would be considered a faithful representation of Tomlinson’s (1999, 2001) model of DI. In contrast to Tomlinson’s (1999, 2001) model, teachers took a single approach to instruction. The single approach originated in the planning phase where teachers focused their instruction on the required content standards. Though they discussed ways to explore the depth of concepts or to extend them, the focus remained on the state-mandated curriculum in contrast to the suggested flexibility of the DI model’s content differentiation, or adapting the what of teaching, with strategies like learning contracts, curriculum compacting, or mini-lessons (Tomlinson, 2001). This study’s teachers relied on the variety of activities through the course of a unit to communicate content in a meaningful way to the diverse range of learners rather than offering that variety within a single lesson to each student. Additionally, teachers relied on multiple choice, short answer, and brief oral quizzes as
the primary mode of assessment instead of larger, teacher-student contracted application-based projects. Given the limits to the scope and degree to which effective middle school science teachers incorporated differentiation, there is an implication that only selected strategies of the DI model are valuable for producing learning gains on a standardized, multiple choice high-stakes test in middle school science.

Two options exist for interpreting the implication that only strategic and practical selections of the DI model are valuable to effective middle school science teaching: (a) the whole of the DI model does promote authentic learning to a diverse set of learners but the context of this study does not sufficiently measure its value; or (b) the practical value of DI for middle school science is truly limited. If the first interpretation is taken, then one questions the value of standardized, multiple choice high-stakes testing as a valid measure of student learning. The participants for this study were selected solely on the criterion of a demonstrated measure of leading diverse set of middle school students to higher than expected test scores. While that is a significant achievement, there may be other valid (or even more authentic) measures of students’ learning in science. If one takes the stance that there are such measures, then the value of DI might be better revealed according to a different measure. However, a practical view asserts state-mandated content standards and high-stakes testing are fundamental elements of the current state of public education. With teacher evaluations tied to students’ test scores, it is problematic to suggest that teachers focus their instruction or base their assessment with any other result in mind. Like with best practices science teaching and the role of inquiry, there may exist a tension between championed theory and actual practice. In any case, the practical value of DI is limited in its scope (how are the needs of each student considered during the four phases of instruction) and its degree (how different should instruction be when the goal is to increase achievement
according to test scores) to the ultimate goal of raising students’ standardized test scores. Within the boundaries of this study’s measure of effective teaching, the value-added teacher evaluation measure, the effective middle school science teachers of this study utilized only selected elements of the DI model in practical, strategic ways according to their beliefs about student learning and with the influence of contextual pressures.

Teachers in this study proved some value of the DI model, demonstrating ways that best practices may be differentiated as part of an effective middle school science teacher’s pedagogy as teachers consider how their students learn best and then develop instructional strategies in response. Combining the lenses of best practices science teaching and DI that the study’s teachers demonstrated developed the model that was the purpose of this study, describing how a middle school science teacher’s practices could be differentiated to lead students to high levels of achievement. The model represents the significant elements for each lens at each of the four phases of the instructional process, implying what pedagogical considerations middle school science teachers should make to be most effective.

During the planning phase, the model recommends that teachers begin by focusing on the big idea(s) of the required content standard. Then, they should consider how the concept could be connected with others in the curriculum and how it may be best communicated (e.g. visually, kinesthetically, direct instruction). Effective middle school science teachers plan with a recognition that students will learn the same concept in different ways and at different paces, so it is recommended to gather a variety of resources (including interesting stimuli in the learning environment) that explain the concept in several modalities. However a teacher decides the concept should be communicated, a purposeful learning environment that maximizes instructional time and engages students will make learning efficient. Classroom routines and
behavior systems give middle school students necessary structure to stay focused on the concept and provide expectations for cooperating toward the goal of mastery. Getting to know students communicates important values of cooperation like caring and respect while also affording a teacher the opportunity to engage students with examples that are relevant to a student’s interests.

The teaching phase is an extension of planning, where teachers practically apply the philosophic idea that students learn in different ways and at different paces. Using multiple instructional inputs of different modalities paired with a variety of increasingly complex sense-making activities helps to reach the diverse set of middle school students public school science teachers generally teach. Modeling how to think through a concept is especially important as teachers present new concepts. Once instruction has been delivered, effective teachers are constantly active during the series of students’ independent and cooperative sense-making work that is typically arranged as a base set, providing kinesthetic and visual elements in particular, to ensure that the majority of different types of learners will be able to approach a concept in a preferential way. Scaffolding students understanding and adjusting the level of support they receive to students’ readiness levels is critical to their building of knowledge at this phase. Cooperative activities can provide some of that support, with homogeneous ability groups being especially useful when tiering sense-making activities and heterogeneous for providing opportunities for peer tutoring.

Effective middle school science teachers constantly formatively assess their students both informally and formally. A teacher’s involvement during the sense-making process during the teaching phase is essential to gather data on student understanding in the back-and-forth flow of assessing and teaching. In informal assessments, teachers ask the whole class questions during
instruction, check on students’ progress during sense-making activities, and individually question students as they work, gathering specific data on how a student is understanding a concept. Teachers then use this information to adjust instruction as needed to meet students’ learning needs. Formally, teachers can use oral quizzes, homework checks, multiple choice tests, and short constructed responses to gather more data on students’ understanding of a concept. These assessments can be made more authentic according to students’ diverse learning needs by offering alternative formats such as read aloud tests or allowing students some accommodations like the option to draw their understanding of a concept. In any case, it is the data that teachers gather through assessment that is most important to students’ learning during this phase as it helps teachers inform future instructional decisions.

Finally, during the reteaching/extending phase, teachers apply the data they have gathered on students’ understanding to provide more learning opportunities according to students’ needs. Effective middle school science teachers focus on a single learning objective over the course of several lessons, smoothly transitioning between lessons to keep students working toward the goal of mastery. The support teachers offer their students during this phase is closely related to the scaffolding given during the teaching phase but can be extended during tier two instruction. Teachers used this extra class period to select specific students to work on specific learning objectives typically in homogeneous groups of students with similar learning needs. However, heterogeneous groups can also be helpful in offering another type of scaffolding support. Though the organization of and reliance on tier two varies among effective teachers depending on the circumstances of their school and their own pedagogical styles, the critical element is focusing instruction on what students have not yet understood about a concept.
and reteaching it in another way, with different resources, or as additional practice to move a student closer to mastery.

Limitations

There were several delimitations in this study so that its research could be specific and focused to the purpose of developing a model of differentiating the best practices teaching methods in middle school science. First, the study was restricted to middle school, grades six through eight—a common transitional time for adolescents to move from concrete to formal operations (Piaget, 1954). The cognitive development adolescents experience in middle school presents unique challenges in meeting students’ learning needs, providing a rich environment in which to study how teachers respond to those learning needs, if at all, through DI.

Next, this study was restricted to general education science teachers so that very specific aspects of what constitute best teaching practices could be examined. I only selected general education science teachers as participants for this study, excluding special education teachers, in order to describe how general education teachers decided on and implemented pedagogies that meet the learning needs of such a diverse student population (including students with special education services). While there may exist universals to best practices teaching, I chose to focus specifically on the idiosyncrasies of science to provide a specific model for this underachieving content area (National Center for Education Statistics, 2011a).

Another limitation of this study was that all the participants teach in the same school district. With this in common, it is likely that the teachers share to some degree the same professional development emphases encouraged by the district and similar collaborative opportunities. Additionally, being in the same school district means that the teachers are in similar circumstances, having in common some organizational structures such as the inclusion of
a tier two class as a part of the daily schedule. These similarities could lead to analogous teaching practices and artificially narrow the pool of best teaching practices and differentiated elements that I gathered data about. A more diverse set of participants in terms of setting could have provided richer data and themes are that more easily generalized to other middle school science classrooms.

Additionally, it is possible that my own bias as the research instrument of qualitative research (Creswell, 2007) could have slanted data analysis and the emergent model. I work as a middle school science teacher in the setting for this research. Though I have not attended all the professional development conferences related to DI, I may unknowingly have been influenced towards certain aspects of DI through professional learning community meetings with my department and with other science teachers in the school district, or even simply by my own opinions of what constitutes DI. However, I have not knowingly or intentionally been partial to any specific result that emerged from the model developed by this research, and I utilized an expert review during piloting to bolster the trustworthiness of data collected from teacher observations. Grounding a definition of what constitutes DI in the current research literature (Tomlinson, 1999, 2001) helped to control for its identification in teacher observations and interviews. I conducted informal member checks to control for the categories and conclusions of the emergent model to ensure that my methods of data collection and analysis were as unbiased as possible but other researchers code the observational protocols and interviews could have enhanced the trustworthiness of analysis by providing inter-rater reliability.

One limitation that became apparent through the course of the study was the amount of time I was able to observe each teacher. Because I was limited to four consecutive observations, I was not able to see all teachers’ complete base sets of activities along with any other activities
developed specifically for particular concepts. While the interview data was valuable in this regard, the observations provided much richer data. Observing more consecutive lessons could have given a clearer picture of the number and types of instructional inputs and sense-making activities that effective middle school science teachers generally use. Also, with the significance of the time teachers spend with students in tier two, it would have been beneficial to observe this class period as a part of the reteaching/extending phase of instruction.

The final and most compelling limitation related to the definition of effective teaching that serves as the foundation for this study. The science teachers that were selected as participants were invited according to a single criterion: a teacher effectiveness, or value-added, score of the highest rating on a teaching evaluation at least once in the previous three years. Since this measure compares students’ previous performance in all core subjects to determine a growth estimate for the current year despite a change in the content from one year to the next (Tennessee Department of Education, 2012), it could be argued that there are other valid selection criteria to determine a science teacher’s effectiveness. This particular measure was chosen as the criterion for the study because of its proposed objectivity as compared to others. All middle school science teachers in the research setting are evaluated on this measure according to results on the same high-stakes test. This does not necessarily imply that it is a good measure to level the playing field of effective teaching, but it is the only one that is standard for all middle school science teachers. Observational teaching evaluations might be the next most objective measure, but those scores are determined by different individuals, introducing a degree of subjectivity not present in the formulaic achievement growth projections and automated grading machinery of the teacher effectiveness (also known as value-added) measure. For better or worse, the measure’s use as a significant component of determining a
teacher’s effectiveness on a teaching evaluation makes it an objective criterion on which to identify strong science teachers. While I believe that there are other criteria that contribute to effective teaching, such as the positive influence a teacher has on his or her students, the teacher’s ability to develop critical thinking skills, and/or a quality of inspiring young minds to desire education, it is difficult to find a more objective criterion. The study’s limitation of being grounded on the teacher effectiveness measure is itself a microcosm of the tension between the practical objectivity of the outcomes-based culture of standardized testing and the subjectivity of authentic learning—as with the current state of public education, what might be best is compromised by what is “fair.”

It is important to consider the significance of the limitation of the teaching effectiveness measure when evaluating the study’s model and its transferability. The results of the study hinge on one’s valuation of the sole criterion. On one hand, it might be myopic to assess the value of DI as a part of best practices science teaching according to multiple choice, high-stakes standardized test scores. On the other, a teacher’s performance will be judged according to those test scores. So, for all practical purposes, understanding the elements of best practices for science and DI that serve that goal is critical for practitioners. Since this study was framed according to the more practical view by delimiting participants according to the teaching effectiveness measure, it should be understood that the model that developed through the course of this study is meant to address the current reality of standardized testing in public education.

**Recommendations for Future Research**

Based on the findings of this study, there are several opportunities for further research on differentiated instruction in the middle school setting. First, future research could be conducted on specific phases of instruction to focus on the generalizable elements of DI and its key aspects
at each stage. In particular, I think it would be valuable to study the reteaching/extending phase in more detail by collecting data during both tier one and tier two instructional time. Because of the targeted nature of this phase, it provides a rich setting for observing the most differentiated aspects of middle school teachers’ differentiated teaching practices.

Next, studying how teachers differentiate the best teaching practices in other content areas would give unique perspectives about the most generalizable differentiated teaching methods and which might be more subject-specific. For instance, comparing the concept-focused science curricula with the more skills-based ones in reading and language arts could theoretically reveal that differentiated teaching is more prevalent, or more specific, in each content area. Since the findings of this study revealed that effective middle school science teachers plan their instruction based on the best way to communicate a particular concept, it is conceivable that teachers in other subject areas do the same. Therefore, uncovering other content area teachers’ instructional strategies could potentially yield different results than the model that developed from this study’s data.

Future research might also consider the role of inquiry at different levels of science teaching. As this study revealed a tension between the open-ended nature of inquiry and the pressure of covering all the required content standards that are measured according to the end of the year high-stakes test to determine teachers’ value-added, or teacher effect, scores, it would be beneficial to consider how inquiry could be utilized within this framework. Focused research on how inquiry could communicate the required content standards would be beneficial to science teachers. Additionally, since Brad raised the question of the developmental appropriateness of open-ended investigation for his eighth graders, research could be done to assess how inquiry should be structured to keep instruction within students’ zones of proximal development at the
different stages of students’ K-12 education. In this way, future research could determine whether the study’s effective middle school science teachers’ reliance on instructional strategies other than inquiry-based instruction is in fact a product of building the foundational knowledge of scientific literacy first before addressing the more complex aspects of actually engaging in inquiry at higher levels of education.

Additionally, comparing how effective teachers differentiate according to the grade level of their students (elementary, middle, and high) would provide insight into how instructional strategies vary according to the cognitive development of students. While there may be some universal differentiated teaching practices that are effective at all grade levels, it would be interesting to extend the results of this study to see what beliefs or strategies of DI are most applicable at each stage of a student’s K-12 career. Also, since the organization of the elementary grades are foundationally different from the secondary grades, such as typically being self-contained classrooms with one teacher instructing students on several content areas, it would be beneficial to discover how differentiated teaching might change based on the number of students a teacher has. Some aspects of differentiating instruction are built upon a teacher’s knowledge of a student, and so the number of students could potentially affect the degree to which teachers differentiate as well as the differentiated strategies they implement. Can an elementary teacher who rarely differentiates score as highly on teacher effect data as a secondary teacher who consistently differentiates? Answering that question and others like it would clarify the value of how much DI truly helps teachers at different levels produce learning gains in their students.

Future research could compare the value of differentiated teaching methods for students receiving special education services compared to those who are not. Since this study focused on
the differentiating methods of general education teachers, it might be valuable to explore how special education teachers differentiate for their student populations so that general education teachers could glean insights from more specific types of differentiation. If the differentiated accommodations students with special education services receive are effective, then it stands to reason that similar strategies could be useful for the general education population as well so long as the strategies are practical for larger groups of students. Essentially, research could more specifically address the degree to which DI is effective for the different student populations and the practicality of its strategies for both.

Finally, future research could seek alternative measures of “effective” teaching that might more completely reveal the value of DI as a part of best practices science teaching. The adaptability of DI makes it somewhat difficult to control, but, if research could select appropriate delimiters, experimental research on the degree of DI’s value could significantly extend this study’s findings. In particular, future research might consider using students’ ability to engage in or evaluate a scientific inquiry, two of the major components of scientific literacy (NRC, 2005), as a measure of learning. Quantitative experimental research could compare the effectiveness of differentiated teaching methods to more traditional ones against that criterion. Qualitative research could examine what elements of DI teachers select when the integrity of scientific inquiry, not standardized test scores, is the desired outcome. It is possible that DI could play a more significant role in developing the inquiry-based aspects of scientific literacy. With the tension between the current state of assessing the content standards in public middle school science classrooms and the facets of scientific literacy that include conducting and evaluating inquiry (NRC, 2005), it would be beneficial for future research to explore alternative types of
assessment that could give a more accurate picture of the development of the whole of students’ scientific literacy.

**Conclusion**

This study investigated how effective middle school science teachers differentiate their best teaching practices. By observing, interviewing, surveying, and gathering artifacts from eight teachers in a Southern suburban school district, the study’s findings led to the development of a model describing the best science teaching practices and how teachers differentiated them to produce learning gains in their students as defined by a teacher effect evaluation score. The model featured elements of best practices and DI in four phases of instruction—planning, teaching, assessing, and reteaching/ extending—noting the factors that influenced those practices and the scope of teachers’ differentiating perspectives. The study contributed to the existing literature on best teaching practices in science and DI by providing a framework for effective teaching in middle school science as well as empirically examining the value of the model of DI. While teachers did not reflect the entirety of Tomlinson’s (1999, 2001) model, they did apply elements of it, particularly in delivering instruction with multiple inputs and a variety of sense-making activities while providing scaffolding throughout the learning process, practically and strategically for their middle school students.
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Appendix A

September 11, 2013

Brian K. [name]
IRS Approval 16466:991113: The Role of Differentiated Instruction in Effective Middle School Science Teaching

Dear Brian,

We are pleased to inform you that your above study has been approved by the Liberty IRB. This approval is extended to you for one year. If data collection proceeds past one year, or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Please retain this letter for your records. Also, if you are conducting research as part of the requirements for a master's thesis or doctoral dissertation, this approval letter should be included as an appendix to your completed thesis or dissertation.

Thank you for your cooperation with the IRB and we wish you well with your research project.

Sincerely,

Fernando Garzon, Psy.D.
Professor, IRS Chair
Counseling
(434) 982-4054

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Appendix B

To the principal of (school name):

The purpose of this letter is to request permission to conduct research for a dissertation on effective middle school science teaching in your school. Based on the publicly available TVAAS averages for your science departments, I’ve identified your (insert grade levels) as being highly effective, and therefore a likely setting to find potential participants for this study. With your consent, I’m asking that you recommend any (or all) of your science teachers from these grade levels that you think might be interested in participating in the study. The goal of this research is to develop a model of how effective middle school science teachers use differentiated teaching strategies. I plan to observe, interview, and collect questionnaire data from participating teachers to gain insight into how differentiated instruction may, or may not, contribute to their effective teaching practices. As a seventh grade science teacher in the county myself, it is my hope to use this dissertation as an avenue for sharing with middle school science teachers ways we can improve and collaborate to develop more effective teaching practices.

Below is the information I’ll be sharing with the potential participants you recommend for the study:

You are being invited to participate in a research study on differentiated instruction in middle school science classrooms. You were selected as a possible participant for this research based on your department’s success in leading students to high achievement gains. I ask that you read this form and ask any questions you may have before agreeing to participate in the study.

**Purpose:** The goal of the study is to develop a model of how and to what degree (if any) effective middle school science teachers use differentiated teaching strategies. Since you have produced such positive achievement gains in your students, I want to learn from your teaching strategies. Specifically, I want to describe how your teaching may or may not be influenced by the concept of differentiated instruction and how you might use it as a part of your science teaching strategies.

**Procedures:** If you choose to participate in this study, you will be asked to allow me to observe and audio record a class period (typically 45 minutes) for four consecutive days, fill out a brief questionnaire on your teaching practices, and attend one audio recorded interview session (around 45 minutes). You will also be asked for any relevant documents (activities, lesson plans, etc.) related to how you planned for the lessons I observe. Some participants may volunteer to help the researcher validate data by providing written or verbal feedback on the analysis of the collected data.

**Confidentiality:** All records will be kept private and protected by the researcher. Pseudonyms will be used for all participants, students’ names, and locations so there will be no way to identify participants in the event any part of the report is published.
**Risks and Benefits:** To protect the identity of the participants, pseudonyms will be used to communicate all data collected in the research; therefore, no risks are anticipated. The intended benefit of the study is to inform the community of practice by helping teachers identify and implement effective middle school science teaching strategies that have been shown to help students achieve at high levels, as evidenced by your teaching. You will not be compensated for participation in this study.

**Participation:** Your participation is completely voluntary. You may withdraw at any time.

**Contacts:** If you have any questions about your participation in this study, please contact me, Brian Jones, at (xxx-xxx-xxxx). You can also email me at ___. You may also contact my advisor, Dr. Lucinda Spaulding, at ___.

Thank you for your consideration in allowing me to conduct research in your school.

Sincerely,
Brian K. Jones

This study is being conducted by a researcher from the Education department at Liberty University.
Date: 08/01/2013

(Participant Name)
(Participant Position)
American County Schools

Dear (Participant):

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree, and I am writing to invite you to participate in my study. The study looks at differentiated instruction in middle school science classrooms, and I’m inviting you because of your departments’ success in leading students to high achievement. Since you have an expertise at producing achievement gains, I want to learn from your teaching strategies. Specifically, I want to describe how your teaching may or may not be influenced by the principles of differentiated instruction, and, if it is, how you might use differentiated instruction (DI) as a part of your science-specific teaching strategies.

If you choose to participate in this study, you will be asked to allow me to observe and audio record a class period (typically 45 minutes) for four consecutive days, fill out a brief questionnaire (5-10 minutes) on your teaching practices, and attend one audio recorded interview session (around 45 minutes). You will also be asked for any relevant documents (activities, lesson plans, etc.) related to how you planned for the lessons I observe that I can collect at the time of the observations. Some participants may volunteer to help the researcher validate data by providing written or verbal feedback on the analysis of the collected data. It should take approximately 20 minutes to review my analysis and provide feedback. Though I will know your identity through the data collection process, I will protect your confidentiality by recording data using personal identifier codes and then destroying all links to your name during the analysis and using pseudonyms to report my findings.

To participate, reply to this email with the attached teacher recruitment form completed, and I will contact you to schedule the classroom observations that I’m looking to conduct in late October or early November.

I have also attached a copy of the informed consent form for your review. The informed consent document contains additional information about my research, but you do not need to sign and
return it. At the time of the first observation, I will provide a hard copy of the informed consent form for you to sign. Please feel free to email me with any questions about it prior to the observation.

Sincerely,

Brian Jones
7th grade science
___ Middle School
Liberty University Doctoral Candidate
Appendix D

CONSENT FORM

Differentiated Instruction in Effective Middle School Science Classrooms.

Brian K Jones

This study is being conducted by a researcher from the Education department at Liberty University.

You are being invited to participate in a research study on differentiated instruction in middle school science classrooms. You were selected as a possible participant for this research based on your department’s success in leading students to high achievement gains. I ask that you read this form and ask any questions you may have before agreeing to participate in the study.

Purpose: The goal of the study is to develop a model of how and to what degree (if any) effective middle school science teachers use differentiated teaching strategies. Since you have produced such positive achievement gains in your students, I want to learn from your teaching strategies. Specifically, I want to describe how your teaching may or may not be influenced by the concept of differentiated instruction and how you might use it as a part of your science teaching strategies.

Procedures: If you choose to participate in this study, you will be asked to allow me to observe and audio record a class period (typically 45 minutes) for four consecutive days, fill out a brief questionnaire on your teaching practices (5-10 minutes), and attend one audio recorded interview session (around 45 minutes). You will also be asked for any relevant documents (activities, lesson plans, etc.) related to how you planned for the lessons I observe that I can collect at the observation. Some participants may volunteer to help the researcher validate data by providing written or verbal feedback on the analysis of the collected data. I expect this review of my analysis and providing feedback to take roughly 20 minutes.

Confidentiality: All records will be kept private and protected by the researcher. Pseudonyms will be used for all participants, students’ names, and locations so there will be no way to identify participants in the event any part of the report is published.

Risks and Benefits: To protect the identity of the participants, pseudonyms will be used to communicate all data collected in the research; therefore, no risks are anticipated. The intended benefit of the study is to inform the community of practice by helping teachers identify and implement effective middle school science teaching strategies that have been shown to help students achieve at high levels, as evidenced by your teaching. You will not be compensated for participation in this study.

Participation: Your participation is completely voluntary. You may withdraw at any time. Your decision whether or not to participate will not affect your current or future relationships with Liberty University and Rutherford Co. Schools. If you decide to participate, you are free to
not answer any question or withdraw at any time without affecting those relationships. If you withdraw after I have begun collecting data from you, all data (including audio recordings) will be immediately destroyed.

Contacts: If you have any questions about your participation in this study, please contact me, Brian Jones, at (xxx-xxx-xxxx). You can also email me at ___. You may also contact my advisor, Dr. Lucinda Spaulding, at ___. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the Institutional Review Board, 1971 University Blvd, Suite 1837, Lynchburg, VA 24502 or email at irb@liberty.edu.

Statement of consent: (You will be given a copy of this form for your records.) I have read and understand the above information. I have asked questions and have received answers. I agree to participate in this study that includes audio recording during classroom observations and during the interview session. ☐

Signature__________________________________________ Date:______________

Researcher Signature:________________________________________ Date:______________
Appendix E

Teacher Recruitment Form

If you are choosing to participate, please fill out the following information below. Thank you for your participation!

Gender: □Female □Male

Years of teaching experience:

Highest level of education: □Bachelor’s □Master’s □Specialist □Doctorate

Please list your teaching certification and endorsement areas

Though you are not required to answer this question, I ask that you would volunteer information about your TVAAS, or value-added, scores. Please share your scores from the past three years if you were teaching middle school science.

One year ago: Level □1 □2 □3 □4 □5 □N/A
Two years ago: Level □1 □2 □3 □4 □5 □N/A
Three years ago: Level □1 □2 □3 □4 □5 □N/A
### Appendix F

**DI Observational Protocol**

<table>
<thead>
<tr>
<th>Component</th>
<th>Success</th>
<th>Process</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td></td>
<td></td>
<td>How are the essential skills and expectations of quality made known?</td>
</tr>
<tr>
<td>Multiple</td>
<td></td>
<td></td>
<td>How are students grouped and encouraged to contribute in class?</td>
</tr>
<tr>
<td>Conceptual Teaching</td>
<td></td>
<td></td>
<td>What is the function of the product assessment?</td>
</tr>
<tr>
<td>Reflections</td>
<td></td>
<td></td>
<td>What resources are used to help apply the information?</td>
</tr>
<tr>
<td>Problem-based Lab Activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role playing debates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperative activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning Contracts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Reflective Notes

Comparison with Interview Data

How may the teacher differentiated according to readiness, interest, or learning preference?
<table>
<thead>
<tr>
<th>Timeline</th>
<th>Content</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>How are concepts connected?</strong> ____________________________________________</td>
<td><strong>Independent work activities:</strong> ____________________________________________</td>
</tr>
<tr>
<td></td>
<td><strong>Connected to students' experience?</strong> ______________________________________</td>
<td><strong>Cooperative activities:</strong> ________________________________________________</td>
</tr>
<tr>
<td></td>
<td><strong>What are the inputs?</strong> ____________________________________________________</td>
<td>(<strong>Long-term investigation</strong>  <strong>Structural</strong>  <strong>Learn Together</strong>)</td>
</tr>
<tr>
<td></td>
<td><strong>Did students have a choice of input or in how to approach the content?</strong> ______________</td>
<td><strong>Did the collaboration move from small to large groups?</strong> ______</td>
</tr>
<tr>
<td></td>
<td><strong>Modeling cooperative:</strong> _________________________________________________</td>
<td><strong>Was evidence used to support or refute ideas?</strong> ______________</td>
</tr>
<tr>
<td></td>
<td><strong>Modeling cognition:</strong> _________________________________________________</td>
<td><strong>Did each group member have a defined role?</strong> ______________</td>
</tr>
<tr>
<td></td>
<td><strong>How are experiences with the content encouraged?</strong> ______________</td>
<td><strong>INQUIRY:</strong> ___________________________________________________________</td>
</tr>
<tr>
<td></td>
<td><strong>Process</strong></td>
<td><strong>Did the inquiry deliver content, or support already covered content?</strong> __________________</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>How did students engage in the inquiry?</strong> (circle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>designing investigations</strong>  <strong>using scientific reasoning</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>using equipment</strong>  <strong>recording data</strong>  <strong>analyzing results</strong></td>
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<tr>
<td></td>
<td></td>
<td><strong>discussing the findings</strong></td>
</tr>
<tr>
<td>Reflective Notes</td>
<td>Product</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Formative or summative?_________________________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Format?________________________________________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified?______________________________________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any observable way the assessment data is used to drive future instruction? ______________________________________________</td>
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</table>

<table>
<thead>
<tr>
<th>Learning Environment</th>
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</thead>
<tbody>
<tr>
<td>How are students encouraged to become engaged?______</td>
</tr>
<tr>
<td>______________________________________________________</td>
</tr>
<tr>
<td>How are students’ emotional safety supported?________</td>
</tr>
<tr>
<td>______________________________________________________</td>
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<tr>
<td>How does the teacher account for student diversity?______</td>
</tr>
<tr>
<td>______________________________________________________</td>
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<tr>
<td>How does the teacher manage activities to maximize instruction?</td>
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<td>______________________________________________________</td>
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</table>

<table>
<thead>
<tr>
<th>DI Leads</th>
<th>Comparison with Interview Data</th>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G

Teacher Questionnaire

Participant ID (for the researcher only)____________________________________

Please check next to any teaching strategy you use at any point during the school year. If you’re not sure, leave it blank.

☐ Curriculum compacting: The teacher uses a pre-assessment to determine what an advanced learner already knows about a topic, then designs activities (possibly with the student) to target instruction on what the student hasn’t mastered.

☐ Using multiple inputs: The teacher provides a variety of resources for the content including alternative texts and other print materials, pictures/diagrams, manipulatives, and/or multimedia.

☐ Concept-based teaching: Instead of focusing on the memorization of facts, material is presented based on its key principles and concepts. The focus of instruction is on the essential concepts that build understanding and lead to application.

☐ Mini-lessons: Lessons are designed for small groups of students based on their current level of understanding. For instance, the teacher might re-teach a skill to a group of struggling students while a more advanced group works on an extending or application activity.

☐ Supports for accessing the content: The teacher provides different avenues for students to access the content such as notes’ organizers, mentors/tutors, marked print materials, summaries, audio/video recorders, etc.

☐ Learning contracts: The teacher and students work together to create a list of skill- and content-based tasks to accomplish in a fixed amount of time. Contracts may differ from student to student based on students’ interests and/or abilities.

☐ Offering choices on how to complete assignments: Students have opportunities to choose from different types of activities to learn the same objective.

☐ Tiering or leveling activities: Simpler tasks/assignments must be mastered before moving on to more complex ones. Students may have individual goals for what level of tasks must be accomplished.

☐ Journals/Reflections: Students have opportunities to make sense of what they’ve learned by recording their thoughts about the content; may occur at different intervals to show the development of their understanding.

☐ Graphic organizers, mind-maps, models, etc.: Students create visual representations of the content or develop teacher-produced ones.
Problem-based or lab activities: The teacher uses open-ended investigations to allow students to approach the content in a way that makes sense to them.

Role-playing/debate: Students may be assigned or choose to defend certain perspectives on a content-related issue.

Centers/Jigsaw activities: Students are broken into groups to study different aspects of the same central topic. For instance, in a unit on cells, some students study and report on the organelles in plant cells while another group focuses on animal cells.

Please answer the following questions, and, if applicable, write brief descriptions to explain your answer.

Do students ever complete different assessments or turn in different types of products for the same lesson or assignment? Yes No

If yes, what are the most common adaptations or alternatives that you provide?


Do students have fixed groups for cooperative work, or do the groups change?

Fixed Changing

On what criteria do you form groups? Check all that apply.

Random Convenience Ability

Interest Students’ preference

Other:

What changes do you make to your classroom to support students’ learning? Check all that apply.

Seating arrangements

Audio/Visual resources

Providing alternative or supplementary texts
Appendix H

Interview Guide

Interviewee:

Date:    Time:   Setting:

**Deliver introduction to the interview.**

**Questions**

I. How did you decide on teaching science?

II. As you have gained experience in a science classroom, how has your teaching evolved?
   A. With respect to instructional goals?
   B. Organization of the curriculum?
   C. Activities and assessments?

III. How do you think students learn best?
   A. How do your teaching practices reflect those beliefs?
   B. How do you engage students with your teaching?
   C. What role does inquiry play in your teaching?
   D. How do your students’ characteristics influence how you teach?
      1. Does a student’s readiness level change how you’ll teach him or her?
      2. What about their personal interests?
      3. Preferred methods of learning?
   E. How do the resources available to you affect your teaching practices?
      1. How do you use what you have to meet students’ needs?

IV. What do you know about differentiated instruction? How would you define it?
   A. If at all, how does DI theory influence your approach to planning/delivering lessons?
1. How do you use it apart from accommodations required by IEP’s?
   a. How do you change what students learn (the content) or how students access it based on their individual characteristics?

20. What adaptations do you make for how students learn the content—the processes that you have students make sense of the content—including how students are grouped to complete activities?
   b. Do you allow students to turn in different products or ways to express what they’ve learned? If so, what alternatives do you allow?
   c. What changes do you make to the learning environment based on what you know about your students?
Appendix I

Artifact Checklist

Participant:

☐ Lesson plans

   Unit: ____________________________________________

☐ Activity hand-outs

   1. ______________________________________________

   2. ______________________________________________

   3. ______________________________________________

   4. ______________________________________________

   5. ______________________________________________

   6. ______________________________________________

   7. ______________________________________________

   8. ______________________________________________

☐ Electronic media

   ☐ Websites:

      ______________________________________________

      ______________________________________________

   ☐ Images

      ______________________________________________

      ______________________________________________

   ☐ Other

      ______________________________________________
Appendix J

Teaching Artifact #1

Teaching Artifact #1. Research guide developed during the planning phase to focus students on a big idea. This figure shows the notes one student developed for Diana’s resource jigsaw activity and features the questions from the guide and the student’s answer. The student used this during the presentation to make sure that all the important details of the big idea were covered.
Teaching Artifact #2. Planning strategies for emphasizing vocabulary. This figure shows the notes one teacher prepared to help her students better understand the vocabulary terms necessary for learning a concept.
Teaching Artifact #3. Organizational routine developed during the planning phase to maximize instructional time. This figure shows how one teacher developed a classroom routine to streamline how students would complete activities using clickers.
Teaching Artifact #4. Room setup, completed during the planning phase, as a resource to communicate content. This figure shows how one teacher arranged her room so that students could experience the concept of a sea breeze.
Teaching Artifact #5. Cell parts analogy table to guide direct instruction during the teaching phase. This figure shows how one teacher supported his or her form of direct instruction by creating a corresponding guide for his or her students.
Teaching Artifact #6. Listening guide as a supplement to direct instruction during the teaching phase. This figure shows a section of students’ listening guides for one teacher’s jigsaw activity on natural resources.
Teaching Artifact #7. Adaptations poster as an example of the variety of sense-making activities in the teaching phase. This figure shows an example of the variety of sense-making activities.
Teaching Artifact #8

Teaching Artifact #8. Cloud index cards as an example of the variety of sense-making activities in the teaching phase. This figure shows another example a teacher’s visually based sense-making activity.
Teaching Artifact #9

Teaching Artifact #9. Camouflage adaptations activity as an example of the increasing complexity of activities during the *teaching* phase. This figure shows the butterfly a student decorated to be camouflaged with a blue-painted section of the wall.
Teaching Artifact #10. Illustrated notes representing an emphasis on visual learning during the teaching phase. This figure shows Brad’s strategy of having students illustrate their notes to provide aspects of an important detail visually.
Teaching Artifact #11. Visual flash cards as an example of the emphasis on visuals in the teaching phase. This figure shows how one teacher included visual elements in instruction and activities based on an understanding of how middle school students learn best.
Teaching Artifact #12. Teacher website arranged according to content standard for targeting students during the reteaching/extending phase of instruction. This figure shows how one teacher organized a system of reteaching.
Appendix K

Audit Trail Summary

<table>
<thead>
<tr>
<th>Participant</th>
<th>Observations</th>
<th>Interview</th>
<th>Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>10/30-11/4</td>
<td>11/1</td>
<td>11/1</td>
</tr>
<tr>
<td>Christine</td>
<td>11/11-11/14</td>
<td>11/14</td>
<td>11/14</td>
</tr>
<tr>
<td>Diana</td>
<td>11/11-11/14</td>
<td>11/13</td>
<td>11/10</td>
</tr>
<tr>
<td>Elise</td>
<td>11/11-11/14</td>
<td>11/11</td>
<td>11/10</td>
</tr>
<tr>
<td>Henry</td>
<td>11/18-11/21</td>
<td>11/19</td>
<td>11/14</td>
</tr>
</tbody>
</table>
Appendix L

Sample Interview Transcript

Interviewee: Fred
Date: 11/20  Time: 7:15am  Setting: home school

Questions

I: How did you decide on teaching science?
Fred: Because it was the position that was available. And the reality is, I’m kind of a history person yet while I was in college I really fell in love with science so it wasn’t a stretch to go for that. I do enjoy it, I don’t think I would teach anything else now.

I: Well, how long have you been teaching again?
Fred: That’s a good question. I graduated in 1999, but I had a bunch of military deployments, so somewhere between 12, 13 years. Depending on how you count it.

I: As you have gained experience in a science classroom, how has your teaching evolved?
Fred: It’s improved dramatically. You know sometimes I even wonder what the heck I was doing back then. The thing that used to frustrate me in previous years when I was having trouble with my value-added scores, you know, if you came into my classroom at any time, it wasn’t like we were sitting around twiddling our thumbs. You know, I’m a big believer of keeping the kids productively engaged. The probably two or three primary areas have changed and that have improved my teaching and my value-added scores is my alignment, one is making sure that I’m teaching what I’ve been hired to teach. You know as I’ve explained to people before, you know let’s say you hired me to put a swimming pool in your backyard and I came in and I came and put a deck. It can be a great deck but you hired me to put in a swimming pool. You know I was teaching science but I wasn’t necessarily focused on the very specific objectives they had hired
me to teach. Now, I try to have a laser focus on that. Another thing is my assessments. You know I rely heavily on the assessment questions provided by the [state] department of education. You know in 2009 they gave out a set of questions and 2013 they gave out a second set of questions. And these questions are written by [company], the company that’s subcontracted out by [parent company] who writes our [state] test so it’s probably the same group of individuals that wrote all this. And what makes those good questions are, It is what the test is going to look like so it’s written by professionals who did this for a living at the appropriate rigor level and so by using those frequently, I don’t like just do a little review two weeks before [the state test], I use them throughout the whole year. I’m trying to prepare the kids for the appropriate alignment and rigor level. And so that, my assessments, and my third thing is my remediation. You know it’s just natural now when I give a test, I understand for the next three to five days after, we’re doing remediation trying to bring up the deficit areas for each and every student you know. And the survey you just had me fill out talked about having groups doing different things, that’s a case you know where my advanced students, they may have had a high degree of mastery and so they don’t have as much to do and the other people might have to do a lot more remediation but I have follow on assignments and I usually tie all this into my website and the computer labs.

I: How has your teaching changed with respect to instructional goals? You mentioned the alignment has kind of changed

Fred: Well it’s just, you know my goal is always to teach well, and now I want to teach well exactly what they want me to teach them. You know the interesting thing is, I always used to feel like I never felt like I had enough time and of course I still often feel that way but as far as getting all my content in, each year for the last few years, I end up with a greater and greater
window of time prior to [the state test] in which I in essence taught everything for the whole year, I’m not going to use the word cover but, I taught it and then I have time to review. I remember when I used to teach over at (school), I mean, like the first year, I had like you know three days and I had wrapped everything up and the next year I had like a week, then two weeks, and this last year I had a month and a half. I was done with my curriculum. The thing is by focusing with a laser intensity on the objective, you cut out the fluff, you know that’s what amazes me when I look back is how much stuff I used to teach that was you know, not that it wasn’t valid science, it just wasn’t part of my curriculum, and I think wow I was just wasting my time on that.

I: How has your organization of the curriculum changed as you’ve gained experience?

Fred: What do you mean?

I: As far as when you teach certain things, how long you spend on them, things like that.

Fred: The length of time I spend on them has changed, the how more or less I follow the scope and sequence you know, they’ve got kind of a chronology you know, (another teacher) and I we rearranged some stuff because they had, they were teaching about atoms after they were teaching about elements, but elements are the different types of atoms so other than that, it’s primarily the district-mandated scope and sequence.

I: How have your activities and assessments changed as you’ve gained experience? You mentioned you changed those assessments to focus on those [state test] questions but are there other things about other activities other tests that you

Fred: That have changed over time? Yeah in two key areas. One, you know my first few years of teaching 8th grade science was at a school where I didn’t have a lab classroom. And so in formative years, I didn’t get into the mindset of doing many hands-on lab activities, and it took
me a while to get comfortable you know designing them, finding them, resourcing all those activities. And so now more or less you know, probably with every unit I’ll have at least one kind of specific hands-on activity. The other thing is the heavy use of technology and all the technology resources such as ExamView software suite, the ability to put those assessments on my webpage, making my webpage, making my webpage with you know the links and everything set up for it so it’s something that can be used year after year and referenced by students on kind of the flipped classroom model.

I: How do you think students learn best?

Fred: I think students learn best when they are challenged and actively engaged. Beyond that, there’s all kinds of different things, you know we talk about the different learning styles and a certain degree of that is true and a certain degree of that is complete bunk too. You know you can be in a classroom environment and have a energetic teacher who’s just dedicated to getting it across to you and you’re willing to learn, it doesn’t matter what your learning style is, you can get it. Sometimes I think we put too much emphasis on that, oh Johnny’s a visual, I can’t, you know, they can’t talk to him, that’s nonsense. That just means he’s probably going to do better with visual stuff. The thing with that is and the overall concept of differentiation is, you know, it used to really challenge me, to think I gotta come up with 3 different lessons for every ability group and everything and that’s not the case. You need to approach your content from a variety of angles. You know the way I teach it the first time is not necessarily the same way I do when I remediate it and you know, sometimes we’ll do standard lecture format and sometimes we’ll do a hands-on activity, sometimes we’ll do a section review, sometimes we’ll do a foldable, sometimes we’ll do a website-based stuff. Just by keeping it fresh and keeping it interesting, I think that gets results.
I: Yeah I remember I’ve seen you once upon a time have the different groups. There was the Newtons and the Einsteins and do you do that anymore?
Fred: Yep, I haven’t done that in a long time.
I: How do your teaching practices reflect those beliefs?
Fred: Well since it comes right down to you know I, we’re, for the set of standards we’re trying to get the kids up to, you know what I do now is, you know I’m taking that standard, one of the thing again that used to really frustrate me was I felt like ok, I gotta have some kind of separate lesson plan for the high group, for the middle group, and the high group’s gotta be stretched and all that and there’s truth to that but the thing is, it’s not an ever-increasing ceiling. I don’t need to have my high group doing 9th grade, 10th grade or college level work. They’ve got to be doing work up to mastery, up to a high degree of mastery of the standards. So I teach all my lessons towards that high group, I expect everybody else to be able to step up. And for the middle and low, it challenges them, but you get a higher set of results. In fact, every year my highest gains always come from my high group. I find that they’re actually the easiest to get gains with if you’re teaching specifically to the standards because those guys are going to get it you know.
I: How do you engage students with your teaching?
Fred: Well just I approach it from multiple facets like I was talking before, try not to teach the same way every time you know. Even on my notes you know I’ll change them up, what we did this last week, so we had six objectives on our benchmark test, for each day for six days we focused on 1 objective so you know I went back over my previous set of notes and I put in different graphics, different images, just to keep it more interesting, variety.
I: What role does inquiry play in your teaching?
Fred: Define inquiry for m., I get confused on that term.
I: I'm kind of curious as to how you would define it for your classroom. When you think this is an inquiry-based lesson, what’s something that’s going to be happening?

Fred: You know, I don’t ever think about whether this is an inquiry-based lesson. I mean, that’s a buzzword that used to be thrown around six, eight years ago and you know, it’s kind of come in and gone away. That doesn’t mean I don’t do inquiry stuff, it just depends on how one interprets it. I guess the closest that would be is when we do our lab activities you know where the kids are supposed to be asking questions and figuring out things, I don’t put a lot of time to just open-ended things because they can just wander off and go in any direction and that’s all beautiful and noble if you have hours and hours of time to spend on it, in reality I don’t. You know, I’m I gotta get them to a target. And so I probably do more than most perhaps extra guidance built into my lesson plans and everything else because I’ve got a goal. And I’m trying to get you to it you know.

I: How do your students’ characteristics influence how you teach?

Fred: You’re talking like personalities and such?

I: Sure.

Fred: Well, this year has been a case in point in that, and just by the luck of the draw, I had a couple classes where you got more than a few mischievous kids you know, it’s like having one or two is not such a big deal, and I have strategies in place and I have my methods which have been very successful but when you have five in one class, that can be tough. And you know, I’ll be honest where I’d not be, not look forward to that class period. Whereas you got you know my first period which is just all my high group and they’re all generally well-behaved and you just love working with them. So what do I do to get around that? But, well just, I don’t know if this fits in the context here, one thing I do, is I pray for them before I come into the building. I pray
to be loving and patient and kind towards all my students, and I’ll specifically think of the ones that are annoying the heck out of me and I’ll say to myself, help me love this child like he’s my own son. And this goes back to something my principal shared with me at my first school when I taught his son, I taught the assistant principal’s son, I taught the you know, it was a small school and everybody wanted their kids to go there, the thing is, he said you know, always try to show love and compassion towards the kid that’s annoying the heck out of you as you would have for your own child because you’ll always cut your child a little more slack, and be a little more patient and that has helped me tremendously.

I: Does a student’s readiness level change how you’ll teach him or her? Ok, like I’ve seen some examples of that with you know your website and what you’re having students do yesterday, those activities

Fred: Yes, yes and no. It’s not like I think, “O Johnny, you know he didn’t do so well last year so I’m going to coddle him” or something like that you know. My sped students are my lower students, I’m teaching to the high level, I’m just going to be more patient with them and more tolerant of them, their mastery level not being as well from the very beginning and I’m also very willing to work extra with those folks aware of their limitations. The thing I would, used to do over at (school), I still do here particularly like before the Thanksgiving Break, before the Christmas break when we have that last half day, you know since the kids are already here, I would coordinate with you know the parents of 30 students who are in those categories, and I’ll say why don’t you just let them stay here for the rest of the day and I’ll do you know targeted enrichment and remediation for the rest of the day. I also occasionally do near the end of the grading periods with the same group, the Saturday school sessions. You know this last time I did it, I thought I was pretty clever about it because it allowed me to double my numbers without
doubling my work because I had 30 students for the three hours in the morning and then I had 30 students for three hours in the afternoon, and I brought in some smart kids to help me out and did the same thing you observed in class yesterday with all the laptops and so it allowed me to process a whole bunch through here.

I: What about their personal interests? Does that change how you teach?

Fred: If I found out that they’re interested in a certain thing you know, I may bring that up in my examples and stuff to try to catch your interest and things of that nature.

I: Does a student’s preferred method of learning change how you teach?

Fred: You know just I try to address diverse learning styles by making my units approach the content from a variety of angles. And so it seems to work.

I: How do the resources available to you affect your teaching practices?

Fred: Well, I’m very thankful to be a teacher in American Co. where we have so much technology stuff, you know I rely heavily upon the ExamView software, I rely heavily on the CPS clickers, I rely heavily on the website access and all that stuff, and our mobile laptop lab. If I didn’t have those things, I would be unhappy.

I: Can you give me an example of how you use what you do have to meet students’ needs?

Fred: Absolutely, you know take for instance the ExamView software suite which, from what I’ve seen is the best one on the market. It’s not the test banks that came with it, those are rather lame, but it’s the software itself so what (teacher) and I did years ago was take those 2009 sample set of questions about a 100 of them from the Department of Education, we converted them into ExamView and then last year I converted the entire 2013 set plus questions I get out of Study Island, USA Test Prep, and you know other states that have similar objectives on their state tests. They often release their tests, and I get these questions off the internet, I embed them
all into ExamView and what makes that very effective is, it’s so easy to scramble up the questions and answers so that, let’s say I give them just a check of learning while I’m teaching a given objective, and I give them you know five or six questions. Well, it helps me make it to where they don’t necessarily see that same exact question the same way the next time I give them an assessment because I’m able to scramble up choices and stuff. And also the fact that that ties into my website so students can complete an assignment online, it will automatically, if you put it in study guide mode, it’ll show them the answers for what they got wrong and if it’s in assessment mode, it will score it for me and email me the results. That’s powerful.

Well it shifts here to the differentiated instruction part

I: What do you know about differentiated instruction? How would you define it?

Fred: I think differentiated instruction is a buzzword again that’s kind of come and moving on its way out but ultimately, the way to deal with differentiation is just, don’t teach the same way every time. Don’t be that boring “Bueller, Bueller, Bueller,” you know you kind of got to step out of your comfort zone and come up with different ways to approach the same content. You know, that’s one of the reasons, that’s the primary reason that you know I formed the 8th grade science alliance. You know I just feel like you know hey I’m working like a dog here to come up with all these resources, but I can still, there’s only so much time I can put in, but if all the other science teachers are doing some or similar things, why can’t we share stuff? And so you know I have, I routinely, every time I update something, I’ll send something out to the entire science alliance, and sometimes we’ll get something back, and here’s how I got this lesson plan, it was this website. It allows you to have a whole different set so maybe the first time I teach this, I use these examples and this PowerPoint notes but when I come back and review it before a test, I’m using a different set of PowerPoints and different links and then we come back for it over here on
my website, I have a different thing. You know that’s differentiation, you’re hitting them from different angles, different modalities, you know, lots of audiovisual stuff because this is 2013 after all with YouTube videos or Teacher Tube, all that kind of stuff.

I: If at all, how does DI theory influence your approach to planning/delivering lessons?

Fred: Well, primarily on the planning side it takes a lot of time to build this stuff you know. I was working on a PowerPoint this morning, you know I got up at four, and it took me about two hours just to finish this up, it’s something I’ve been working on. You know my average PowerPoint packet if it’s 10 pages, it takes me probably two to three hours to prepare and part of the problem is I’m basically a perfectionist so I’ve gotten better and better at all the aspects of available say in PowerPoint, the animations and stuff and that goes with differentiation as well, you know rather than having, I could get rid of my projector and just have the old type projector and put just you know a piece of transparency down, but this is 2013, these kids are used to technology so I try to make my notes exciting and they do weird things they haven’t seen before, but it takes a lot of time.

I: How do you use it apart from accommodations required by IEP’s?

Fred: Well first let me talk about the accommodations by IEP’s, you know I always found that very challenging because you have this small subset that you’re supposed to do this and this and this for, and I found the only way I could remember and adequately address those was, I just applied those modifications to every student. If I'm supposed to let Johnny do the test over, I let everybody do the test over. If I was supposed to give Jonny a multiple choice thing, I gave everybody a multiple choice thing you know and so, that just made it a lot simpler, particularly you know you’re having an IEP meeting with their parents and they say, am I doing all this, yes and more. You know things like that, read the question again.
I: How else might you use it apart from those accommodations in IEP’s?

Fred: Ok, well it goes back to the same thing I said before is, it’s not like I think, I know you know, sometimes I do the learning style surveys for whatever they’re worth, I’m not really convinced that they’re all that accurate or anything. That doesn’t mean that Johnny’s not more of a visual learner, great. That doesn’t mean that I just come up with visual lessons for Johnny. It comes with the whole package. I, I have enough in my unit that’s visual that Johnny’s going to be stimulated. I have me talking, I have video clips so that’s going to address audio, I try to address all modalities in a unit plan. It may not all be addressed in one given lesson, although often these things are, but during a unit plan you’re going to have hands-on kinesthetic stuff, visual, all these good things.

I: How do you change what students learn, you know the content, or how students access it based on their individual characteristics?

Fred: I don’t change the content, you know. I’ve got 32 objectives that I’m required to teach, in fact, kind of a little bit of a debate with our boss this year, he wanted us at the very beginning our PLC things to establish what was our essential learning to narrow that down to the key things. Well I said I have 32 key things. They’re going to get all of it. That’s my job you know. For me, I don’t know how many objectives you have, 32 is certainly a do-able thing. As I said earlier, I taught all 32 but I still had a month and a half left before [the state test] to review that. I know for history, if they’ve got like 100 objectives, perhaps it’s a little more daunting, but that’s what I’m going to teach them. That’s what I’m being, that’s what they’re going to have on [the state test]. You know it’s like I’m the football coach, I’m trying to take my team to the Superbowl, and I plan on winning. Well we’re going to be able to run the ball, we’re going to be
able to throw the ball, we’re going to be able to pass, we’re going to be able to block, we’re going to do it all.

I: What adaptations do you make for how students learn the content—the processes that you have students make sense of the content—including how students are grouped to complete activities?

Fred: It, it seems like this is kind of redundant, like maybe I’m saying the same things.

I: That’s fine

Fred: It goes back to the whole differentiation. For a given unit, one or more hands-on kinesthetic activities. For a given unit, we’re going to have a PowerPoint presentation. We’re probably also going to have some YouTube videos that sometimes we’ll watch here as a class and I’ll talk about them or sometimes I’ll get the computer lab, either the mobile laptop or whatever else and they’ll be able to go to the website themselves. Sometimes you know we’ll use study island with lessons and stuff that goes with that. There’s a competitor Study Island called USA Test Prep which is similar. One thing I like about them is they actually have little five-minute video clips about the topics and so you know we might give them something like that. It’s just that hitting it from a variety of stimulating and technology-based resources, I think accomplishes all that differentiation stuff.

I: Do you allow students to turn in different products or ways to express what they’ve learned? If so, what alternatives do you allow?

Fred: You know I think one of the questions on your survey addressed that and I was hesitating how I’d reply but, yes and no. I haven’t done a lot with it, you know, not that I don’t want to do more with it, it’s just a matter of time and creating alternative things. What I have started doing some this year is this, you know, for instance we just finished our benchmark test, it’s a you
know four-answer multiple choice thing because that’s what [the state test] will look like. You know of course there’s multiple choice just because you can do well on a multiple choice test doesn’t mean you can do good on an equivalent constructed response test even with the same topics so sometimes what I’ll do here for say these next few days is, I’m going to be working with my lower end group to make sure they can answer the multiple choice questions. But for my higher group folks who have already had mastery of that, what I’ll go back and do is I’ll take the multiple choice questions and I’ll convert them into constructed response, and I’ll say you demonstrated, you’ve got a 99 on multiple choice but let’s see what you really know, can you write that out? And that’s a whole other thing so, you got two different things going on at the same time, and it kind of addresses that, and that’s really the only case where I do stuff like that.

I: What changes do you make to the learning environment based on what you know about your students?

Fred: I probably don’t make hardly any changes to the learning environment based on the students. I do it as I apply a positive learning environment what I think is commiserate for learning for all 8th grade students, you know. I try to be energetic, I try to be positive, you know I try to be respectful, all those kinds of things whether I have a class full of hellions or a class full of angels, I’m going to try be the same consistent, positive, energetic teacher that I always wanted.

I: Now because I’ve seen the way you’ve done this groups, what is this? (pointing to the whiteboard where each class is divided into 2 teams, designated by the names of their captains. Each team has a series of checkmarks in differing amounts)

Fred: This is a simple way to manage student behavior. You know years ago I read a book called Flight of the Buffalo, and it’s a business management thing, and it says basically the old
paradigm in the business world was, is you have the CEO of the company, he’s like the lead goose and everybody else is flying in this formation, you know he’s doing most of the work and everybody else is trailing off of him. To be really competitive in today’s market, you need to have every employ to have a vested interest in the profit of the company, you know from the custodian to the guy who puts the cream in a donut to the CEO. And he said if you can make it more like a stampede of buffalo, there’s no particular buffalo that’s the leader, everybody’s pushing for the same goal. And so I started thinking years ago, how can I make this happen in my classroom? And, what I’ve done is basically I’ve divided each class into two groups, 2 teams which I change every few weeks and then based upon a variety of small things typically, whether or not they have their books, whether or not they have their agendas or their homework or they’re talking out of turn, you know they get you know a mark up on the board. And I even try to emphasize the positive. Rather than giving somebody an X for misbehaving, I’ll give a checkmark for the other team. And so immediately you have on the spot correction, doesn’t require me to do any nonsense paperwork sent to the principal, and you you know, and you’ve got a vested interest because now that team is losing. What we do for the reward, what I used to back when I had, back when my wife still had a job, was you know the winning class they all got what I call a working party. And it was, we’re not going to stop and have a party, we got things to do in (teacher’s) class, but you know, might bring in cookies or whatever else, or popcorn while we’re doing our lesson and that’d be like the first place class, because I used to compete between classes but I think it’s more effective within one class. What’s good about this now is again, everyone has their vested interest, you know if you’re causing, you keep misbehaving on your team and you’re going to get your other teammates, hey, what are you doing? Be quiet you
know, because that means the other time on Friday, they’re going to have cookies and donuts and you’ll have to sit there and watch them.

I: How often do you do those reward parties?

Fred: What I used to do is for the first grading period I was doing, I do it once every week and then the 2nd grading period we do it every 2 weeks, and then 3rd 3 weeks, and that’s usually as far as I go. And the one thing I do now is since my wife retired from teaching this year so we’re $48,000 short, from what we used to have, I don’t know why I thought of it before, it’s really quite brilliant, the winning team, I go great, congratulations, you win the prize. Now when you bring in the cookies and donuts, we’ll have this party.

I: I got you.

Fred: And you know they bring it in. You know.
Appendix M

Sample Observation Protocols

Best Teaching Practices Observational Protocol

<table>
<thead>
<tr>
<th>Participant</th>
<th>Date</th>
<th>Obs. #</th>
<th>Timeline</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>How are concepts connected? - What cell is - types - how like school</td>
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<td>Connected to students' experience? - Introduces cell parts of relating it to a school - relates structural content - - Venue example - story + chart</td>
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<td>Did students have a choice of input or in how to approach the content? - Yes - KWL, what does it want to know, link</td>
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<td>Modeling + cooperative:</td>
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<td>Modeling cognition: I'm a 7th grade, what's going on here? Addressed anticipated misunderstanding</td>
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<td>How are experiences with the content encouraged?</td>
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<td>Process</td>
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<td>Independent work activities: KWL, notes</td>
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<td></td>
<td>Cooperative activities: Share of NBL, PAL, buddy (not end - notes side)</td>
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<td>Did the collaboration move from small to large groups?</td>
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<td>Was evidence used to support/refute group ideas?</td>
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<td>Did each group member have a defined role?</td>
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<td>INQUIRY:</td>
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<td>Did the inquiry deliver content, or support already covered content?</td>
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<td>How did students engage in the inquiry? (circle)</td>
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<td></td>
<td>designing investigations using scientific reasoning</td>
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<td></td>
<td>using equipment recording data analyzing results</td>
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<td></td>
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<td></td>
<td>discussing the findings</td>
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371
<table>
<thead>
<tr>
<th><strong>Product</strong></th>
<th><strong>Formative or summative (circle)</strong></th>
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**Notes**

- How does the teacher manage activities to maximize instruction?
- How does the teacher account for student diversity?
- Any observable way the assessment data is used to drive future instruction?
- Product-focus acting on data.

**Form:**

- Learning Environment
- Teacher/Student Engagement
- Materials
- Student

**Notes:**

- Revisit 04.
- What did the teacher do to increase student engagement?
- What did the teacher do to modify the learning environment?
## DI Observational Protocol

**Date:** 11/11  
**Participant:**  
**Obs. # 1**

<table>
<thead>
<tr>
<th>Content</th>
<th>DI Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compacting:</strong></td>
<td><strong>Process</strong></td>
</tr>
<tr>
<td>Multiple Inputs:</td>
<td></td>
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<tr>
<td>- Image of &quot;Why learn&quot;</td>
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<tr>
<td>- KWL Chart on easel</td>
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<tr>
<td>- Notes from pg.</td>
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<td>- Story (T. reads)</td>
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<tr>
<td>Concept-based Teaching</td>
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<td>- &quot;Cell like a school&quot;</td>
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<tr>
<td><strong>Mini-lessons</strong></td>
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<tr>
<td>- Notes - Story - BW</td>
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<tr>
<td>- Teach w/ diff. obj. focus</td>
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<td><strong>Support for Accessing</strong></td>
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<tr>
<td>- Display &quot;Reasons why I say&quot;</td>
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<tr>
<td>- Writing on paper (KWL)</td>
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<tr>
<td>- T. reads Story that students copy</td>
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</table>

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<tr>
<th><strong>Choice?</strong></th>
<th><strong>Tiered?</strong></th>
<th><strong>How are the essential criteria and expectations of quality made known?</strong></th>
<th><strong>How are students grouped and encouraged to contribute in coop work?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>- Display notes/sheets</td>
<td>- Students in pairs or small groups</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Journals/Reflections</strong></th>
<th><strong>KWL for cells</strong></th>
<th><strong>What is the format(s) of the product/assessment?</strong></th>
<th><strong>What supports or accommodations are provided for?</strong></th>
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| **Problem-based/Lab Activity:** | | | |
| **Role-playing/Debate:** | | | |
| **Centers/Jigsaw Activities:** | | | |
| **What are the modifications?** | | | |
|                                | | | |
|                                | | | |
|                                | | | |

**Learning Contracts**

- Screen images/notes on chart
**Points of Contact**

- Lot, just write notes
- Then, immediately after, stand: share something w/ elbow
- X2: tell in theory: ex/pro.
- L explain/illustrate part of story, show chart, then go write

---

**Comparison with Interview Data**

How may the teacher differentiated according to readiness, interest, or learning preference?

- Wait, listen
- Understanding of how prefer/best learn: math, talk by choice (challenging)
Appendix N

Sample Researcher Memo

- mentioned little assessments: pull for HP
- st. had made change T in scores
- short assess, grade in class: 80% (abd)
- Pace: st. starting as walk in (not bell)
- fast-talk, often has to hold st.'s (use hands)
- supports material on screen, reads/explains strings
- during BW, T V's w/ indv. on marker, etc.
- Vocab support: explains as come up
- "consume" (BW), "protein" (slide) <protein> (anticipating: cytoplasm, "mito"
- randomly calls on st. for BW
- Jays: LOTS
- digging deeper ("why"); extending, diversifying
- Connect back: wraps E; will review
- forward: preview topics - you'll like it tough!
- mentions systems, cell structure
- Routines: BW, N book, colored folder w/ story, Compass

- Obj/Concept: how cell like school - organelles
- begins unit by trying to connect to exp
- sts predict image (muscle cell)
- personal story of daughter to connect to real life w/ sts