# Supporting Students with Learning Disabilities in Inclusive Middle School Science Classrooms

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THESIS

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# ABSTRACT

The Next Generation Science Standards (NGSS) require students to use language in different ways. Expressive and receptive language skills are necessary to participate in the standards--based scientific practices of asking questions, constructing explanations, and engaging in arguments from evidence during scientific discussions. Participating in scientific discussion requires use of domain-specific vocabulary and comprehension of complex texts or science concepts. At the same time, the introduction of NGSS offers opportunities to identify interventions for teaching scientific practices to all students, including students with learning disabilities who frequently receive science instruction in general education science classrooms. Through three case studies of science and special educators co-teaching in middle school classrooms and a cross-case analysis, I described the educators' perspectives on the use of language in science and the interventions they offered to all students and specifically to students with LD, as they taught NGSS-based science during nine observed lessons. Three main findings emerged from the study. First, teachers reported that expressive and receptive language skills and vocabulary knowledge impacted their students' ability to learn science, and they frequently planned literacy-based instruction. Second, science teachers and special educators revealed limited understanding of how to teach students to ask questions, construct explanations, or argue from evidence. Third, although the teachers used some evidenced-based practices for teaching students with LD, they did not explicitly identify the practices as interventions for students with LD. Instead, they frequently identified the special educator as the primary intervention.

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## I. Introduction

Science instruction in middle school classrooms and specifically science instruction for students with learning disabilities (LD) in inclusive middle school classrooms is an area of education worthy of attention for several reasons. For over a hundred years, the U.S. has had a policy in place to promote equal access to science and technology education for all citizens. The Science and Engineering Equal Opportunities Act of 1980 was amended in 1985 to include students with disabilities. Although the policy calls for equal access, DeBoer (2013) argued that the policy has not been effective at providing equal access for students belonging to underrepresented groups because the motivation for science education equality was frequently related to economic benefits for society as a whole. He argued that morality should serve as the motivation for equal access to science and technology education for all because it would lead to "more persistent efforts to achieve equity and, therefore, to more consistent and more effective policies and outcomes" (DeBoer, 2013 p.18). Currently, the dismal outcomes of science learning for students with and without disabilities is concerning and is another reason to study science education. Additionally, the way science is taught in general education classrooms will change with the adoption and implementation of the Next Generation Science Standards (NGSS), placing the focus on the integration of disciplinary core ideas, cross-cutting concepts and scientific practices. NGSS-based science instruction requires students to use rich and varied language. As students with LD are increasingly receiving science instruction in general education classrooms, with varying types of interventions including co-teaching, such language intensive standards-based instruction may create challenges if interventions are not provided for receptive and expressive language use and connected literacy skills. In light of those reasons, it is vital to examine the instructional practices and interventions used to help students with LD access the reform-based instruction NGSS promotes in inclusive middle school classrooms.

**Middle School as a Distinct Phase of Learning**

The concept of educating young adolescents, ages 10-14, in middle schools uniquely designed to meet their developmental needs emerged in the 1960s. Over the next fifty years, researchers built a body of literature related to a view that the developmental needs and challenges of pre-adolescents warranted unique pedagogical practices. Organizations such as the National Middle School Association and Association for Middle Level Education developed and promoted special beliefs and practices for pre-adolescents as well. Schaefer, Malu & Yoon, (2016) analyzed over fifty years of literature related to educating middle school students and highlighted the major trends during each decade. They reported that early middle school literature focused on educating the whole student through interdisciplinary teams of teachers aimed at developing students academically, emotionally, physically and socially. "Advisory" times with one teacher on the team were designed to develop peer and student/teacher relationships in addition to academic learning goals. Interdisciplinary teacher teams shared common planning time with the aim of developing cross subject-matter academic units and to monitor student progress and development. In the 1990's, advisory, cooperative learning, teaming, and engaging all students continued to be at the center of middle school literature. Differentiating instruction began to appear in the literature in the 1990's. Differentiated instruction to meet the needs of diverse learners was a middle school practice that paved the way for the inclusion of middle school students with learning disabilities in general education classrooms (Schaefer, Malu & Yoon, 2016).

As the middle school movement reached "adulthood" and shifted to research-based models (Schaefer, Malu & Yoon, 2016) in the early 2000's, the Association for Middle Level Education, identified four attributes of successful middle schools (a) developmentally responsive decision making (b) challenging instruction and high expectations for all students (c) instruction in knowledge and skills to empower all students and (d) relevant learning opportunities for all students. Yoon, Schaefer, Brinegar, Malu & Reyes (2015) reviewed nearly 700 articles and concluded that middle schools were most effective when all the attributes were in place.

The study of middle school is relevant because science literature shows that middle school is the time that many students lose interest in science (Lee, Hayes, Seitz, DiStefano & O'Connor, 2016). Adhering to the attributes of the unique middle school educational focus could be especially important when providing access to science instruction for all middle school students, and especially middle school students with LD in inclusive science classrooms.

**Inclusion and Co-teaching**

There has been a steady increase in the number of students with disabilities receiving instruction in general education classrooms since the Education for All Handicapped Children Act (PL 94-142) in 1975 guaranteed students with disabilities a public education in the least restrictive environment (LRE), IDEA 1997 required that students with disabilities be in programs that "meet the educational standards of the State education agency" and be included in standardized assessments, and IDEA 2004 required the use of scientifically, research-based instructional practices. Increasingly schools are meeting their legal responsibility by placing greater numbers of students with disabilities in the least restrictive environment, which is the general education classroom. In 2016, nearly 68 percent of students with LD spent at least 80 percent of the day in general education classrooms (Kena et al., 2016).

The language used to describe placing students with disabilities in general education classrooms changed over the last 40 years. Mainstreaming was a term used during the 1980's to describe the practice of including students with mild disabilities in general education classrooms, only if the students were able to access the general education curriculum with little or no accommodations. Mainstreaming was viewed as a privilege reserved for students who were thought to be capable (McLeskey & Waldron, 2000). In 1986, Madeleine Will announced the regular education initiative and called on regular educators to take more responsibility for the education of students with disabilities. As a result, there was an increased effort to include students with disabilities in neighborhood school and general education classrooms. With the passage of IDEA 1997, receiving instruction in a general education classroom was viewed as a right rather than a privilege and the term inclusion was used to describe the practice. When summarizing science education research for students with disabilities, Scruggs, Mastropieri and Boon (1998 p. 34) defined inclusion in general education science classrooms as, "the practice of teaching students with disabilities in general education classroom settings, often with assistance of special education personnel who provide services to facilitate learning in these environments." Inclusion is not a federally defined term, but emerged in part from the language in IDEA 2004:

> To the maximum extent appropriate, children with disabilities, including children in public or private institutions or other care facilities, are educated with children who are not disabled, and special classes, separate schooling, or other removal of children with disabilities from the regular educational environment occurs only when the nature or severity of the disability of a child is such that education in regular classes with the use of supplementary aids and services cannot be achieved satisfactorily.

Reflecting the teaming approaches promoted in middle school education, co-teaching has become an increasingly common practice to support students with disabilities in inclusive classes. It is defined as

> the partnering of a general education teacher and a special education teacher or another specialist for the purpose of jointly delivering instruction to a diverse group of students, including those with disabilities or other special needs, in a general education setting and

in a way that flexibly and deliberately meets their learning needs. (Friend, Cook, Hurley-Chamberlain & Shamberger, 2010 p. 11)

Solis, Vaughn, Swanson and Mcculley (2012) assert that although the definition of co-teaching is straightforward, the implementation varies greatly and is often impacted by the relationship between the co-teachers. Further highlighting the variability, Zigmond and Magiera (2001 p. 2) explained that "research on co-teaching is very difficult to conduct in a way that informs practices." They cited the variability among co-teachers, their roles, and their students' diversity as reasons that "precise investigations" and "validation research" are limited. In spite of the mixed results, co-teaching is increasingly being employed to provide students with disabilities access to the general education curriculum while still receiving special education services (Friend et al., 2010). Co-teaching is a complex service delivery model that is influenced by the relationship between the co-teachers, as well as the content and pedagogical knowledge of each teacher.

Although many models of co-teaching have been presented in the literature, often the special education teacher serves as an assistant in the classroom (Scruggs, Mastropieri, and McDuffie, 2007; Solis et al., 2012). To maximize the benefits of co-teaching, Brown, Howerter and Morgan (2013) suggest that co-teaching teams engage in active communication, co-plan to prepare for instruction, share instructional delivery and assessment and have a structure for resolving conflicts that may arise. After reviewing nearly 150 studies on inclusion and co-teaching, Solis et al. (2012) noted that the greatest improvements in co-taught instruction occurred when changes began at the curricular level. The researchers reported that "when the specialists coordinate curriculum changes, significant changes are more likely to occur" (Solis et al., 2012 p. 507). The implementation of NGSS presents an opportunity to coordinate curricular changes that utilize the specialized knowledge and skills of co-teachers in inclusive classrooms to provide access to science for all students, including students with LD.

**Characteristics of Students with LD**

To provide such opportunities to all students, educators need to acknowledge the increased use of language and literacy skills essential to meeting the requirements of NGSS. For students with LD, and the concomitant challenges some have with language and literacy, appropriate interventions could be especially important. A learning disability is defined in IDEA 2004 as "a disorder in one or more of the basic psychological processes involved in understanding or in using language" (IDEA, 2004). Although students with LD typically have average or above intelligence and many areas of strength, the students tend to underachieve in some academic areas, with a lack of an easily identifiable cause (Swanson, Harris & Graham, 2013). In the past, a learning disability had been identified after other causes were excluded. Exclusionary conditions might have been intellectual disabilities or behavioral, economic or social issues that tended to interfere with learning. If those types of conditions did not exist, a learning disability was believed to be the cause of underachievement. In an effort to better understand what a learning disability is, inclusionary conditions are now used to identify the presence of a learning disability. Common inclusionary methods for identifying a learning disability are cognitive discrepancies between a cognitive measure and achievement, low-achievement and inadequate response to instructional interventions.

In science, students with disabilities, including those with LD, perform significantly below their peers without disabilities (Therrien, Taylor, Hosp, Kaldenberg & Gorsh, 2011). There are a variety of ways a neurological disability might impact how a student with LD perceives and/or processes information in science classrooms. Some students with LD struggle to process oral language (Matson & Cline, 2012), a key skill in classroom instruction that utilizes teacher-directed instruction and discussion. That might lead to misunderstood directions and awkwardness during a discussion (Baxter, Woodward, Voorhies, & Wong, 2002). For other students with LD, deficits in selective attention may make attending to lectures or discussions difficult (Greenham, Stelmack & van der Vlugt, 2003). Some students with LD might not be able to fluently read and comprehend grade-level text (Gersten, Fuchs, Williams, & Baker, 2001; Vaughn, Levy, Coleman, & Bos, 2002), such as the complex, informational texts called for in the CCSS English Language Arts Standards for Science & Technical Subjects. For some students, visual perception problems may interfere with the ability to read informational texts or understand diagrams, charts, and graphs frequently used to display information in science (Betjemann & Keenan, 2008). Scruggs et al. (2013) suggested that learning complex science vocabulary, analyzing higher-level text and writing in scientific formats may be areas of relative weakness for some students with LD. Therefore, without appropriate interventions, the language intensive NGSS standards may present challenges for students with LD who perceive and process receptive and/or expressive language differently than those without LD (Brigham, Scruggs, & Mastropieri, 2011; Villanueva & Hand, 2011). While we recognize the need for interventions, we lack research about the types and intensity of the interventions for the success of students with LD receiving science instruction in inclusive general education classrooms.

## Science Instruction for Students with LD

While science continues to be the content area in which students with LD are most likely to receive instruction in a general education classroom, Cawley, Hayden, Cade and Baker-Kroczynski (2002) argued that educators have not yet created and tested a comprehensive program to meet the learning needs of students with LD who learn in the general education classroom. That is in spite of the fact that there is a bank of research-based practices for instructing students with LD in science. Numerous studies have indicated that students with LD can be successful in science when provided with appropriate interventions (Minner et al., 2010; Scruggs et al., 2013; Therrien et al., 2011). For example, based on a meta-analysis of 12 studies published between 1980 and 2010, Therrien et al. (2011) reported that students with LD in science benefit from teacher-directed structured inquiry that explicitly focuses on concepts. Additionally, the researchers reported that formative feedback to ensure task engagement increased science learning for students with LD. Mnemonics for the recall of basic science knowledge and a structured peer-tutoring program that offered tiered instructional materials were other interventions that showed a positive impact. Minner et al. (2010) noted similar findings for structured inquiry, especially inquiry instruction that focused on students' critical thinking, drawing conclusions from data, and performing scientific investigations. Scruggs et al. (2013) likewise reported the benefits of hands-on, small group activities and experimentation, as well as class discussion and adapted instructional materials. Based on an analysis of six articles, Dexter, Park, and Hughes (2011) concluded that the use of graphic organizers increased science vocabulary knowledge and factual comprehension for students with LD.

Research that described effective adaptations to science instruction for students with LD is readily available. McGinnis (2013) reviewed the literature related to making science instruction accessible and relevant and compiled suggestions for adaptations organized around three categories (a) curriculum adaptation, (b) instruction and (c) assessment. Recommendations for curriculum adaptations included modifying curriculum materials by adapting readings and activity sheets to match the student's level of ability, providing written and oral directions, shortening assignments, giving directions in small steps and reading directions to the student. The recommended instructional adaptations were hands-on activities, peer-tutoring, reteaching vocabulary, recording lectures for later review, multimodal instruction, and frequent checks for understanding. Additionally, McGinnis suggested modifying assessments by embedding strategic information, modifying assessment procedures by differentiating time limits, and/or modifying grading as appropriate for individual students.

Evidence-based practices have also been identified through rigorous, randomized experimental or quasi-experimental studies. The Council for Exceptional Children identified evidence-based practices for students with LD in science through a joint initiative of the Division for Learning Disabilities and the Division for Research, two divisions of the Council for Exceptional Children (CEC). They defined evidence-based practices as “practices for which there is solid research evidence of effectiveness” (Espin, Shin & Busch, 2000 p.1). Instructional practices categorized as “Go for It” have a solid research base, while instructional practices categorized as “Use Caution” have preliminary, incomplete, mixed, or negative results. Class-wide peer-tutoring, vocabulary instruction, mnemonic instruction, formative evaluation, and direct instruction are “Go for It” instructional practices that have been shown to be effective for teaching students with LD in science classrooms. In light of the current level of science achievement for all students, those research-based, evidence-based practices could lead to improved instruction and learning in inclusive middle-school science classrooms as NGSS are being implemented.

**Science Achievement**

Standardized test results show science achievement in the U.S. is lagging behind science achievement in other modernized countries. Results from the 2015 Programme for International Student Assessment (PISA) reveal that the U.S. ranked 25 out of 72 participating counties, and scored only slightly above the average score (OECD, 2016). Furthermore, results from the National Assessment of Educational Progress (NAEP) indicated that by the end of eighth grade, 33 percent of U.S. students had less than a basic understanding of fundamental science concepts (NCES, 2016). Science achievement for students with disabilities was even more dismal.

Nearly 75 percent of eighth-grade students with disabilities scored below the basic level, meaning they had less than a basic understanding of fundamental science concepts (NCES, 2016). Performing below the basic level in eighth grade indicates that students might be unable to recognize science principles or explain natural phenomena at microscopic or global scales. For example, eighth-grade students might not be able to describe common physical and chemical changes, the levels of organization of living systems, or the effects of potential and kinetic energy on moving objects. Additionally, those students may be unable to design observational and experimental investigations or critique science evidence or arguments (NCES, 2016).

Having a citizenry with at least a basic comprehension of science and technology is vital in our modern society (NRC, 2012). A grasp of science and technology is necessary to evaluate policies at the national and local levels and to make informed decisions at the personal level (NRC, 2012). At the personal level, individuals make decisions about important issues such as medical care or career choices. Therefore, in addition to the morality of science education for all, a workforce with a fundamental knowledge of science, technology and engineering is necessary for economic development in the United States. (NRC, 2012). The implementation of NGSS provides an opportunity to improve science instruction for all students.

**Next Generation Science Standards, Inquiry, and Scientific Practices**

As a result of stagnant student achievement in science and advances in science and science education since national science standards were last published in the 1990’s, the Committee on a Conceptual Framework for New K-12 Science Education Standards created a new framework for science education. It was the first step toward new national standards and served as the foundation for NGSS. In collaboration with The National Research Council (NRC), the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve, state boards of education developed a new set of science standards for grades K-12. The Next Generation Science Standards (NGSS) define three dimensions of science learning: (a) Scientific and Engineering Practices, (b) Crosscutting Concepts, and (c) Disciplinary Core Ideas. Scientific and Engineering Practices describe the "doing of science." Doing science has often been referred to as inquiry in science education literature, and numerous studies have established that inquiry-based science is an effective instructional practice for students with disabilities (Minner, Levy & Century 2010; Scruggs, Brigham & Mastropieri, 2013; Therrien Taylor, Hosp, Kaldenberg & Gorsh, 2011; Yager & Ackay, 2010). However, the term "inquiry" has been loosely defined in research, and therefore, the results of those studies have not been helpful for informing classroom instruction (Therrien et al., 2011).

In science education literature, scientific inquiry has been referred to as the processes students engage in as they design and conduct investigations, and it has been referred to as the pedagogy used to develop students' understanding of scientific concepts through investigations (NCR, 2012). Minner et al. (2010) identified three necessary components of inquiry-based science (a) science content, (b) active student engagement and (c) opportunities to perform the work of scientists. In contrast, Banchi and Bell (2008) described an "Inquiry Continuum" that spans four levels of engagement (a) confirmation, (b) structured, (c) guided and (d) open inquiry. Yager and Akcay (2010) similarly described a spectrum of inquiry that ranged from open inquiry to guided inquiry. Since inquiry has been loosely defined in the past, science teachers may have varied understandings of inquiry, and those understandings may not align with the clearly defined Science and Engineering Practices in NGSS. As a result, teachers may not know the best ways to teach NGSS practices. In fact, Haag and Megowan (2015 p. 422) report that most of the 710 middle school and high school science teachers who completed a readiness assessment for

NGSS-based science were "anxious about inadequate training" as they begin to implement NGSS practices.

To address the ambiguity of the definitions of inquiry, creators of the NGSS Framework used the term *practice* instead of inquiry (Scruggs et al., 2013). The term practice implies that students need to learn a set of skills related to scientific inquiry and then use them to refine their abilities. Bybee (2011) explained that using the term practice highlights the necessity for repetition in order to develop the skill. The eight inquiry-oriented practices in NGSS describe what students should be able to do as they develop an understanding of the nature of science and how scientific knowledge is developed. Students in grade K-12 are expected to use each scientific practice at an increasing level of complexity as they advance in school. The eight NGSS Scientific and Engineering Practices for students in kindergarten through twelfth grade are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (NRC, 2012 p. 43)

All students are expected to gain experience using all of the scientific practices. NGSS learning progressions describe increasingly complex behaviors, skills, and ways of thinking and communicating related to each scientific practice.

To guide teachers as they integrate the three dimension of NGSS (Scientific and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas), the NGSS developers suggested bundling performance expectations. Disciplinary core ideas were intertwined with the scientific practices that teach critical thinking and communication skills in science (NRC, 2013 p. 489). Bundles, or units, integrate the three dimensions of NGSS with Common Core State Standards (CCSS) for English language arts and math. Bundles show connections between ideas, facilitate phenomenon-driven instruction, and promote efficient use of instructional time (NRC, 2013 p. 489). As students are expected to read, write, listen, and speak in science classrooms, CCSS in English language arts were included in the NGSS bundles. Consequently, NGSS-based science instruction presents increased language demands and requires students to participate in classroom discussions. The importance of developing language skills in science is highlighted by the overarching goal set forth in the Framework.

> By the end of 12th grade, … *all* students possess sufficient knowledge of science and engineering to engage in public discussions on related issues (National Research Council, 2012 p. 1)

Engaging in public discussion requires students to gain a comprehension of scientific concepts and a strong command of the language of science (Villanueva & Hand, 2011). Taken together, NGSS and CCSS have increased demands regarding what students must be able to do with language as they engage in science learning (Hakuta, Santos & Fang, 2013; Honig, 2012).

**Statement of Problem**

In light of the increased inclusion of students with LD in general education science classrooms, the learning challenges many students with LD face accessing science content and the enhanced language demands inherent in NGSS-based instruction, it is important to know how general and special education co-teachers think about language and literacy in inclusive classrooms as they implement the language intensive NGSS instruction. In addition to language and literacy demands, the NGSS practices define new ways of engaging students in science inquiry. Those scientific practices may require that teachers adjust their instruction to teach the specific skills defined by the NGSS practices.

An investigation of instruction related to three particular NGSS Science and Engineering Practices of asking questions, constructing explanations and engaging in arguments from evidence could shed light on ways that teachers provide instruction and interventions to all students. These three practices were selected because they lend themselves to classroom discourse. As students share their questions and explanations and support arguments through scientific discourse, they have opportunities to build knowledge of the scientific practices along with the disciplinary core idea. Additionally, these practices can be linked as students think and speak like scientists to understand a natural phenomenon. For instance, after observing a phenomenon, they can ask questions about variables that affect the phenomenon and then use their observations and knowledge of scientific principles to construct explanations. Finally, they can engage in arguments from evidence to evaluate competing explanations. Conflicting views in science literature as to how to best teach students to construct explanations and argue from evidence is another reason to examine teachers' perspectives and instructional practices for those two NGSS scientific practices. Additionally, investigating in inclusive, co-taught science classrooms may also shed light on ways to enhance access for students with LD as they learn science and participate in the scientific practices of asking questions, constructing explanations, and arguing from evidence. In co-taught, middle-school, inclusive science classrooms, we lack a rich research base about teachers' perceptions (including co-teaching pairs) and the interventions they use.

## Research Questions

The research questions that guided the study are as follows.

(a) How do science and special educator co-teaching pairs describe the language demands associated with asking questions, constructing explanations, and engaging in arguments from evidence for students with and without learning disabilities in inclusive middle school science classrooms?

(b) What interventions do science and special educator co-teaching pairs provide as middle school students ask questions, construct explanations, and engage in arguments from evidence in inclusive middle school science classrooms?

(c) How do science and special educator co-teaching pairs provide interventions to middle school students, targeting especially students with learning disabilities, within inclusive middle school science classrooms?

## II. Review of the Literature

In this review, I provide the theoretical framework for the study in which I explore the language demands and teacher practices aimed at helping all middle school students in co-taught inclusive classrooms succeed in learning three specific NGSS-promoted scientific practices: asking questioning, constructing explanations and engaging in arguments from evidence. I investigated related literature in the following domains: middle school science, inquiry-based science instruction, inclusion of student with mild disabilities, science interventions for students with LD, vocabulary instruction and NGSS scientific practices and related research. With the advent of the NGSS, science instruction will focus on three dimensions of science: disciplinary core ideas, scientific practices and cross-cutting concepts (NRC, 2013 p. 14). There are eight scientific practices designed to teach students to "do" science in the same manner as scientists when they investigate the natural world through the practices defined in NGSS. Three of the eight practices (asking questioning, constructing explanations, and engaging in arguments from evidence) are language-intensive and require students to think and speak like scientists (NRC, 2013 Appendix F p. 30). Classroom discussions can be used to develop students' skills to participate in the scientific practices. In that way, students' understanding of science is socially constructed, and for that reason, sociocultural theory serves as a foundation for this study.

### Theoretical Foundation

Fagan (2010 p. 95) explained that socially constructed ideas undergo "a process of development that is in some way mediated by social structures, interactions or values." That process reflects what scientists do as they build disciplinary knowledge; that is, they routinely present ideas, models and findings to others for analysis and scrutiny. Only after numerous and often ongoing reviews and revisions by experts in the field are ideas accepted as possible explanations for natural phenomena. For that reason, I draw on sociocultural principles to provide a theoretical framework. Sociocultural theories developed from Vygotsky (1978; 1986) and those following (e.g., Tharp & Gallimore, 1988; Wertsch, 1991, 1998). I draw on two particular principles: cultural environment and Zone of Proximal Development (ZPD). The first principle emphasizes the role of the cultural environment in developing thinking skills; that is, the expectations and norms and routines of conversation in the setting. According to the theory, “every function in the child's development appears twice: first, on the social level between people, and later on the individual level” (Vygotsky, 1978 p. 57). Knowledge is gained through social interactions and “all higher functions first originate as actual relations between human individuals” (Vygotsky, 1978 p. 57). Bruer (1994) asserted that learning and knowledge are social phenomena, and therefore a social interaction does not make thought visible, but rather, thought is internalized conversation or discourse. Sociocultural theories of learning view social interactions as vital elements for learning and interactive dialogue as crucial for developing knowing (Wiebe, Berry & Kim, 2008). In an inclusive science classroom, a cultural environment that provides opportunities for productive, interactive dialogue is necessary for developing students’ proficiency in the use of scientific practices.

The second principle of sociocultural theory that forms the foundation of this study is Zone of Proximal Development (ZPD). The ZPD is the range between what a child can do independently and what a child can do with assistance (Vygotsky, 1978). An interactive dialogue guided by a more knowledgeable other guides a child’s cognitive development when it is within the child’s ZPD. Sociocultural theorists believe interactions with a more knowledgeable other can scaffold learning of a new skill. Often the more knowledgeable other is the teacher, but the role can also be held by a student with a stronger grasp of the skill. Dewey (1902 p. 22) described a similar idea about scaffolding student learning in *The Child and the Curriculum* where he wrote, “Guidance is not an external imposition.” He went on to explain that some educators "see no alternative between forcing the child from without, or leaving him entirely alone" and added that both fail to see that development is a process that must consider the child's current experience.

In a more recent study of the impact of guidance by a more knowledgeable other, Lepper, Aspinwall, Mumme, and Chabay, (1990) studied expert math tutors to identify how they guide or scaffold learning. Instead of modeling or giving an answer, the tutors (a) asked questions or made remarks to indicate an error had been made, (b) asked questions regarding possible next steps to solve the problem, or (c) gave hints, often in the form of questions, about a part of the problem to think about. Asking questions and giving hints can be considered forms of interactive dialogues students should engage in during inquiry-based science instruction.

**Interactive Classroom Dialogues**

Sociocultural theory stresses the importance of a cultural environment that provides guided interactive dialogues. However, numerous studies have shown that most classroom interactions follow the I-R-E pattern of discourse (Cazden, 2001). During that type of interaction, the teacher initiates (I) the discourse by asking a question. A student is selected by the teacher to respond (R) to the question and the student's' response is then evaluated (E) by the teacher for how closely it matched the pre-determined answer. The correct answer is provided, and the process is repeated with a new question. I-R-E interactions are the most typical form of discourse in classrooms even though it has been well established that engaging students in interactive dialogues positively impacts student engagement and ultimately their learning. For example, interactive dialogues allow students to share the burden of thinking and provide more informational rich contexts for learning while also giving teachers an opportunity to model and scaffold instruction to match the student's zone of proximal development (Englert, 1994). Additionally, Bruer (1994) stated that dialogues that require language comprehension and production is demanding and may result in deeper processing of information. Furthermore, social interactions allow skilled thinkers to demonstrate expert strategies (Bruer, 1994).

Many forms of interactive dialogues have been described in research. One example is from Goldberg (1991), who defined instructional conversations (ICs) as lessons that use classroom discussion to advance student learning of concepts as well as language skills. ICs provide opportunities for students to share their thinking. They also advance students' construction of new knowledge and understanding about the world as teachers guide discussions to increasingly sophisticated levels. Goldberg proposed that ICs are suitable for analyzing complex concepts often presented in literature or history, as well as other domains of learning that are not hierarchically organized, such as math problem-solving. Similar to what Goldberg described, Michaels, O'Connor and Resnick (2008) described interactive talk using the term "accountable talk." They define that as talk used for sense-making and scaffolding or layering ideas linked to each other in discussions that call for particular forms of talk and lead to increased learning of concepts and improved critical thinking. The researchers suggested that three critical features of accountable talk are (a) "accountability to the learning community," (b) "accountability to standards of reasoning," and (c) "accountability to knowledge" (Michaels et al., 2008 p. 283). They emphasized the importance of careful planning as students learn to participate in discussions. Furthermore, the researchers argue that norms of discourse have been shown to "promote equity and access to rigorous academic learning" and "resulted in academic achievement for diverse populations of students" (Michaels et al., 2008 p. 284).

Reciprocal teaching, an instructional practice that has been shown to improve reading comprehension for students with disabilities (Palincsar, Ranson, & Derber, 1988), is another kind of interactive dialogue. In reciprocal teaching, the teacher and students participate in a structured discussion around a text. Students are taught and assigned roles that are based on reading strategies used by successful readers.  As students gain skill in using the strategies, the teacher releases more control of the discussion to the students.  Herrenkohl (2006) modified reciprocal teaching specific to science classrooms, aiming to increase participation during whole group discussions in heterogeneous science classrooms.  He identified three important science thinking practices: (a) "predicting and theorizing," (b) "summarizing results" and (c) "relating predictions and theories to results" (Herrenkohl, 2006 p. 48).  The thinking practices became the basis for roles that students took on whenever small groups of students presented their investigation results to the whole group.  Students were assigned a role and instructed to develop questions based on that role.  Over time, many students became more skillful at asking questions and more students participated in the discussions.  However, it was noted that the teachers' ability to facilitate the discussion was critical to students' successful use of the roles.  That finding could be relevant to teachers in middle school science classrooms as they align their instruction with the language-intensive NGSS standards.

**Middle School Science Instruction and Students' Attitudes**

Literature on science instruction in middle school classrooms reveals that students do not have frequent opportunities to engage in science inquiry practices. Yet as students ask questions, conduct investigations, and discuss explanations and/or theories, their understandings of science phenomena could be socially constructed and provide a foundation for engaging in scientific inquiry practices. In this section, I present a review of middle school science instruction and middle school students' attitudes about science and science instruction.

Kesidou and Roseman (2002) examined middle school science programs to identify research-based criteria for assessing curricular materials. They reviewed eight widely-used science programs to determine how well they identified and supported appropriate learning goals through the teacher guide and instructional design.  The researchers reported that in every curriculum, key ideas about science phenomenon were diluted with less-important, distracting ideas. Neither the content nor the structure focused on consistently presenting key ideas. Notably, none of the programs provided adequate explanations of phenomena through connections to real-world examples nor provided support teachers could use to address students' misconceptions. Furthermore, Kesidou and Roseman (2002) could not examine how these programs presented inquiry skills or discussion because the lack of literature about how students learn those skills made it difficult to establish criteria for examining that feature of the programs.

A broad focus on many disconnected ideas and a lack of authentic scientific inquiry may be the reason many students lose interest in science during middle school. Carlone, Scott and Lowder (2014) conducted an ethnographic study to examine three students' self-identities about science as they progressed from fourth-grade to sixth-grade. The students viewed themselves as high-performers in fourth grade science, and they were the highest achieving students in the class. Through student and teacher interviews, classroom observations and analysis of student work, the researchers documented the attitudes and science performance of the three students in fourth grade and sixth grade science. The fourth grade science instruction was described by the researchers as child-centered, collaborative, and empathetic. The science teacher encouraged students to ask questions, listen to each other and develop their own investigation as a result of those discussions.

In contrast, sixth grade science instruction was notable different. It consisted of reading, worksheets and independent work. Students were required to raise their hands and stay in their seats. Collaborative work was not encouraged nor appreciated. Although the three students continued to do well in science, they lost the passion for asking questions and discussing scientific ideas they displayed in fourth grade. Instead, they thought of science as a list of assignments and a percentage grade to achieve. At the end of sixth grade, none of the students reported an interest in pursuing a career in science.

Wolf and Fraser (2008) also examined how science instruction impacted students' attitudes in middle school science. They compared male and female students' attitudes toward the learning environment and science in inquiry laboratory instruction and non-inquiry laboratory instruction. Students' attitudes were measured using two surveys and their science achievement was measured with an assessment of conceptual understanding. All of the student participants (n=1, 434) completed the two attitude surveys. A subset of students at one school (n=165) participated in the laboratory investigations. Half of the students in the subset completed an eight-week unit of study in which they designed and conducted investigations to answer questions posed by the teacher. The other half completed the same unit of study, but were given step-by-step direction for the investigations. A t-test was used to establish groups that were not statistically different at the beginning of the study. The researchers reported that collaboration was rated as statistically significantly higher by students in the inquiry group. The male and female students' attitudes toward the learning environment differed. Males rated the inquiry instruction more positively, and females rated the non-inquiry instruction more positively. However, the researchers reported that all students in the inquiry group gained skill and confidence as the unit progressed, although female students were more often concerned about performing the investigation correctly and gained confidence slowly. The results of this study shed light on the complexity of inquiry-based science instruction.

Another large-scale study supports the Wolf and Fraser (2008) findings. Aschbacher, Ing and Tsai (2014) reported that by the end of middle school, many students are not interested in studying science or pursuing science-related careers. The researchers administered the Science Is Me survey to 493 eighth-grade students. The 10-statement survey asked students to rate their present level of science proficiency and their anticipated level of science proficiency. Students also rated statements that measured how much they valued learning science and the field of science as a whole. Finally, students were asked to rate their interest in a list of science-related careers. Students were classified into four groups: *Science is me; I value science but I don't do it well; I can do science but I don't value it; Science is not me*. Only twelve percent of students were classified in the *Science is me* group. Those students gave positive answers to nearly all of the survey statements. Fifty-seven percent of the students responded negatively to all of the survey statements and were classified as *Science is not me*. The researchers reported no statistical differences for gender or race, but did note that more students with low socio-economic backgrounds were classified as *Science is not for me*. Overall, students' self-perceptions were significantly related to their interest in science-related careers. Additionally, only eight percent of the *Science is not for me* group were interested in a science-related career. Aschbacher, Ing and Tsai (2014) asserted that skillful implementation of NGSS with greater focus on science inquiry and relevancy to students' lives might change perceptions.

**Inquiry-based Science Instruction**

Though it is widely accepted that inquiry-based science instruction is an effective pedagogy for teaching science (Minner et al., 2010; Villanueva & Hand, 2011; Yager & Akcay, 2010), the use of the term has been vaguely defined. For instance, the term inquiry can refer to the processes students engage in as they design and conduct investigations, or it can refer to the pedagogy used to develop students' understanding of science concepts through investigations (NCR, 2000). Minner et al. (2009) identified three necessary components to inquiry-based science. The first is the presence of science content in the areas of physical science, life science, earth/space science or science inquiry. The second is that students are actively engaged with the content. The final and most complex component describes the roles students take on as they ask questions, design investigations, collect data, draw conclusions, and communicate findings. There are many variations of those inquiry roles that span from completely teacher-directed to completely student-directed inquiry.

Yager and Akcay (2010) described a "spectrum of inquiry" that ranged from open inquiry to guided inquiry. During open inquiry, students are self-directed and take responsibility for decision-making in all essential features of the inquiry process. They pose their own questions, develop their own plan to gather evidence, generate explanations, make connections, and communicate findings with a minimal amount of direction from the teacher (NCR, 2000). Some teachers or students are not ready for open inquiry, so more guidance is provided by the teacher in one or more of the essential features of science inquiry (Maskiewicz & Winters, 2012; Minner et al., 2010; Yager & Alcay, 2010). Furtak, Seidel, Iverson and Briggs (2012) recognized a middle ground of teacher-guided inquiry in which the teacher actively guides students' hands-on activities. Teachers use professional judgment to determine the right amount of guidance for their students based on what they know about learning the science content and their students' readiness to take more responsibility (Yager & Ackley, 2010).

Based on their studies of inquiry science, Banchi and Bell (2008) described an "inquiry continuum" that spans four levels: confirmation, structured, guided, and open inquiry. The first level, confirmation, is used when a teacher wants to reinforce a concept or skill that has already been introduced. Students are provided with the question, the procedure, and even the results to gain additional experience or practice. During structured inquiry, students answer a question using a procedure that is provided by the teacher, but they gather their own data and generate results. The researchers believed these are necessary levels of inquiry in elementary schools when students are developing inquiry skills. Once those skills are developed, students can progress to guided inquiry in which the teacher presents a question and students develop an investigation to answer the question. At that level, the teacher serves as a facilitator and guides students thinking about their investigation. Banchi and Bell (2008) cautioned that the final level, open inquiry, requires the most scientific reasoning and cognitive demand from students. Students develop their own questions, plan investigations, record and analyze data, and draw conclusions from their evidence. The authors believe that students in fourth-grade or fifth-grade can be ready for open inquiry after many experiences at the first three levels. Participating in inquiry-based science requires develop of increasingly sophisticated inquiry skills. Guiding students with disabilities to develop those skills requires teachers to have specialized understanding of effective instructional practices and interventions, especially when instruction is delivered in the general education classroom by the general education science teacher.

**Evolution of Inclusion of Students with LD**

Over the last one hundred or so years, the education of students with what has been called historically “mild disabilities” has evolved. As compulsory education laws were enforced in the early 1900’s, more students with mild disabilities were enrolled in school, and they were most often educated in separate classrooms or separate schools. For example, in the 18 years between 1948 and 1966 the number of students identified with mild disabilities increased by 400 percent, and nearly 90 percent were educated in separate classrooms (McLeskey, 2007). Dunn (1968) identified concerns about the way students with mild disabilities were being educated. He argued there were moral and pedagogical problems in the field of special education stemming from the over identification of children from low-income or minority backgrounds and from poorly trained special educators. He recommended that students with mild disabilities receive reading, writing and mathematics instruction in a resource class from a highly trained special educator. He further recommended that the students should receive instruction in all other content areas, including science, in the general education classroom. Deno (1970, p. 234) recommended a “cascade of services” for students with disabilities. Following in part from Dunn’s and Deno’s recommendations, the federal legislation of P.L. 94-142 passed in 1975 and required that students receive instruction in the “least restrictive environment” in order to gain access to the best curriculum and instruction.

Drawing on research and recommendations from the 1960s, “learning disability” was coined as a distinct disability, and in the 1970s around the same time as P.L. 94-142 the U.S. Office of Education released a definition for “specific learning disability.” School districts were required to provide free and appropriate education to all students, now including students with specific learning disabilities. IDEA 2004 strengthened the requirement to educate students with disabilities alongside their nondisabled peers. Furthermore, the law required that other separate placements be considered “only if the severity of the disability is such that education in the regular classes with the use of supplementary aids and services cannot be achieved satisfactorily.” (IDEA 2004). As students with learning disabilities are increasingly receiving instruction in general education middle school science classrooms, their teachers will need to learn which instructional practices and interventions will meet their learning needs.

**Professional Development for Teachers of Inclusive Science Classes**

Four studies described below examined how professional development impacts science instruction in the general education classroom for students with LD. Although the number of studies was limited, each illustrated the benefit of professional development. As part of a multi-year professional development project called *Guided Inquiry supporting Multiple Literacies* (GIsML), Palincsar et al. (2001) studied the challenges and opportunities presented to 22 students with LD in fourth-grade and fifth-grade science classrooms. During the first year of the study, the researchers used video recordings, field notes, formal assessments, artifacts, and student interviews to collect data to understand how the students with LD responded to the challenges presented in the general education science classrooms. The researchers then created case study vignettes based on their observations and used them to guide focus group conversations with the participating science teachers. As a result, the teachers and researchers co-constructed a list of instructional practices designed to "exploit the opportunities provided by GIsML instruction and to meet its challenges" (Palincsar et al. 2001 p. 24). The teaching practices that emerged were (a) "monitoring and facilitating student thinking," (b) "supporting print literacy" and (c) "improving group work." Those instructional practices were implemented by participating teachers during the second year of the study.

Each teacher determined how the instructional practices would be implemented in her own classroom to meet the unique needs of the students. To monitor and facilitate student thinking, teachers began rehearsing with students and/or engaging them in mini-conferences. For print literacy, teachers explicitly taught vocabulary and posted a glossary of terms in the classroom. Additionally, the teachers provided more structured prompts for lab book entries. Some used peers or paraprofessionals to scribe the thoughts of students with serious writing deficiencies. For the last instructional practice, Teachers strategically formed groups of students based on their ability to work well together. Additionally, students were taught to take turns, and teachers observed their interactions and provided feedback.

Palincsar et al. (2001) reported that the advanced instructional practices served as a means to delivering instruction to students with LD, and led to greater participation by students with LD. Based on the results of pretests and posttest from both years of the study, they concluded that all students (IEP-identified, low-achieving, and generally achieving students) demonstrated greater conceptual understanding of science concepts when the advanced instructional practices were implemented during the second year of the study. Students with identified LD showed gains similar to their non-disabled peers.

Cawley, Hayden and Cade (2002) examined the academic and behavioral outcomes of seventh and eighth grade students with and without disabilities in inclusive classroom after the science and special educators participated in a professional development program. Fifteen pairs of science and special educators completed an 80-hour summer program with 20-hours of school-year support that focused on implementing hands-on activities typical in middle school science instruction. At the conclusion of the program, participants were required to develop a plan to improve science instruction for all of their students, including students with disabilities. Cawley et al., (2002) reported the outcome of one triad, an eighth-grade science teacher, a seventh-grade science teacher and a special educator. The teachers provided instruction to 114 students. Sixteen of the students had identified disabilities. During data collection for the study, students with disabilities received science instruction in one general education science classroom at each grade level. A science teacher and special education teacher were present during each lesson. A second general education science classroom at each grade level did not include students with disabilities or a special education teacher. The researchers reported student academic achievement on a district-mandated unit test and behavioral outcomes based on referrals and attendance.

Cawley et al. (2002) reported that the passing rate of the students with disabilities was similar to the passing rate of the students without disabilities. Additionally, students with disabilities and the special education teacher were accepted and treated with respect in the general education classroom. In fact, the inclusive science classrooms had fewer behavioral referrals than the same-grade classroom without students with disabilities. The researchers concluded that the professional development provided a link between research and practice and supported teachers to implement the instructional strategies and interventions they learned.

More recently, Brusca-Vega, Alexander and Kamin (2014) examined the changes to science and special educators' instructional practices after participation in joint professional development. The researchers used a mixed methods study to look at two features of the participants' practices and changes to their practices during the professional development. The researchers focused on instruction in the science classroom and action research related to interventions for students with disabilities. Fifty-eight teachers from 25 urban schools participated in the three-year professional development. Special educators taught science in resource classrooms or served as consultants for the general education science teachers. The pairs of participants taught at the same school but did not co-teach in the same classroom.

The professional development program consisted of a four-day summer institute, action research projects, classroom consults by university faculty and in-school and cross-school meetings. A co-teaching model was used to deliver the professional development. A science expert presented the concepts and guided teachers through inquiry activities. Then an instructional expert taught an instructional strategy to reinforce the concept. Participants practiced the instructional strategies in their classrooms with the support of a program mentor.

Brusca-Vega, Alexander and Kamin (2014) reported that after the professional development, two teachers co-taught an astronomy unit for their action research project. The teachers incorporated collaborative reading, a note-taking strategy, small group instruction, and peer-assisted learning. The teachers believed that incorporating instructional strategies into co-taught lessons increased their students' participation and led to increased learning. The researchers concluded that science and special educators changed their instructional practices in many ways that supported diverse learners. Specifically, they were able to use the interventions they learned in the program. However, they also reported that there was little change in how student shared their ideas or how they made predictions about science phenomenon. The type of professional development described in these studies will become more necessary as the language-intensive NGSS are implemented and more students with LD are receiving science instruction in general education classrooms.

**Characteristics of Students with LD in Science**

As stated earlier, roughly 68 percent of students with LD spent at least 80 percent of the day in general education classrooms (Kena et al., 2016). Frequently, students with LD are receiving science instruction in general education classrooms (Cawley et al., 2002). However, being included in general education science classrooms is not enough to ensure academic achievement for students with LD (Cutter et al. 2002; Therrien et al., 2011). Although students with LD possess a variety of strengths to employ as they learn science, some studies indicate that engaging in interactive dialogues in inclusive classrooms to meet the NGSS scientific practices could be challenging. One challenge might be limited content knowledge some students with disabilities possess, especially in math and science classrooms (Stone, 2002). Stone (2002) concluded that students with LD were able to engage in literature and social studies discourse more successfully than science or math, which requires a basic understanding of content and evidence-based discussions that students might not have successfully developed in early grades. A students' limited content knowledge combined with a teacher's inability to scaffold a discussion, may impede participation in discussions.

Baxter et al. (2002) reported that a teacher in an inclusive fourth-grade math classroom was often conflicted between involving students with less language and mathematical skills and maintaining a focused discussion. Palincsar, Magnusson, Collins, & Cutter (2001) reported that academically struggling students were reluctant to participate in class discussions, and when they do, their participation tends to be meager. Wiebe et al. (2008) analyzed patterns of teacher talk across four inclusive math classrooms. They found that students with disabilities were less involved and participated less in whole group instruction. They concluded that with more attention to the use of involvement strategies, teachers would be able to develop their students' mathematical thinking and communication skills.

There is a growing achievement gap in science performance of students with and without disabilities. In 2009, the percent of students with disabilities performing below a basic level in science ranged from 46 percent of fourth-graders to 70 percent of twelfth-graders (National Center for Educational Statistics, 2011). Furthermore, the gap between the average score of students with disabilities and students without disabilities increased from 30 points in 2009 to 31 points in 2011. That indicates that students with disabilities are slipping further behind their peers without disabilities. That is concerning in light of the fact that students with disabilities, with an average score of 124 in the NAEP exam in 2011, are achieving dramatically below 155, the average score of all eighth-grade students. These NAEP results indicate that although more students with disabilities are receiving science instruction in general education classes, they are not progressing academically with their peers.

**Science Inquiry in Inclusive Science Classrooms**

In this section, I present studies of science instruction for students with disabilities in inclusive science classrooms. One study compared inquiry-based instruction to textbook-based instructions. Two studies compared different inquiry approaches within inclusive classrooms.

Mastropieri et al. (1998) conducted a mixed methods study described as a qualitative/quasi-experimental methodology to gain an understanding of the inclusion process and compare student achievement in an inclusive science classroom with student achievement in a general education classroom that was not inclusive. Three fourth-grade teachers taught the same science concepts related to ecosystems to their students during the same time period. The target classroom used inquiry-based methods, while the other two used textbooks. The target classroom contained 5 students with disabilities. Qualitative data (video recordings, field notes, student-created artifacts, and teacher guides) were collected during all lessons in the treatment classroom. Additionally, building administrators, teachers and students were interviewed. A group-administered, 20 question test was used as a pretest and posttest to provide quantitative data. Students were given an additional ten questions at the conclusion of the unit to assess conceptual understanding. The researchers generated several conclusions based on the qualitative data. Interviews revealed approval of the curriculum from administrators, personnel, and teachers. Through observations, the researchers noticed that the classrooms had an open, accepting atmosphere, teachers were using effective disability-specific teaching skills, and peers offered assistance to students with disabilities. Quantitative data revealed that pretest scores did not vary statistically in the three classrooms. However, there was a statistical difference on the posttest, and the students with disabilities in the target classroom demonstrated the greatest gains from pretest to posttest.

McCleery and Tindal (1999) compared the effects of explicit, rule-based instruction used in combination with hands-on activities to constructivist, hands-on instruction to teach the scientific method in two sixth-grade classrooms that included at-risk students and students with LD. Students in Group A and B received the same constructivist, hands-on instruction throughout the unit. Group A also received one class period of laboratory instruction taught by a trained teacher who focused on an emphasis on concepts, rule-based instruction, and hands-on activities. Six students in Group A additionally participated in five 40-minute pull-out sessions taught by the trained teacher over the course of the six-week unit. The outcome measure showed a statistical difference for the students in the pull-out group. All students in that group provided an explanation for a science problem that demonstrated they had a solid understanding of the material. Only 43% of Group A and 36% of Group B provided a similar response. Though the size of the pull-out group was too small to make generalizations and the teacher selection criteria for those students were not clear, the researchers made two conclusions relevant to this study. Hands-on activities have some benefit, but they should not replace explicit instruction in science classes. Also, the researchers called for an increase in research about explicit, concept-based instruction for enhancing student science literacy.

Lynch et al. (2007) compared outcomes of two randomly assigned groups of students with disabilities (not just LD). One group received instruction through a guided inquiry unit, and the other through the traditional district mandated unit. The participants were students with identified disabilities eligible for special education services, who received science instruction in the general education classroom. There were 103 students in the treatment group and 99 students in the comparison group. Student pre- and post-tests and observational data were gathered. Researchers reported that students with and without disabilities benefited from guidance during inquiry-based science, and the teacher played a critical role in guiding inquiry. Students gained deeper conceptual understanding, they concluded, when the teacher guided the inquiry by asking questions or highlighting information that might otherwise be missed.

These students demonstrate that inquiry-based science instruction is an effective instructional practice for teaching science to students with and without disabilities in inclusive classrooms. Additional studies revealed other interventions that improved science learning for students with LD.

**Interventions for Students with LD**

I now review the current body of research on science interventions for students with LD. In order to identify effective instructional practices for teaching science to students with LD, studies taking place in inclusive classrooms and in separate classrooms are considered. I begin by summarizing the findings of two meta-analyses that report effective instructional strategies for teaching students with LD in science. Therrien et al. (2011) reviewed articles published in peer-reviewed journals from 1980 - 2010 that focused on classroom-based science interventions. Twelve experimental or quasi-experimental articles were identified. Students with LD in third grade through twelfth-grade were participants in the studies. The studies were coded according to these features: kind of LD, grade level, IQ reported, type of intervention, duration, source of measure, type of dependent measure, and frequency. The researchers did not code the type of instructional setting in which the intervention took place. Three types of interventions emerged from the review (a) structured inquiry, (b) differentiated materials and peer-assistance (c) supplemental mnemonic and nonmnemonic instruction to reinforce vocabulary and key ideas.

Therrien et al. (2011) found a moderate positive mean effect size (ES = .78) across all the interventions and concluded that mnemonic instruction is highly effective (ES=2.0) for increasing recall of science vocabulary. Results also indicated that inquiry-based instructional approaches could be effective if they are structured and the teacher provides formative feedback and behavior interventions to ensure students are appropriately engaged in the activity. Notably, over a 30-year period, only 12 studies met the criteria and were included in this meta-analysis.

Dexter et al., (2011) conducted a meta-analysis to determine the overall effects of using graphic organizers (GO) to teach science to intermediate and secondary level students with learning disabilities. The researchers identified six experimental or quasi-experimental studies that included a GO as an independent variable and science content as a dependent variable. Each study provided quantitative information to allow calculation of an effect size. The researchers reported that instruction for each GO included explicit instruction during 1-2 sessions, prompted practice in the use of the GO during the next 1-2 sessions, and independent student use for the remainder of the unit. They reported a large effect on science learning for students with LD across all studies (ES= 1.052). Additionally, they found a strong effect size for maintenance

(ES= 0.80). With explicitly taught GOs, students with LD learned science concepts and vocabulary and remembered the content longer. All of the studies included in the meta-analysis took place in resource rooms. The findings of Therrian et al. (2011) and Dexter et al. (2011) are similar to the findings of several other studies conducted in inclusive classrooms.

Dalton, Morocco, Tivnan and Rawson Mead (1997) compared two approaches of inquiry-based science. The Supported Inquiry Science (SIS) approach integrated eight principles based on constructivist learning and teaching for conceptual change. The activity-based science (ABS) approach was also inquiry-based instruction but did not incorporate the eight principles. The investigators used a pretest and a posttest to assess science learning of 172 fourth-grade students. Thirty-three students had identified disabilities. After receiving instruction under each condition, students completed a paper and pencil assessment that required them to write and draw explanations of science concepts taught during the unit. The average gain score for students with LD, Low-Average, Average, and High-Average was compared in the treatment and control group. Students in the SIS condition, with and without LD, outperformed students in the ABS condition. The researchers attributed the performance to a focus on uncovering and correcting student misconceptions and the co-construction of science knowledge. In the SIS condition, the teachers served as guides and coached students as they shared emerging ideas about science concepts.

To study the benefits of providing opportunities to work at differentiated levels, Simpkins, Mastropieri, and Scruggs (2009) designed a study to determine if differentiated curriculum enhancements would be effective for students at risk or with LD in elementary-grade classrooms. Three teachers and 61 students participated. Fifteen students were at risk and three were identified with learning disabilities. A crossover design was used to maximize experimental power. Each teacher taught two 5 week units, one under control conditions and one under experimental conditions. Curriculum materials provided by the district were used to teach the unit under control conditions. The experimental unit was provided by the research team. Specific preparations occurred before the experimental unit was taught. Teachers received training on how to interact with the materials and were introduced to the content of the teacher's manual. During science instruction, students were strategically paired according to ability level and taught roles for engaging in the cooperative tutoring partnership. The researchers provided step by step directions for each science activity. Students were also taught how to complete daily data sheets. The researchers were available throughout the unit to provide guidance and clarification.

In addition to teacher-directed lessons, participating in inquiry and viewing a DVD, students in the experimental condition were given level 1 activities for which they identified correct answers and level 2 activities for which they produced answers. The activities were structured to be similar to well-known games. Students completed the activities with their tutoring partner by answering science content related questions. After completing each activity, students used an answer key to correct their own work. The students engaged in the activity sessions once or twice each week and completed 1 to 2 activities per session. The time students took to complete the level 1 activities differentiated their experience. Higher ability students were able to complete more level 2 activities.

Several sources of data were used to determine the effectiveness of the experimental condition materials. Student surveys indicated that the students enjoyed using the materials to review science content. Teachers reported that overall the activities increased student engagement, but at times the directions for level 2 activities were too difficult. All students had a higher gain score in the experimental condition than the control condition, but not significantly higher. The effect size for students with learning disabilities was 0.237 for level 1 (identification) activities and was 0.436 for level 2 (production) activities.

**Vocabulary Instruction**

In addition to a body of literature focused on inquiry-based science teaching to students with LD, another large corpus is about teaching discipline-specific vocabulary. Additionally, direct vocabulary instruction has been shown to increase reading comprehension (Allington, 2005; Bravo & Cervetti, 2008; Harmon, Hedrick & Wood, 2005). Therefore, it may be useful to consider how direct vocabulary instruction might impact students' abilities to engage in the NGSS practices of asking questions, constructing explanation and arguing from evidence in inclusive science classrooms.

Science contains unique vocabulary words that are used to form the language of the discipline. Being able to use content-specific science vocabulary to ask questions, construct explanations, and engage in arguments from evidence is a requirement of NGSS performance expectations and a critical component of understanding a science concept. Bravo and Cervetti (2008 p. 131) asserted that words are "the instantiations of the deeper underlying concepts" and knowing disciplinary vocabulary is fundamental to conceptual understanding. Science, in particular, presents many terms and related concepts that are unfamiliar to students (Harmon et al., 2005). Harmon et al. (2005) explained that internalizing discipline-specific language is at the core of content learning. In the following sections, literature related to teaching science vocabulary will be described.

**Selecting vocabulary terms.** Selecting the correct vocabulary terms to teach and how to teach them are two of the many critical decisions teachers must make when planning vocabulary instruction (Fisher & Frey, 2014; Graves, 2009). Most science curriculum materials identify a large number of complex terms. Armstrong and Collier (1990) reported that an introductory biology book presents over 3.500 new words or more than 17 words per day in a typical school year. Additionally, science vocabulary is often unfamiliar to students or they may know common meanings for polysemous terms, but not the scientific meaning. For example, most students will know a model might be seen on runways or in magazines, but they may not understand how a model is used in science. Teachers frequently struggle with narrowing down a long list of scientific words and terms to one that is manageable and will lead to improving students' learning (Graves, 2014).

Beck, McKeown and Kucan (2002) defined three categories or tiers of vocabulary. High-frequency words (Tier I) are words that students typically learn through conversation. The authors stated that high frequency words don't typically require direct instruction in school. General academic words (Tier II) are words that often referred to as those used by "mature language users" and are generalizable across content areas. Beck et al. (2002) suggested that teaching 400 general academic words each year is needed to reach a depth of instruction necessary to affect students' text comprehension. Marzano, Rogers and Simms (2015) identified 227 general academic words in CCSS that describe cognitive processes students use to complete academic tasks. Domain-specific terms (Tier III) are words that are usually only encountered in studying the content area. For example, in a Middle School Heredity Unit, *development* is a general academic word, while *chromosome* is an example of a domain-specific word. Categorizing words is the first step in the process of selecting words to teach.

To select general academic words, Beck et al. (2002) suggested using three criteria. First, consider the word's importance and utility in a variety of domains. Next, think about the instructional potential the word has to create connections to other words and concepts. Finally, consider the student's' current level of conceptual understanding and how the word will provide a more precise understanding of the concept. The authors further explained that there is not a perfect list of grade-level vocabulary to teach. Instead, teachers' instructional decisions should be based on their students and the learning outcome they determined for their students.

Graves et al. (2014) built on Beck's categorization of words and developed the "SWIT" process to guide teachers as they plan vocabulary instruction. The process begins by identifying words that are unfamiliar to students and sorting them into four categories: essential, valuable, accessible, and imported. Essential words are crucial for understanding the text or concept. Valuable words are generalizable and similar to Beck's general academic words, but decisions are based on knowledge of students' readiness to learn the words. Accessible words are the bridge between the two and provide help for students who have limited vocabularies, such as English Language Learners or struggling readers. Imported words are not included in the text, but can be used to explain themes or concepts presented in the text. During the next step of the process, teachers decide what kind of instruction they will provide. Graves et al. (2014) recognized that the process is time-consuming when teachers begin using it, but they found that teachers became more proficient after the first year of practice with the process.

Fisher and Frey (2014) developed another procedure to identify words for direct instruction. They created 6 categories of questions to guide teachers' decisions: "Representative, Repeatability, Transportable, Contextual Analysis, Structural Analysis, and Cognitive Load" (Fisher and Frey, 2014 p. 596). The authors explained that words that are representative of grade-level words and are repeated in other contexts or used in follow-up tasks should be explicitly taught. However, if the meaning of the word can be determined from the text or word structure, it should probably not be taught. The authors provided guiding questions teachers could use to identify words for direct vocabulary instruction. Fisher and Frey (2014) asserted that in addition to learning isolated words, students must also learn vocabulary strategies that they can use independently when they encounter an unfamiliar word.

**Research-based vocabulary instruction.** Several studies have shown that vocabulary instruction improves science learning for students with LD (Bryant et al., 2003; Therrien et al., 2011; Wolgemuth et al. 2008 ;). An effective vocabulary program includes frequent opportunities to interact with vocabulary through text and discussion, direct instruction of individual words, instruction of vocabulary strategies and a culture that promotes excitement and interest in words (Graves, 2011). Several researchers provide findings from studies with elementary students with and without LD. For example, Nagy (1988) identified three properties of effective vocabulary instruction as integration, repetition, and meaningful use of words. Beck and McKeown (1991) demonstrated that print-based vocabulary instruction is strengthened by supplementation of interactive and verbal components. Baker, Simmons, and Kameenui (1997) described the following scaffolded methods for vocabulary instruction: use clear strategies, strategic integration into content area learning, mediated scaffolding for individual support, activating background knowledge, and doing a careful review of learning. Because one size vocabulary instruction does not fit all students or all words (Graves, 2009), I did a review of evidence-based instructional strategies identified in the research. Word learning strategies that have been shown to be effective are context clues (Harmon, Buckelew-Martin, & Wood, 2010), semantics (Hedrick, Harmon, & Wood, 2008; Newton, Padak, & Rasinski, 2008;), nonverbal representations (Cohen and Johnson, 2012; Schwartz & Raphael, 1985), morphology (Harmon et al., 2005; Kieffer and Lesaux, 2007; Nagy, Carlisle & Goodwin, 2014), and mnemonics (Condus, Marshall, & Miller, 1986; Scruggs & Mastropieri, 1990; Wolgemuth et al., 2008).

***Context clues.*** All words do not need to be explicitly taught if students are able to recognize unfamiliar words, use background knowledge, and locate context clues in the text to determine the meaning. Harmon et al. (2010) taught high school students to use the Cognitive Vocabulary Approach (CVA) during reading. CVA has three facets: identify the unfamiliar word, examine the unfamiliar word, and relate the word to prior knowledge and the text. Students learned to ask themselves questions to activate metacognitive thinking and use cognitive strategies when they encounter an unfamiliar word. The authors reported that becoming proficient in using context clues is a slow process, but students did become more metacognitive about unfamiliar words.

Manzo and Manzo (2008) identified two other approaches for developing word consciousness. Community of Learners is a strategy to help students begin to notice new words posted in the classroom and then develop an understanding of the words through repeated exposures in a variety of contexts. Secret language is a similar approach but differs in that two students select the words and present the context clues to their classmates. Yet importantly, Allen (1999) cautioned that not all words can be learned in context. If the text doesn't provide enough detail, the word should be explicitly taught if it is critical to comprehending the text.

***Semantics.*** All vocabulary instruction involves developing conceptual understanding. Newton et al. (2008) explained that students must be familiar with a concept before they can know the meaning of a term. Even when students understand a concept, they need instruction to help them make connections to the new term. Visual displays such as semantic maps or semantic feature analysis have shown promising results for students with learning disabilities (Hedrick et al., 2008). Semantic maps are graphic organizers that show the relationships between vocabulary terms to further explain the term and related concept. A semantic feature analysis grid lists related vocabulary terms along one axis and characteristics or features along the other. Students complete the grid by inserting Yes or No, or more detailed answers in the intersecting sections (Hedrick et al., 2008).

Graves (2009) identified semantic mapping as an effective practice for developing conceptual understanding. He stated that a "richer and more powerful instruction" could come about when the teacher and students work together to create the semantic map. He showed that using graphic representations, such as semantic maps, increased achievement for low-achieving seventh-grade students without disabilities. He concluded that the map allowed students to present ideas in a visual, graphic structure. Likewise, Bos and Anders (1990) reported that junior high students with learning disabilities attained greater comprehension and vocabulary learning when using semantic maps or semantic feature analysis than they did with traditional vocabulary instruction.

***Nonverbal representations.*** The use of visual and tactile representations is another vocabulary instructional practice that increases conceptual attainment. Cohen and Johnson (2012) compared students' abilities to learn science vocabulary words under four conditions, three of which included looking at or creating an image. They reported that students in the three "Picture" conditions outperformed students who learned vocabulary through words only. Similar findings about the worth of using images to learn words emerged from Schwartz and Raphael (1985) who created Concept of Definition maps. Allen (1999) created a task in which students display a word, an image, a student-friendly definition, and examples/non-examples. Marzano's (2009) 6-step process for teaching vocabulary integrates images into two of the steps. Teachers present a new term with a student-friendly definition and an image. They explain how the image relates to the new term. Then students create a new image for the term.

***Morphology.*** Visual displays, images, semantic maps, and semantic feature analysis grids can be used to develop conceptual understanding of the relationships between terms, but other vocabulary strategies can be used for words with common morphemes. Morphology is the study of the structure of words. All words are formed from morphemes- the smallest unit of a word that holds meaning. Knowledge of morphology improves reading comprehension and seems to have a reciprocal relationship with vocabulary. Students who have broader vocabularies seem to have a stronger understanding of morphology, and having an understanding of morphology increases vocabulary (Keiffer & Lesaux, 2007). Morphology is an important part of vocabulary instruction because it teaches students to make connections between semantically related words (Harmon et al., 2005; Nagy et al., 2013). Science vocabulary lends itself to the study of morphology because many terms have common Greek or Latin roots (Padak, Newton, Rasinski, & Newton, 2008). The ability to generalize learning to unknown words is a benefit that goes beyond learning isolated words.

Harris, Schumaker and Deshler (2011) compared the effects of teaching two vocabulary strategies to high school students with and without learning disabilities. One class learned to use a mnemonic strategy, another learned to use morphological analysis, and a third class served as a control. The researchers found that both classes of students who received instruction on the use of a vocabulary strategy learned the taught words better than students in the control class. However, the students who learned morphological analysis scored significantly higher in a test of unknown words. The results indicated that students with and without LD were able to generalize the morphological analysis skills to determine the meaning of unknown words.

***Mnemonics.*** Multiple studies have demonstrated the effectiveness of using mnemonic devices. Lombardi & Butera (1998) described mnemonics as a words, sentences, or pictures used as devices or techniques aimed at improving memory. Scruggs & Mastropieri (1990 p. 8) defined mnemonics as memory-enhancing strategies that “provide specific reconstruction of target content intended to tie new information more closely to the learner's’ existing knowledge base and, therefore, facilitate retrieval.” The use of mnemonics can improve students’ abilities to remember factual information in content areas (Mastropieri & Scruggs, 1998). Three types of mnemonics have been the focus of research for students with LD: keyword, pegword and reconstructive elaboration (Wolgemuth, Cobb, & Alwell, 2008, 2008).

Keyword mnemonics (Atkinson, 1975) refers to a method of using a concrete, acoustically similar keyword to remember the meaning of the vocabulary term to be learned. The unknown word is linked to a known word acoustically and through an image that connects the two words. For example, King-Sears, Mercer, and Sindlear (1992) used "homes" as a keyword for "biome," They linked the definition- *large land areas where specific animals live-* to an image by drawing a forest biome with houses for animals. Although keyword mnemonics has been criticized for being cumbersome and artificial, it does enable students to remember basic meanings of terms and is a useful first step in a comprehensive vocabulary program (Manzo & Manzo, 2008). The pegword method extends the keyword method to include sequential information. A pegword is a familiar rhyming word for the numbers one through ten, for instance, one and run. Reconstructive elaborations are created to link the pegword, the rhyming word and the sequential information. The technique provides a framework for adapting all content-area information into more familiar and more concrete interactive elaborations (Scruggs & Mastropieri, 1990). As students are expected to think and speak like scientists, they will need to know the unique terms that describe the phenomenon about which they are learning. In other words, students will use domain-specific vocabulary as they engage in the NGSS scientific practices.

**NGSS Scientific Practices and Related Research**

The three scientific practices I explore in this study are all identified by NGSS as language intensive and require a particular way of thinking, speaking, and listening. Appendix F of the NGSS (2013) contains a description and set of performance expectations for each practice. The performance expectations explain exactly what students should be able to do at the end of four grade bands (K-2, 3-5, 5-8, and 9-12). All students are expected to engage in all of the scientific practices at increasing levels of sophistication as they move through the grade bands.

**Asking questions.** The scientific practice of asking questions requires that students at all grade levels

> ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. (NRC, 2012, p. 56)

Students develop an increasingly sophisticated ability to ask scientific questions as they progress through the grades. For example, they ask questions about observed phenomenon in grades kindergarten through second-grade, and they distinguish between science and nonscience questions in grades three through five. By the end of eighth-grade, students ask questions to determine the relationship between variables, and twelfth-grade students ask questions after examining a model or theory or to determine quantitative relationships between variables.

Although most of the empirical research on the effectiveness of question generation refers to its use as a cognitive strategy for reading instruction, there is a growing body of evidence that demonstrates that question generation has numerous benefits in science classrooms (Chin & Osborne, 2008; Rosenshine, Meister & Chapman, 1996). In a review of the empirical literature on student questioning in science, Chin & Osborne (2008) identified several benefits for students as well as benefits for teachers. The researchers found that students benefit from questioning as they reflect on what they do not yet know, and then think critically to generate explanations to fill their knowledge gaps. Additionally, when students ask questions during interactive dialogues, they explore, refine, and co-construct their understanding of the scientific phenomenon. That interactive dialogue serves as the foundation for internal dialogue or "private speech" (Vygotsky, 1978) that ultimately aids metacognition and self-regulated learning. Chin and Osborne (2008) additionally report that teachers benefit from student questioning when the questions are used for formative assessment to reveal students' critical thinking and interest in the topic. The quality of the questions can be used to reflect on the effectiveness of instruction and guide future instruction.

Although it is well established that student-generated questions advance students' reading comprehension, there has been more research on the effects of teacher-generated questions than the effects of student-generated questions. Chin and Osborne (2008) argue that the lack of student questioning naturally occurring in classrooms may be the reason. Using the available literature, the researchers identified 4 focus areas for studying student-generated questions: (a) "the nature and types of questions" (b) "the effects of teaching students questioning skills" (c) "the relationship between students' questions and selected variables" and (d) "teachers' responses to and perceptions of student questions" (Chin and Osborne, 2008 p. 9). They conclude that although student question generation holds great educational potential, obstacles might prevent students from asking questions. Obstacles can occur at an individual level or social level in the classroom. They asserted that questioning could be encouraged by creating a cultural environment that encourages questioning, tapping into students' curiosity, modeling questioning and scaffolding students' questioning skills by providing prompts. However, notably the majority of the studies in the review focused on comprehension of science text rather than student-generated questions during inquiry, and few of the studies were conducted in middle school classrooms. None of the studies looked at how students with learning disabilities learn to ask questions in science.

In one recent study of question generation in science, Garcia, García, Berbén, Pichardo and Justicia (2014) used a quasi-experimental design to study the effects of using prompts to teach students to form scientific questions. The researchers randomly assigned three ninth-grade classrooms to one of three conditions, which they named "questioning-training by providing prompts" (Gl), "question-generation without any explicit instruction" (G2) and "no question control" (G3) (Garcia et al., 2014 p. 387). Garcia et al. (2014) concluded that training students in the use of question generating prompts could improve how students think about their science learning, and ultimately their knowledge attainment. The researchers asserted that the metacognitive characteristic of self-questioning was key to its effectiveness. Specifically, questioning-training by providing prompts resulted in a medium to large effect size. Similarly, Bulgren and Ellis (2015) developed a protocol that increased students' proficiency in asking questions to evaluate an argument. The results of these studies reinforce the necessity to establish interventions aimed at developing proficiency in questioning in science classrooms.

**Constructing explanations.** Constructing explanations progresses naturally from asking questions and offers additional opportunities for interactive dialogue. NGSS state:

> The goal of science is to construct explanations for the causes of phenomena. Students are expected to construct their own explanations, as well as apply standard explanations they learn about from their teachers or reading. (NRC, 2012 p. 69)

Students begin to construct explanations in the primary grades by creating evidence-based accounts for observed natural phenomena. In grades three through five students begin to use evidence such as measurements, observations, or patterns to support their own and others' explanations. Students in grades six through eight should be able to "construct explanations that are supported by multiple sources of evidence consistent with science ideas, principles, and theories." By the end of twelfth-grade, "students make quantitative and/or qualitative claims regarding the relationship between dependent and independent variables" and generate their own evidence to support their explanations (NRC, 2013 p 425).

The literature on scientific explanations indicates that students benefit from structures and prompts. Wang (2014) asserted that often middle school students struggle to write scientific explanations. Their explanations tend to be summaries of observations and personal experiences, with little scientific evidence or causal relationships (Wang, 2014). To teach students to write better explanations, Wang (2014) introduced cognitive prompts to 173 seventh-grade students in inquiry biology classes in China. Cognitive prompts were statements based on curriculum standards written in student-friendly language. For example, two prompts were "Write a complete sentence." and "Provide a causal account of the investigated phenomenon" (Wang, 2014 p. 253). The statements were introduced and then reintroduced to the students in different ways throughout the study. First, they were given high-quality and poor-quality evidence statements to analyze and discuss in partnerships. Then the students used statement prompts to independently write an explanation. The statements were reviewed by a peer and returned to the author for revisions. Wang (2014 p. 237) concluded, "Incorporating cognitive prompts with the explanation scaffolds facilitated knowledge integration better and resulted in greater learning gains of content knowledge and better quality evidence and reasoning." This study was similar to the studies that focused on asking questions in that the researchers provided explicit instruction. Clear guidelines, prompts, and multiple opportunities to practice with peers and independently were effective instructional activities for learning the scientific practices. Similar results were reported from studies that looked at teaching students to argue from evidence.

**Arguing from evidence.** Engaging in arguments from evidence is a practice that requires students to weave together their questions, explorations, knowledge, and explanations of a natural phenomenon.

> Argument in science goes beyond reaching agreements in explanations and design solutions. Whether investigating a phenomenon, testing a design, or constructing a model to provide a mechanism for an explanation, students are expected to use argumentation to listen to, compare, and evaluate competing ideas and methods based on their merits. (NRC, 2012 p. 73)

In the real world, scientists examine and question evidence and compare the evidence to their prior understandings to generate claims that explain a natural phenomenon. Then they engage in scientific discourse with other experts in the field to identify the best explanation. Chin and Osborne (2010) asserted that in classrooms, arguing from evidence is a social activity that involves collaborative group discussions. In those discussions, students ask questions, use evidence to support claims, and challenge each other's ideas.

Students in grades kindergarten through twelfth grade are expected to "use argumentation to listen to, compare, and evaluate competing ideas." In the earliest grade band, kindergarten through second grade, students develop an understanding of argumentation by listening actively to arguments to indicate agreement or disagreement based on evidence. In third through fifth-grades, students "cite relevant evidence about the natural world" to respond to their peers' explanations. By eighth-grade, students should be able to "compare and critique two arguments on the same topic" and determine whether or not they emphasize similar evidence and interpretations of facts. By the end of high school, students "compare and evaluate competing arguments in light of currently accepted explanations, new evidence, limitations, constraints, and ethical issues (NRC, 2013 Appendix F p. 63).

Cavagnetto (2010) reviewed 54 studies that established a connection between argument and scientific literacy and inquiry in kindergarten through twelfth-grades. He reported that three types of interventions were typically used to teach scientific argument. The most common intervention was using argument to create new understandings, followed by using argument as a culminating activity. The third intervention, using argument as "an integral component to a student investigation" (Cavagnetto, 2010 p. 341) was found least frequently. He concluded that the diversity of interventions for teaching argument is an area needing more research in order to gain a better understanding of the practice and how to teach it to students.

As discussed above, Chin and Osborne (2010) sought to develop pedagogical strategies that teachers could use to scaffold student questioning and scientific argument. Additionally, they demonstrated the impact of using a protocol that used student-generated questions to support a scientific argument. Their work showed the links between the scientific practices. They investigated student discourse and the written work of twelve to fourteen-year-olds as the students worked in groups to analyze two graphs to determine which best represented a natural phenomenon. The students followed a protocol of analyzing a graph, generating questions and then discussing the answers to the questions. They were given a set of evidence statements about the phenomenon represented in the graph and an *Our Argument* handout on which to write their claim, evidence, and reason(s) for their answer. They were also to write a counterargument and rebuttal. The *Our Argument* listed the components of an argument and a sentence starter for each component. After constructing the argument, students created an argument diagram to show connections between the parts of the argument. The researchers concluded that the protocol increased the quality of the arguments and developed students' scientific literacy.

In summary, as all students learn to use the language-intense scientific practices of asking questions, constructing explanations and arguing from evidence, they will need repeated opportunities to practice, guided by explicit instruction and scaffolds.

**Conclusion**

Numerous studies have shown that students with LD can successfully learn science in inclusive general education middle school classrooms when they are provided with appropriate interventions. Moreover, researchers have provided literacy-based interventions and strategies shown to support students' academic success. Socially constructing understanding of science through guided inquiry has been shown to be particularly effective. Teaching the NGSS practices of asking questioning, constructing explanations and engaging in arguments from evidence could present opportunities and challenges for students with LD. As teachers shift to NGSS-based instruction and recognition of language-intensive nature of the scientific practices, drawing on evidence-based literacy skills could be important to help students with LD. There are currently no studies of how students with LD learn the NGSS practices of asking questions, constructing explanations, or engaging in arguments from evidence in inclusive middle school science classrooms.

## III. Design and Methods

This study provided findings within a qualitative research paradigm using a case study design to illustrate participants' experiences teaching science in inclusive middle school classrooms. A multiple case design was used to allow comparison between and among the cases. Analyzing multiple cases rather than one extensive single case has the potential to rule out rival explanations that might occur in single case studies (Cohen, Manion & Morrison, 2011).

As do most research methodologies, case studies have strengths and weaknesses. One significant advantage is that they are readily understood by a wide audience (Nisbet & Watts, 1984). A second advantage is that case studies can be completed by a single researcher (Nisbet & Watts, 1984). Furthermore, in a case study, we can describe unique features within a naturalistic situation, as well as unanticipated events and uncontrolled variables that may arise (Nisbet & Watts, 1984). Adelman, Kemmis, & Jenkins (1980 p. 59) describe case study data as being "strong in reality" and able to recognize the complexity of social settings. Case study methodology was selected for this study because it enabled consideration of the many variables that impact instruction in a typical classroom, as well as teachers' thinking about them. Therefore, a case study offered the potential to present the full reality of the situation.

In spite of the many benefits of case studies, there are some weaknesses. Case studies are prone to problems of observer bias (Nisbet & Watts, 1984). Additionally, the results are not readily generalizable. To ensure validity, a variety of data sources must be used for triangulation, which is the practice of corroborating and interconnecting data from different sources. Yin (2009 p. 99) recommends six possible types of qualitative data collection for a case study: "guides, archival records, interviews, direct observation, participant-observation, and physical artifacts." In this study, a detailed description of the cases emerged through multiple interviews, direct observations, and a reflection guide.

**Recruitment Process**

The recruitment process began by securing approval from the University of Illinois at Chicago Institutional Review Board (IRB) (See Appendix I) on February 8, 2016 (protocol #2015-1237). Due to the focus of this study on the implementation of NGSS with attention to instructional practices supportive to all students and especially those with LD, I searched district public websites to identify those districts meeting the requirements. Next, I sent the IRB approved recruitment letter to the superintendent of School District A to request a meeting. After our meeting, the superintendent shared the study information with the middle school principals in the district and granted me permission to contact the principals.

The IRB approved principal letter was sent to the principals of all the middle school in the district. The principal of School A replied, and we scheduled a meeting, after which he sent me a letter of support, which I then submitted to IRB. The principal nominated three science teachers and three special educators. I invited the teachers to a recruitment session at the school before the school day began. Two science teachers and two special educators attended the recruitment session. Two of the attendees were co-teachers, and two teachers attended without the co-teaching partner. One science co-teacher was interested in participating in the study but was unable to attend. I met individually with that science teacher. At the end of the recruitment session, the teachers were given a copy of the Participant Criteria Checklist (Appendix A) and a copy of the Informed Consent (Appendix I). Two pairs of co-teachers agreed to participate.

After recruitment efforts at the first district did not yield additional pairs, I realized I needed to recruit at additional districts, so I submitted an Amendment to my Initial Application with revised recruitment materials. After receiving approval on May 27, 2016, I contacted the superintendent at District B by phone and was granted permission to email the principal of the middle school. I met with him at the school and received the letter of support, which I sent to

IRB. He shared contact information for four nominated teachers. The teachers were invited to attend a recruitment session in the morning before the school day began. Three teachers attended the session: the seventh-grade science teacher, the seventh-grade special education teacher, and the eighth-grade science teacher. After I described the study, the attendees were given the Participant Criteria Checklist and the Informed Consent and directed to contact me if they were interested in participating. The seventh-grade science and special educators were enrolled in the study. Because the 8th-grade special education teacher was not interested in participating, the 8th-grade science teacher was not enrolled. A Continuing Review was approved on January 19, 2017.

**Setting**

Two middle schools served as the setting for this study (See Table 1). Middle school classrooms were selected because middle school science teachers were required to have additional training in science content for state licensing. Additionally, science education literature shows that students tend to lose interest in science in middle school (Aschbacher, Ing & Tsai, 2014; Wolf & Fraser, 2008). School A was part of a large suburban school district located in the Midwest serving approximately 5,000 students. During the 2015-2016 school year, the average general education class size was 25 students. Approximately 18% of the students were identified as low income, 12% percent had IEPs for identified disabilities, and three percent were English Language Learners.

This district was selected because of its multi-year plan that prioritized both NGSS-based science instruction and the identification of instructional strategies to meet students' diverse learning needs. In 2014, district officials identified the implementation of NGSS as one part of the district-wide plan. This intentional effort to implement NGSS offered the potential for rich data to respond to this study's research questions. Secondly, District A reported well-established services for students with disabilities.  Science instruction was provided in an inclusive classroom with the daily presence of a special education teacher.  A general education science teacher and a special education teacher co-taught to provide instruction to students. Finally, an on-going goal of the district's' multi-year plan posted on their website was the development of instructional practices to teach students with disabilities.  Additionally, while the District offered a continuum of services for students with disabilities who receive services under Section 504 or the Individuals with Disabilities Education Act (IDEA), inclusion in the general education classroom was highly valued. Taken together, a focus on NGSS and instructional strategies to address the needs of all learners, the district goals aligned well with the focus of this case study research.

Table 1

*Middle School Demographics*

| Demographics | Middle Schools | |
|---|---|---|
| | A | B |
| Enrollment (n) | 600 | 750 |
| Grades | 6-8 | 7-8 |
| Low Income (%) | 18 | 60 |
| Students with IEPs (%) | 12 | 12 |
| English Language Learners (%) | 3 | 15 |

Middle school B was part of a Midwest suburban district that served approximately 3,500 students. The middle school that served as a setting for this study had nearly 750 students enrolled in grades seven and eight. The average class size was 20 students. Approximately 60%

of the students were identified as low income, 12% percent had IEPs for identified disabilities, and 15% were English Language Learners.

School B was selected because district-wide professional development for the implementation of NGSS was provided to all science teachers. The district was in the process of implementing NGSS. Full implementation of the new curriculum began in the primary grades and was progressing through the grades as students advanced each year. At the point of this study, science teachers in grades seven and eight had participated in district-level professional development to review, update and align existing science units to NGSS. A second reason for selecting School B was that it provided inclusive science instruction with the presence of a special education teacher in the science classroom. A general education science teacher and a special education teacher were assigned to co-teach science on a daily basis.

**Participants**

Participants in this study were general education science teachers and special educators (See Table 2). Participants were recruited as a pair consisting of a general education science teacher and the special education teacher with whom he or she co-taught to provide instruction to students with disabilities enrolled in the general education science classroom. For this study, two students with learning disabilities served as the criteria for inclusion. Two teachers, assigned to teach in at the same time in a science classroom served as the criteria for co-teaching. Although high-quality co-teaching involves active communication, co-planning, sharing instructional delivery and assessment (Brown, Howerter, & Morgan, 2013), those features were not included in the recruitment criteria. Each pair of teachers provided science instruction to at least two students with learning disabilities in at least one general education science class. The general education science teachers were (a) state licensed general education teachers with at least five years of teaching experience, (b) endorsed to teach science in grades six through eight, (c) currently teaching science in grades six through eight, and (d) teaching at least two students with identified learning disabilities enrolled in at least one science class. The special educators were (a) state licensed special educators with at least five years of teaching experience, (b) co-teaching with the science teacher.

Selecting only licensed, science-endorsed, general education teachers ensured that the teachers had a thorough understanding of the content they were teaching. Also, with five years of experience, the teachers had likely developed effective skills in instruction, classroom management and reflection of their instructional practices (Biomeke, Hoth & Dohrmann, 2015; Kagan, 1992). Grades six through eight were selected because science instruction at that level becomes more in-depth and introduces more specific content, vocabulary and scientific practices that students may not have experienced in other settings (Brown & Concannon, 2016; NRC, 2012). According to NGSS scientific practices should be integrated into all disciplinary core ideas. Therefore, choosing a particular topic of study during data collection was not a part of the selection criteria. To investigate what instructional practices and interventions for students with disabilities were provided and how, participants were only accepted into the study when both the general education teacher and the special education teacher enrolled in the study. Teaching experience for the six participants ranged from 12 to 28 years. Each participant held a master's degree in an educational field of study.

The three pairs of general education science teachers and special educators with whom they co-taught are described in Table 3. Mr. Green and Ms. Lewis (Case A) and Ms. Jones and Ms. Morgan (Case B) taught at the same school (School A). Ms. Martin and Ms. Lacey (Case C) taught at School B. Mr. Green and Ms. Lewis co-taught two classes of sixth-grade science. I now describe the teachers in Case A. Mr. Green had 20 years of experience teaching science at the middle school level. He had a master's degree in animal science and endorsements in agricultural education, biology, physics, general science, social studies, and language arts. Mr. Green taught six classes of sixth-grade science each day. During the two years prior to this study, he completed 40 hours of professional development related to NGSS and the use of technology in the science classroom. He reported that, during that two year period, he did not have professional development aimed at teaching students with learning disabilities.

Table 2

*Participants' Teaching Experience and Professional Development*

| Teacher | Position | Grade | Years | Degree(s) Certification | Professional Development in Previous Two Years |
|---|---|---|---|---|---|
| Mr. Green | Science | 6 | 20 | M.A. in animal science | NGSS by District<br>District level-Technology in Science |
| Ms. Lewis | Special Education | 6 | 12 | M.A. in special education<br>M.A. in administration | |
| Ms. Jones | Science | 8 | 25 | M.A. in administration<br>National Board Certification – EA Science | NGSS by District<br>Leads Professional Learning Community for Science Teachers |
| Ms. Morgan | Special Education | 8 | 28 | M.A. in special education<br>M.A. in administration | |
| Ms. Martin | Science | 7 | 13 | M.A. in curriculum studies | NGSS by District<br>STEM Conference |
| Ms. Lacey | Special Education | 7 | 36 | M.A. in special education | Museum Education Dept. Science Teaching |

Ms. Lewis had 12 years of teaching experience. She had a master's degrees in special education and educational administration and was endorsed to teach health, physical education, and social science. In addition to co-teaching two sixth grade science classes, Ms. Lewis taught two sixth grade and two 8$^{th}$ grade health classes. During the time of this study, she was in her first year co-teaching in the sixth grade science class. She did not report completing professional development in science during the two years prior to this study. Ms. Lewis and Mr. Green did not co-teach prior to the year of this study.

I now describe Case B. Ms. Jones and Ms. Morgan co-taught one class of physical science to eighth-grade students at School A. Ms. Jones had 25 years of experience teaching science at the middle school level. She earned National Board Certification in Early Adolescent Science, as well as endorsements to teach high school chemistry and physics. She had a master's degree in educational administration. In addition to the co-taught eighth-grade class, Ms. Jones taught two seventh-grade honors classes, two eighth-grade honors classes and one eighth-grade class. Ms. Jones reported that, during the previous two years, she participated in approximately two hours of professional development related to teaching students with disabilities, provided by the district during institute days. She reported that she completed approximately "one-and-a-half months' worth" of science professional development in the previous two years.

Table 3

*Co-teaching Pairs and Units of Study*

| Case | School | Science Educator | Special Educator | Co-Teaching (Year) | Science Discipline | Unit Topic |
|---|---|---|---|---|---|---|
| A | A | Mr. Green | Ms. Lewis | First | Physical and Earth | Matter |
| B | A | Ms. Jones | Ms. Morgan | Fourth | Physical | Force and Pressure |
| C | B | Ms. Martin | Ms. Lacey | Second | Life | Cells and Heredity |

Ms. Morgan had 28 years of teaching experience and served as a special education teacher for 14 years. She had master's degrees in special education and educational administration. In addition to the eighth-grade co-taught science class, Ms. Morgan provided instruction to students with IEPs in math and reading classes. Ms. Morgan did not report professional development completed in the areas of science or special education during the two years prior to this study. While Ms. Jones and Ms. Morgan co-taught the science class for three years, the district discontinued co-teaching in science for ten years. They had just started to co-teach again during the year of this study.

What follows is a description of Case C teachers. Ms. Martin and Ms. Lacey co-taught seventh-grade life science. Ms. Martin had 13 years of teaching experience. She had a master's degree in curriculum studies and was licensed to teach biology and chemistry in grades 6-12. Additionally, she had endorsements to teach general science and social science in middle school. In the last 2 years, she participated in multiple district-level curriculum meetings focused on NGSS, and she attended a STEM conference. Although Ms. Martin reported extensive professional development in science, she said that she was “lacking” professional development in teaching students with learning disabilities.

Ms. Lacey has 36 years of teaching experience. She had 28 years of experience teaching special education and taught science to students with disabilities for 27 of those years. She had a master's degree in special education and was also endorsed to teach music. In the last two years, Ms. Lacey completed 30 hours of professional development in science offered through a science museum’s education department. The year of this study was the second year Ms. Lacey and Ms. Martin co-taught seventh-grade science.

**Instruments**

This descriptive case study was designed to “explore multiple bounded systems through in-depth data collection involving multiple sources of information” (Creswell, 2013 p. 97). Moreover, for case studies, Stake (2000) recommended data collection include information that reveals the nature of the case, the historical background and the physical setting. I used a variety of instruments to develop a rich data set for each case that included multiple kinds of interviews and observation. Interviews provided data about the teachers' perspectives, and structured observations provided a non-self-reported data source to triangulate with self-reports. Each research question was addressed using analyses from data sources (see Table 4).

**Teacher and class profile.** The Teacher and Class Profile (Appendix B) was used to collect demographic information about the participants and their classrooms. Each teacher described his or her professional development by listing advanced degrees and endorsements. They also listed any professional development related to teaching science or teaching students with learning disabilities that occurred during the two years before this study. Additionally, they described their daily schedule, the total number of students enrolled in each class and the number of students with identified learning disabilities in each class.

**Initial interview protocols**. The Initial Interview Protocol for Science Teachers (Appendix C) and Initial Interview Protocol for Special Educators (Appendix D) served as guides for the semi-structured interviews. The protocol was developed and organized to invite participants to speak generally about their instruction at the beginning of the interview, and to focus more narrowly on responses to questions aligned with the research questions as the interview progressed (e.g., about teaching science to students with LD). The Initial Interview Protocol semi-structured interviews used a variety of question types that Kvale (1996 p. 133) described. He spoke of "introducing questions" at the beginning of the interview to invite rich and broad descriptions. "Direct questions" used during the interview introduced topics for a series of questions and add clarity to switch topics during an interview. Using a semi-structured interview allowed me to change the sequence and form of questions to follow up on answers given by the participants. The follow-up and probing questions were added to provide more detailed factual information and encourage participants to elaborate on personal experiences (Cohen et al., 2011).

The Initial Interview Protocol for Science Teachers had eleven questions. With the first two questions, I asked science teachers to describe the science instruction delivered in the two weeks before the interview and then describe a typical lesson. Next, I asked teachers to explain how they determined what to teach. The next four questions focused on scientific practices. I first asked how students used scientific practices in the two weeks prior to the study and then how the teachers promoted the NGSS-based practices of teaching students to ask questions, construct explanations, and engage in arguments from evidence. The focus of the questions then shifted, and I asked about the ways language was used in science. The final three questions were related to teaching students with LD. I asked teachers to describe the supports their students with LD received in science class. The term "support" was used during interviews because it is vague and did not limit the types of answers teachers might give. I defined "supports" as instructional practices, strategies, interventions or adaptations (modifications or accommodations) used to teach science to students with LD. Then I asked participants to describe how the instruction helped students learn science or ask questions, construct explanations, and argue from evidence. Finally, I asked how science teachers collaborated with the special educator.

The Initial Interview Protocol for Special Educators had eight questions. Because many models of services for students with disabilities exist, the special educator interview protocol had questions aimed at gaining information about the type of interventions and services students with LD received in the science classrooms. The first question referred to the special educator's role in teaching students science before, during class and after class. With the next set of questions, I asked what instructional practices, strategies, interventions or adaptations (modifications or accommodations) were used to teach science to students with LD and how they were provided. I asked special educators to describe the instruction provided to students with LD the two weeks prior to the study. Additionally, I asked special educators to describe how the instruction and services helped students with LD engage in science, scientific practices in general, and then specifically asking questions, constructing explanations, and arguing from evidence. The focus was shifted with the seventh question when I asked special educators how students use language in science to engage in scientific practices and how they were supported. Finally, I asked special educators to describe how they collaborate with the science teacher.

Table 4

*Data Sources for Each Research Question*

| Research Question | Data Source |
|---|---|
| How do general education middle school science teachers and the special educators with whom they co-teach describe the language demands associated with asking questions, constructing explanations, and engaging in arguments from evidence for students with and without learning disabilities in inclusive middle school science classrooms? | Initial Interview<br>Pre-observation Interview<br>Written Reflection Guide<br>Paired Interview |
| What scientific practices and interventions do general education science teachers and special education teachers with whom they co-teach use as students ask questions, construct explanations and engage in arguments from evidence in inclusive middle school science classrooms? | Initial Interview<br>Paired Interview<br>Observation Field Notes |
| How do general and special educators provide interventions to students, targeting especially students with learning disabilities, within inclusive middle school science classrooms? | Initial Interview<br>Pre- and Post-observation Interviews<br>Observation Field Notes<br>Paired Interview<br>Written Reflection Guide |

**Pre-observation interview protocol.** Before each observation, I interviewed each teacher using the Pre-observation Interview Protocol. I first asked identifying information for the lesson, such as date, time, number of students, and number of students with LD. In the next three questions, I asked science teachers to provide a general description of the science topic, the learning outcomes for the lesson and how the teachers anticipated the overall sequence and flow of the lesson activities they had planned. Next, I asked how students would use language during the lesson, and what challenges the science teacher anticipated due to the language demands. The final questions were about how students with LD would engage in the lesson, and I asked about the planned supports and how the supports were offered. (Appendix E).

The special education teacher pre-observation protocol had five questions and began by noting if the lesson would be co-taught. I first asked the special educator to state the learning outcome for the lesson. The next two questions were related to the language demands in the lesson. I asked the special educator to explain the language demands, and then the anticipated challenges language might present to students with LD. With the final two questions, I asked what supports were planned and how they were to be provided.

**Post-observation interview protocol.** After each lesson, I used the Post-Observation Interview Protocol to talk with each teacher. It had seven questions (Appendix F). With the first two questions, I asked teachers to reflect on what went well during the lesson and what he or she would change. Then I asked them if, and how, students met the learning outcomes and how learning was assessed. The next two questions were about scientific practices and the language demands presented in the lesson. I asked teachers to describe how each was present or not present in the lesson and then asked them to describe the students' performance in those areas. With the last two questions, I asked about the supports offered to students with LD during the lesson and if the supports were effective.

**Science instruction observation guide.** Observations provide a continuum of data that range from uncontestable facts, such as the number of students in a classroom, to the researcher's interpretations and judgments of situations (Cohen et al., 2011). When a researcher knows what he or she is seeking to observe, a structured observation can be used. Specifically, the researcher uses an observation guide that identifies discrete categories of behavior. In this study, The Science Instruction Observation Guide (Appendix G) was used to record interval observations as well as descriptive and reflective field notes. The observation guide used discrete categories developed by Bunch, Shaw and Geaney (2010). Additionally, and directly related to this study, Bunch et al. (2010) developed the Science Assessment Language Demands (SALD) framework to measure the language demands embedded in inquiry-based science performance assessments (SPA). To describe the development of the categories, Shaw, Bunch and Geaney, (2010 p. 909), explained the researchers used "functional and interactional views of language and language use" to "developed the framework via an inductive, iterative, and systematic review of written assessment materials associated with three fifth grade science performance tasks."

Bunch et al. (2010) identified three dimensions of language demands: participant structures, communicative modes, and texts that were read by students and written by students. In a later study, Lyon, Bunch and Shaw (2012) used SALD to analyze videotaped lessons for the language demands students encountered as they completed the same science performance assessment in three different science classrooms. Lyon et al. (2012 p. 632) explained that

> Science performance assessments (SPA) are designed to resemble authentic scientific processes. They call for students to use different kinds of productive and receptive language abilities as well.

SPA reflect the performance expectations put forth by NGSS, and ultimately the instructional pedagogies that will be necessary to meet those expectations. In the observation guide, I used the discrete categories Bunch et al. (2010) developed in order to capture the teacher and student participant structures and communicative modes observed during the lessons at set intervals of time. Looking at the participant structures and communicative modes through the discrete categories described in SALD provided insight into how the teachers were structuring their instruction to incorporate language and literacy with scientific practices, and specifically the scientific practices of asking questions, constructing explanations, and arguing from evidence. In summary, the SALD discrete categories served as a guide to observing the language demands present during the lessons.

In addition to interval observations with discrete categories, field notes were used to record notes about scientific practices and receptive and expressive language demands observed during each lesson. Field notes capture what a researcher sees and hears during an observation along with the researcher's reactions and impressions about the situations or interactions observed. Field notes were used to note the role of the special educator and the interventions provided to students with LD. Additionally, instruction related to the scientific practices, and specifically the practices of asking questions, constructing explanations, or arguing from evidence, as well as examples of receptive and expressive language were noted. A two-column design was used, and reflective notes were added to the descriptive notes captured during the observation. Reflective notes were added within 24 hours of the observation so that the details of the observation remained fresh.

**Reflection guide instrument**. The Reflection Guide Instrument (Appendix H) had three distinct parts (a) Lesson Segment Reflection, (b) Paired Interview and (c) Final Reflection. The three parts were completed in a meeting with the science teachers and special educator. Before the meeting, I selected and transcribed a lesson segment from one of the observed lessons. A lesson segment is "a block of time with a particular focus or intention" (Burns & Anderson, 1987 p. 31). I selected the lesson segment based on the opportunities within it for students to use receptive and expressive language and opportunities to engage in the scientific practices of asking questions, constructing explanations, or engaging in arguments from evidence. In cases where those scientific practices did not occur, lesson segments that provided rich examples of language demands were selected. I also chose segments that showed the students' and teachers' involvement in an activity from the beginning to the end of it. After selecting the segment, I transcribed the general education teachers' directions, questions, and explanations. Since students were not participants in this study, their responses were not transcribed. The purpose of the transcript was to refresh the teachers' memories of that part of the lesson since, in some cases, the reflection occurred three weeks after the lesson.

After the lesson segment transcript, I listed six questions with space for written responses. I first asked each teacher to describe the science concepts or scientific practices as well as the language demands presented in that part of the lesson. Additionally, I asked teachers to explain how the language demands impacted students' learning of science. I also asked them to describe the supports (instructional practices, interventions, strategies) offered to all students, and specifically to students with LD, and to explain how the supports increased participation for students with LD.

The second part of the Reflection Guide Instrument was a paired interview. The paired interview was conducted with the science and special educator present. The interview consisted of five questions. I asked the co-teachers to explain the opportunities and challenges language demands (expressive and receptive language) presented to all students, and then specifically to students with disabilities. Finally, I asked participants to describe the supports that best enabled students with LD to learn science concepts or scientific practices. Probing questions were used to encourage participants to share examples to explain their answers.

The third part of the Reflection Guide was the Final Reflection. It consisted of three question that each participant answered independently in writing. The teachers were asked to explain how they believed language demands impacted learning science. They were also asked to identify the supports they believed were best to teach all students, and then the supports that were best to teach students with LD as they learned science and/or scientific practices. The final open-ended question asked participants to share any additional thoughts.

**Procedures**

Data collection began in the fall of 2016. Participants received a phone call to inform them of their acceptance into the study, and the Initial Interview was scheduled. Two copies of the Informed Consents were signed before the interview began, and the participant was given a signed copy.

**Initial interview.** The interviews were scheduled at the participant's convenience and took place before or after school. All of the interviews were conducted privately with only the participant and me present. Interviews happened either in a school conference room or the teacher’s classroom. The participants were told that I would be taking notes and audio-recording with their permission. Although permission was previously granted through the Informed Consent, I asked participants again about audio-recording as a means to build trust and transparency. All of the participants agreed to audio-recording. The process of the interview was explained by telling participants that approximately ten questions would be asked, and the focus of the questions would be scientific practices, language demands of science instruction, and supports for all students and specifically, students with LD. To increase the participant's comfort level, each was asked to share any questions they had before the interview began.

Each member of the teaching pair was interviewed separately. At the conclusion of the interviews with science teachers, each science teacher was asked to identify three lessons for observations that were to occur within the following five-week period. I stressed that the lesson should include NGSS-based scientific practices. Because all of the teachers were familiar with NGSS and involved in professional development to implement the standards, there was a shared knowledge that scientific practices would engage students in inquiry or “doing science.”

Additionally, because the teachers were assigned to co-teach together each day, it was requested that both teachers be present during each of the three lessons. At the conclusion of the interviews with special educators, I told each person that the science co-teacher would identify lessons for three observations and the suggested dates would be shared with her. To ensure that both teachers were present during the observed lessons, the special educators were asked to review the dates and communicate whether or not the observation dates were acceptable. The teachers were given a set of pre-lesson interview questions and post-lesson interview questions for their reference. A convenient time for pre-observation and post-observation telephone interviews was arranged with each teacher.

**Pre-observation interview.** Prior to the observation, I called each general education science teacher and special education teacher. As each teacher answered the questions, I recorded their answers in a spreadsheet. The spreadsheet listed the questions along the top row with a cell for additional information. A tab was created for each teacher, and I added responses to the spreadsheet directly during the telephone interview. Each interview lasted seven to ten minutes. If the teacher did not answer the telephone call, I left a message to remind the teacher of the observation time and request that they write the answers to the pre-observation questions and give them to me before the observation.

**Observations.** Multiple observations are necessary to overcome the Hawthorn effect, which is the tendency of participants to change or improve their behavior while being observed (Roethlisberger & Dickson, 1939). Three structured observations were scheduled in each science classroom, and each observation encompassed one science class period. A passive participation approach (Mertens, 2005) was used during the observations. Before the first observation, the science teacher informed students of the purpose of the observations, and then did not provide any further explanation of my presence. I entered the classroom during the passing period and sat in a discreet location in each classroom. The audio-recorder was placed on the table next to my folder and observation form.

During the observations, momentary time sampling was used to record the participant structure and the communication modes directed by the general education science teacher every 8 minutes. A stopwatch app was used to measure 8-minute intervals. At each interval, I would identify the participant structure that was occurring at that moment in time. To determine the communicative mode, I listened for one minute. If a teacher or a student asked a question within the minute, the interpersonal mode was marked. When a question was not asked, the interpretive mode was marked. When a student was presenting information without questions from the audience, the presentational mode was marked. Because the length of class periods differed at each site, seven intervals were observed at School A, and six intervals were observed at school B. Additional notes were added as needed to capture the context of the participant structure or communicative mode. For example, if the teacher directed students to work in pairs, a description of the activity was included in the notes.

Descriptive notes of instruction related to scientific practices, language demands, and interventions offered by the science or special education teacher were recorded throughout the observation. Reflective notes were added to the observation guide within 24 hours of the conclusion of the observation. The audio-recording was named with the participants' pseudonyms and lesson number and saved in a file on a password-protected laptop computer.

**Post-observation interview.** The post-observation questions were left with each participant after the observation. Participants were asked to write their responses to prepare for the telephone interview. I called each teacher within two days of the observation. Each interview lasted between 8 - 11 minutes. When the teacher was not available for the phone call, a message was left asking him or her to return the call or provide written responses at the next observation, which occurred the following week in most cases. The responses were added to the pre-observation interview matrix so that both sets of data for the lesson were stored in the same place. The observation procedure (pre-observation questions, observation, and post-observation questions) was repeated for two more lessons, for a total of three observed lessons for each pair of teachers.

**Reflection guide instrument.** The final phase of data collection was a face-to-face meeting with each science teacher and special education teacher pair. The science teacher and special education teacher were given the Lesson Segment Reflection. They individually wrote answers to the reflection questions for approximately five minutes. I then facilitated a 20 to 25 minute paired interview using Part 2 of the Reflection Guide Instrument. The paired interview was audio-recorded. I jotted notes and asked follow-up questions as needed to keep the discussion going. To encourage dialogue between the science teacher and the special education teacher, I utilized silent pauses and probing questions. Silence allows each participant "ample time to associate and reflect and then break the silence with significant information" (Kvale, 1996 p. 61). Probing questions were used to encourage deeper description or more examples without providing direction for the discussion.

At the end of the paired interview, I thanked the teachers for sharing their ideas and introduced the final reflection. I explained that this was a final opportunity to share their individual thoughts. Each participant completed a written reflection that contained three questions. Teachers took between eight to ten minutes to complete the writing.

**Data Analysis**.

In a multi-case study, a researcher first analyzes and describes individual cases and then looks across the cases to complete a cross-case analysis. The many forms of data can be used to provide convergent and concurrent evidence within a case and possibly across cases (Cohen et al., 2011). In this study, the research questions were answered through the combination of multiple data sources (see Table 4). After analyzing and describing each case, a cross-case analysis was done to look for similar themes or variances to provide a description of the phenomena I sought to explore.

Data analysis was ongoing and occurred as each type of data were collected. The first step in data analysis was the preparation of the data. To prepare the data, the initial interviews were transcribed and presented to the interviewee for a member-check. Observation field notes were converted into a "write-up" or an intelligible form (Miles, Huberman & Saldana, 2014). Participants' written responses to the Reflection Guide Instrument were typed and saved as a Word document. The Reflection Guide discussion was transcribed and added to a separate Word Document. Each participant's responses to the pre-observation and post-observation interviews were compiled onto an Excel spreadsheet. Each data source was named with the source of data and the teacher's pseudonym and saved in Nvivo 11. A project was created for each case to ensure data sources were kept separate. Nvivo 11 was used solely for storing the data.

During the second step of the analysis process, each data source linked to each participant pair was closely read to identify patterns, particular questions and discrepancies that did not fit with the patterns. I wrote analytic memos to track thoughts, questions or hunches about the data. After looking at each data source separately, I compared and contrasted across each case the patterns and discrepancies that emerged from each data source. I identified assertions, that is, statements about the patterns and evidence that supported it. The data set was reread throughout the analysis process because a researcher has to review the data many times to make sure that all of the data fit the analyses (Cohen et al., 2011).

The next step was open coding. To analyze data, I used open coding techniques to identify major categories or themes (Creswell, 2013). Open coding refers to the process of breaking down segments of text data into smaller units and labeling or coding them with a name that represents the meaning of the unit. (Cohen et al., 2011). Then the constant comparison method (Miles et al., 2014) was used as each data source was analyzed. Units of text with similar meanings were given the same code. Then the codes that represented similar aspects were grouped together or categorized. Coding is not a “one-off” exercise (Cohen et al., 2011), so the data were reread, and codes were refined and reorganized until no new codes emerged. The objective was to group similar codes and look for redundant codes to create a smaller, more manageable number of codes (Creswell 2013). When coding was exhausted, and no new codes emerged, I identified themes in the data. I drew on Creswell’s definition of themes, which he writes can also be called categories. Themes or categories “…are similar codes aggregated together to form a major idea in the database.” (Creswell, 2013, p. 201).

For the observational data, I arrayed the time samplings and associated data in a matrix. Additionally, I created a set of “a priori” codes to identify effective instructional practices for teaching students with LD. Those codes were drawn from a list of evidence-based instructional practices identified by CEC (Espin et al., 2000) and described through CEC Current Practice Alerts. Labeled “Go for It,” they are instructional practices for “which there is solid research evidence of effectiveness” (Espin et al., 2000).

Finally, I created matrices to display the reduced data. Displaying data in a systematic way allows a researcher to think about the research questions and what parts of the data answer them (Miles et al., 2014). A matrix was created for each question, and portions of the data that answered a question were added to the matrix (See Table 4).

**Cross-Case Analysis**

After analysis and a write-up for each case was finished, I did a comparative analysis across the three case studies that helped me identify and explore themes across the cases.

Multiple cases allow a researcher to both generalize explanations and test them systematically (Miles et al., 2014). I created a matrix for each of the themes I described in each case. I then used a similar routine as in the single-case analysis. I identified similar patterns and variances across the cases and explored reasons why they might exist. That comparative analysis was used to answer the research questions.

**Trustworthiness**

In qualitative research such as a case study, a researcher strives for trustworthiness (Cohen et al., 2011). Trustworthy qualitative research demonstrates credibility, transferability, dependability, and confirmability. Credibility refers to the internal validity that is established through triangulation, the use of established research methods and thick descriptions of the phenomenon. Transferability is established by demonstrating applications of the findings to similar situations or other research. Dependability is established through detailed description of the design and methods. Confirmability is established through a neutral reporting of the findings. Researcher bias is addressed by describing limitations and proving a detailed description of data collection and analysis. Triangulation of the many data sources was used to establish trustworthiness in this study. Table 4 (see p lists the data sources used to answer each of the research questions.

For quantitative data gathered during the observations, I established inter-rater reliability to demonstrate the reliability of the observational data (Mertens, 2005). For this study, a retired educator with extensive experience conducting teacher observations established inter-rater reliability. The teacher and I met for one hour, during which time I described and provided examples of each category on the Science Instruction Observation Guide. The teacher asked clarifying questions to gain a deeper understanding of the categories. Then I presented hypothetical situations that are typical in a science classroom, and we separately identified the participant structure and communication mode for the situation. Differences in selected categories were discussed, and the definition of each category was reinforced. That activity was continued until all categories were identified at least once, and the researcher and the teacher identified the same categories for three consecutive hypothetical situations. We then observed two science classes. The observations occurred in a participant's classroom, but the two observed lessons were not included in the data. The inter-rater reliability of the first observation was 91.6%. We examined the discrepancy and determined that it was due to the timing of a transition from a whole group to small group setting. The inter-rater reliability of the second observation was 100%.

Code checking was used to increase the reliability of the coded data. A second coder, who has a Ph.D. in Special Education and was not familiar with the study, coded the interview and observation data for one case. In qualitative research, intercoder agreement checks with adequate results add to the reliability of the results (Miles et al., 2014). The researcher shared the list of codes and operational definitions with the co-coder, clarified the meaning of each code, and provided directions for coding. The co-coder and I reached greater than 85% agreement after the first round of coding. We clarified our understanding of codes that showed discrepancies (i.e., mnemonics as memory devices and real-world examples) and reached 100% agreement.

# IV. Results

I developed three case studies, each of which focused on a general educator and a special educator co-teaching in the same general education inclusive middle school science classroom. Teachers were in the early phases of implementing the NGSS standards, and I focused on learning about their planning, implementation and reflection on science teaching and learning with special attention to the NGSS scientific practices of asking questions, constructing explanations, and arguing from evidence. Furthermore, I was interested in the instructional practices and interventions the co-teachers used to provide students with LD access to science instruction. I sought to answer three questions.

(a) How do general education middle school science teachers and the special education teachers with whom co-teach describe the language demands associated with asking questions, constructing explanations, and engaging in arguments from evidence for students with and without learning disabilities in inclusive middle school science classrooms?

(b) What scientific practices and interventions do general education science teachers and special education teachers with whom they co-teach use as students ask questions, construct explanations and engage in arguments from evidence in inclusive middle school science classrooms?

(c) How do general and special educators provide interventions to students, targeting especially students with learning disabilities, within inclusive middle school science classrooms?

I reported findings in each case in four sections: (a) Teacher perceptions of students (b) teachers perceptions of language and literacy demands for learning science, (c) Stated outcomes, lesson overview and reflections (d) Interventions in an inclusive science classroom, and (e)

Summary of findings. In the first section, I used the initial interviews and reflections to compare and contrast science teachers' perceptions and special educators' perceptions of how language and literacy demands impacted science learning for students with and without LD. In the second section, I presented a description of the three observed lessons. First, I used the pre-observation interviews to compare the co-teachers' stated outcomes and the teachers' roles to my observations. Then I described the instructional modes I observed and provide examples of each. Next, I described how the teachers integrated language and/or literacy and student participation in each observed lesson and compared and contrasted co-teachers' reflections on how students met their stated outcomes.

In the third section. I reported teachers' stated interventions for NGSS scientific practices and their stated interventions for students with LD for the three observed lessons. Additionally, I presented the evidence-based instructional practices I observed. The general term "supports" was used to ask teachers how they taught science and NGSS scientific practices, and how they provided students with LD access to the general education curriculum and met the requirements of students' Individualized Education Programs. In presenting the teacher stated supports, I used the terms intervention, strategy and evidence-based practice, when applicable. In the final section, I presented a summary of my findings and restated the main finding of each case. After presenting each case, I reported a cross-case analysis.

**Case A: Mr. Green (Science Teacher) and Ms. Lewis (Special Education Teacher)**

Mr. Green, the science general educator, and Ms. Lewis, the special educator, co-taught two periods of sixth-grade science each day. This was their first year of co-teaching. The unit of study, *Understanding Matter*, was a new unit designed by the district's science committee to align the curriculum to NGSS. Newly-designed NGSS units were introduced in sixth grade, with a plan to introduce additional units as this particular group of students continued through middle school. *Understanding Matter* was the first newly designed unit taught by Mr. Green and Ms. Lewis. The unit focused on metric measurement, metric conversion, subatomic particles, the properties of matter and mixtures and solutions.

The unit lasted roughly ten weeks, and I observed during the second through fourth weeks. I observed three lessons over a three-week period in September and October 2016. The observations took place on two consecutive Tuesdays and the following Wednesday. Each observation was an entire 50-minute class period. In the first lesson I observed, Ms. Lewis reviewed metric conversion. In the second lesson, I saw Mr. Green introduce scientific notation and exponential change and Ms. Lewis facilitate a carousel activity. In the third lesson, I saw Ms. Lewis teach students how to set up a two-column graphic organizer to complete a vocabulary assignment. Finally, I observed both teachers interact with individual students as they completed independent practice.

**Teacher perceptions of students.** Mr. Green and Ms. Lewis taught science to 26 sixth-grade students. Five students had IEPs for specific learning disabilities. Ms. Lewis explained that some of the students with LD had "higher needs" so she frequently led the class. She used a "slower pace" and presented content in multiple and varied ways. She explained that the students needed to build confidence, and she believed hands-on activities built their confidence. She explained

> I could say, "This is how you measure mass with a triple beam balance, but try to figure it out on your own first." I think that actually helps with those kids, or any kid really, to give them more confidence. [They think] "Oh, I can do this instead of asking a million questions all the time."

Mr. Green believed that students with LD had unique learning needs. He said, "I find it important to avoid painting all [students with LD] with the same brushstroke. Individual students need material presented in different ways." He also explained that some students needed strategic seating to minimize distractions. Both teachers expressed concern about how students with LD struggled to identify key information during independent work. Ms. Lewis said, "They may get confused on what to write down," and Mr. Green explained, "Some students may not identify all the information that others deem to be important." However, the teachers' perceptions of how students participated in discussion differed. Ms. Lewis believed students with LD did a good job participating in class, possibly because they were "in an environment where it's going a little slower so it's easier for them to build up their confidence a bit more." Mr. Green thought students with LD were "hesitant to share out during whole-class discussion."

**Teacher perceptions of language and literacy demands for learning science.** Mr. Green and Ms. Lewis shared similar perceptions, and both cited (a) the importance of discussion to clarify student understandings of science, (b) reading science text was a challenge for students and (c) the importance of multi-modal teaching. First I explore their ideas about discussion. When asked to describe his science instruction, Mr. Green focused on his use of whole group discussion to clarify science concepts. He said,

> What I like is to start a new topic with an exploration where they try to make some discoveries on their own. Then we come together to discuss those things and make sense out of it.

Ms. Lewis explained that students participate in whole-group discussions as well as one-on-one discussions with a teacher. She assessed students' reactions and altered instruction based on those discussions. She said students with LD in the eighth-period class tended to participate in discussions more than the students with LD in the first-class. She thought it might be because "they're in an environment where it's going a little slower." Ms. Lewis encouraged her students to participate in class by providing wait time to "give others a chance to answer."

During the paired reflection interview, both teachers specifically talked about the benefit of peer discussions. Mr. Green said,

> It allows them to converse with others and just from small group discussion with others at tables. It helps them to pick up on things that they were a little unclear on.

Ms. Lewis added, “And even in ways that the kids may be able to explain it to them a little bit better.” Mr. Green expressed similar ideas about peer-to-peer discussion when he reflected, “I do like to use discussion between peers to process scientific information.” When asked to reflect on an activity observed in Lesson 2, Ms. Lewis provided an example of how students with LD benefited from small group, peer discussions. She wrote,

> Since the students were with the general ed population, they were able to hear what those students came up with and expand from there.

A second common perspective related to language and literacy in science was the struggle students have reading and comprehending science text. To accommodate, Mr. Green said he gives “more opportunities in the other three areas [listening, speaking, and writing] to support the reading.” Ms. Lewis added that reading is a challenge for students with and without LD. She said,

> Whether they’re regular ed or special ed, sometimes they read through it quickly and get distracted. Are they really going back and rereading what they didn’t understand or what they didn’t pay attention to?

Mr. Green responded that he brings in content area reading through *Science World* magazine because it “has really interesting science content to promote reading.”

Another shared perspective was the benefits of multimodal instruction. Mr. Green wrote, “The assortment of activities with all the language types are really critical.” Ms. Lewis went further in her written reflection by explaining why multimodal instruction benefits students. She wrote,

> If we had students read all the time, some students would understand and comprehend, but a lot of them would not. By using the four language demands daily throughout the class, it allows all students to benefit since all students learn differently.

**Stated outcomes, lesson overview and reflections.** The teachers' outcomes for each observed lesson differed in levels of specificity and/or identification of the primary lesson focus. For example, although both teachers' outcomes for Lesson 1 included metric conversion, Mr. Green added more detail by connecting the outcome to previous lessons. He said, "Know what unit to use for mass, volume, and length. Then use prefixes to convert measurements." While, Ms. Lewis stated that students would "accurately use metric conversions," she did not provide the same level of detail. While Lesson 1 outcomes had a similar focus, the outcomes identified for Lesson 2 differed greatly. Mr. Green's outcome was to introduce a new unit. Ms. Lewis identified two outcomes unrelated to Mr. Green's outcome, "students will achieve 85% accuracy on metric conversions" and "gain a basic understanding of matter through the carousel activity." The outcomes for Lesson 3 were also very different. Mr. Green's outcome focused on the science core idea of "identifying and describing the parts of an atom," while Ms. Lewis's outcome focused on developing the skill of taking two-column notes.

A common feature in both teachers' outcomes was the use of measurable and non-measurable verbs. To write his outcomes, Mr. Green used the verbs "know and convert" and "identify and describe" for Lessons 1 and 3, while Ms. Lewis used the verbs "use," "achieve," "understand" and "take." Each teacher used one non measurable verb. Mr. Green said his students would "Know what unit to use," and Ms. Lewis stated they would "understand the basics of matter and atoms." Ms. Lewis made her outcomes more specific by adding "accurately" and identifying an accuracy level of 85% for the conversion outcome. With the exception of Mr. Green's outcome for Lesson 2, each teacher's outcomes were student-focused, rather than teacher-focused. When asked the outcome for Lesson 2, Mr. Green said, "We are introducing a [new topic in] the unit, *Understanding Matter*." His response was teacher-focused because he described what he would be doing, rather than what students would be able to do by the end of the lesson.

***Teachers' roles.*** When asked to describe her role, Ms. Lewis described the functions she performs before, during and after science class. Because it was early in the school year, she explained that she had not adapted many materials. However, at the beginning of the year, she told Mr. Green to give her "whatever he had that needed to be updated." Mr. Green explained that "the day before or week before" a lesson, he lets Ms. Lewis "know what's coming up" and shares materials with her. At the time of the interview, Ms. Lewis had reformatted one quiz and converted it to a Google document. Because they did not have shared planning time, Mr. Green shared that the co-teachers were learning where they "can sneak in a few minutes" to collaborate. Ms. Lewis explained that it was frequently "five minutes at the end of the school day."

The teachers explained that Mr. Green led instruction during the first period of co-teaching each day, and Ms. Lewis led most of the instruction during the eighth period class. She explained that she would "rather be in the classroom up doing instead of sitting there" so she would observe the first class and then "make my changes." When she ran the class, she said she went "at a slower pace" and used "different ways to explain ideas," often "reiterating the concepts more" than they did during the first period class.

During the three lessons I observed, Ms. Lewis led teacher-directed, whole group instruction for 42 out of 150 of the observed minutes. I saw her lead a review of metric conversion for 20 minutes in Lesson 1, facilitate a carousel activity for 12 minutes in Lesson 2, and guide students to set up two-column note-taking charts for ten minutes in Lesson 3. Within these three observations, Mr. Green led teacher-directed, whole group instruction for 22 minutes and focused on metric conversion and scientific notation. In the remaining time, both teachers worked with students during independent or small group practice.

***Instructional modes***. I observed three major ways of presenting science content, and the teachers shared the responsibility of delivering instruction in each. Teacher overview and feedback was the instructional mode used most frequently. Slightly more than 80 out of 150 of the observed minutes included teacher overview and feedback in whole group, small group or individual practice. Teacher overview and feedback happened while students worked independently for 44 of the observed minutes. For example, while students practiced metric conversions in Lesson 1, both teachers moved from table to table and checked students' work. After checking in with several students, Ms. Lewis called three students to a separate table in the classroom. She worked with the students for nearly 15 minutes. In lesson 2, students completed a quiz independently on their personal devices. Mr. Green reminded students, "Don't submit until we've given the okay." Each student would raise a hand to indicate they were finished, and then one of the co-teachers reviewed the answers and had a one-to-one conversation with each student. The length of the conversation was based on the students' needs. If the student's work was accurate, the teachers gave positive feedback such as "Great Job" or "Super" and told the student to submit their answers. If a student had errors, the teachers provided one-to-one instruction by asking the students how he/she arrived at an answer or telling the student to recheck an answer. A third example was in Lesson 3 while students independently completed their two-column note-taking chart. Ms. Lewis approached a student who was watching the video and not recording notes. She asked, "What word are you working on?" and directed the student to look at the notes page. She suggested he watch the video until he heard the word. She stayed nearby and observed the student until he added notes to his paper. Similarly, Mr. Green worked with a different student and showed him how to stop the video and replay the section that included the term he was describing.

In addition to students' independent practice with feedback, teachers also facilitated guided practice with the whole class for 36 minutes. Ms. Lewis reviewed metric conversion for 20 minutes at the beginning of Lesson 1. She asked for volunteers to solve metric conversion problems at the board and prompted them to explain as they showed how they converted the measures. Mr. Green reviewed metric conversion and scientific notation for roughly 15 minutes at the beginning of Lesson 2. He asked for volunteers to "walk us through" two of the metric conversions the students previously completed on a quiz and then, to review scientific notation, he called on a student explain how to convert $1x10^2$ and $1x10^5$ to standard form. He asked guiding questions such as, "Why did you put the decimal point there?" throughout the review.

Use of multimedia was the second most frequently used instructional mode, slightly more than 45 out of 150 minutes of the observed minutes. Students viewed a video as a whole group for 11 minutes during Lesson 2. Mr. Green introduced the video, *The Power of Ten,* and told students to pay attention to the number written in scientific notation and especially look at how the exponents and units changed throughout the video. In Lesson 3, students used a personal device to independently view a video on an educational web site to gather details about six parts of an atom. They spent 30 minutes viewing the video and adding information to a graphic organizer the teachers called "two-column notes."

Small group peer-collaboration was another instructional mode I observed, though there was much less time devoted to it, 15 out of 150 minutes of the observed minutes. Ms. Lewis worked with three students at a separate table during Lesson 1 after circulating and checking their independent work. She facilitated a carousel activity during the last 15 minutes of Lesson 2. Six terms related to matter were each written on the top of six pieces of chart paper. Ms. Lewis assigned students to groups and then said,

> What you'll do in groups is move from poster to poster to poster, and with your group members, you're going to write down anything you know about atoms, about matter, about states of matter.... It doesn't need to be in complete sentences. It can be a word or phrase.

She urged students to talk to each other to come up with ideas to write down.

I observed one example of teacher-directed instruction for nearly 10 out of 150 of the observed minutes during Lesson 3. Ms. Lewis gave step-by-step directions for setting up two-column notes and writing descriptions of the vocabulary terms related to parts of the atom.

***Students' language use and participation.*** I saw mostly attention to the receptive skill of listening. I observed students listen to teacher-directed instruction for 90 out of 150 observed minutes. Students listened to a teacher or peer in a whole group setting for roughly 50 out of 150 observed minutes. Additionally, they listened to multimedia in two of the three observed lessons for approximately 40 out of 150 observed minutes.

Listening was, however, often paired with an expressive language skill. Listening and speaking were paired during whole group teacher-guided practice. For example, after calling two students to the whiteboard during Lesson 1, Ms. Lewis said, "Stay up there because you are going to explain to us." Additionally, she prompted her students to listen to each other during that same lesson. In response to a student's explanation, she said,

> Oh, I see. I get what you're saying. What you're getting at is that if you have 2,600 that this is going to be the same. I wouldn't necessarily say it's going to be the same.

Then she asked the class, “Do you think it will be the same?” In order to answer that question, the students had to listen to their classmate’s statement and Ms. Lewis’ response. A student volunteered and replied, “No.”

The carousel activity at the end of Lesson 2 provided students with another opportunity to speak and listen to their peers. Groups of four or five students discussed a term written at the top of a chart paper while one group member wrote their ideas. After two minutes, each group moved to a new chart. Ms. Lewis encouraged the students to discuss the terms by saying, “See if by talking amongst your group members and having that conversation, you can come up with an idea to write down.”

Typically, speaking in whole group and small group settings was voluntary. Most often students raised a hand to participate and occasionally, they were prompted to answer chorally. In addition to speaking in a small group and whole group, students had opportunities to speak individually with a teacher in each of the observed lessons.

Choral response was another way students participated. I observed instances in which students were prompted to respond chorally. One example occurred after reviewing the quiz in Lesson 2. Mr. Green asked a question, and then noted that all students answered it correctly on the quiz. He asked everyone to chorally say the correct response. Ms. Lewis did the same choral response prompting before the students began independently completing the two-column notes. She had the students chorally read the vocabulary words. During the two-column note activity, listening was also paired with writing. Ms. Lewis told students

> The video's not that long, so you can do what if you need to? …Yes, pause it. If you need to hear that definition or explanation again, you can go back. You have that feature, so you should utilize that.

As students watched the video and listened to the narration, they used expressive writing skills and visualization to describe the parts of an atom and sketch an image. Ms. Lewis encouraged students to listen and then write a description in their own words. She said,

For the definition or the description, does it need to be exactly what the video tells you?

No. Sometimes with the definition or description, we need to change it.

She asked the class how they might change it and after a student replied, she said “Yes, by making your own description. And by making our own description, do we sometimes remember it better?” Some students replied, “Yes” and Ms. Lewis concluded by saying, “So we’re not asking you to write word-for-word.”

***Teachers’ reflections of outcomes.*** In reflecting on how well students met the lesson outcomes they had stated, Mr. Green and Ms. Lewis shared similar perceptions, with variation in how they justified their perceptions. For example, both teachers believed students met the Lesson 1 outcome. Mr. Green explained that he knew that because he worked with individual students. Ms. Lewis stated that working with the small group of students helped students with LD meet the outcome. Similarly, when reflecting on Lesson 3, both teachers stated students met the outcomes but provided different justifications for their answers. Mr. Green believed “the graphic organizer [two-column notes] guided students to collect the necessary information from the video,” while Ms. Lewis knew the outcome was met because “all the students completed the 2-column notes with at least 90% accuracy.” Lesson 2 reflections revealed the greatest difference. While Mr. Green said there was not an outcome to meet, Ms. Lewis provided overall results of a metric conversion warm up. She said students met the outcome of converting metric measures because “most students answered the conversions correctly or knew exactly why they answered it wrong.”

**Interventions in an inclusive science classroom.** In the next section, I present the interventions I observed and the interventions reported by the teachers during the initial interview, pre-observation interviews and post-observation interviews. First I present the interventions teachers reported using to teach scientific practices, and then the interventions used to help students with LD access the science lesson. I describe how I saw those interventions used during the lessons. Finally, I described how EBP were used during the science lessons.

***Interventions for NGSS scientific practices.*** I asked teachers individually how their students engaged in the scientific practices of asking questions, constructing explanations, and arguing from evidence. In addition, they were asked how they support students as they engage in those scientific practices. Mr. Green described how he guided students to ask questions earlier in the school year. He presented his students with an imaginary, newly discovered object and they had to figure out what it was. He modeled questions that students might ask, such as “How does this work?” and guided them to think about “what kind of questions do you need to answer to figure out how it works?” He “led them down that path of trying to ask a series of questions to get to it.” In describing how she taught students to ask questions in science, Ms. Lewis said they “hadn’t gotten to the deepness of science yet.” Instead of asking scientific questions, the students asked questions when they were confused. She said she responded to students by asking them questions so that “they are thinking about the information instead of me telling them.”

Because it was early in the year, Mr. Green explained that his students had not had opportunities to construct explanations or argue from evidence. In the past, his students would “write an explanation of an observation,” and he would guide them to write better explanations by asking questions that “might be a little bit of a silly interpretation about the explanation, but enough to get them to see that it wasn’t clear.” As an example of how students constructed explanations, Ms. Lewis stated that she asked students to explain how they measured volume with a graduated cylinder. Additionally, she monitored their work and asked them to repeat measurements that were "way off."

Both teachers reported that the students had not argued from evidence. Mr. Green believed it would be "easier with the new curriculum" and said he would love to "have a debate where a students are assigned a position to take and use research to sway people to your side." In an effort to provide an example of arguing from evidence, Ms. Lewis identified an activity in which students proved or disproved their hypothesis about the volume of an object by using water displacement as the closest they got to using evidence. She explained, "I say evidence-based because this is what it is based on, the measurement, but we really haven't done much of any type of debate." In light of the fact that students were not yet engaging in the scientific practices, the teachers did not share interventions for teaching the scientific practices.

***Teachers stated interventions for students with LD.*** Mr. Green identified Ms. Lewis, the special educator, as the one major intervention. He identified her as the intervention in every pre-observation interview, referring to her as the "resource teacher" and "co-teacher." In her pre-observation interviews, Ms. Lewis described specific actions she used to teach students with LD. For example, she explained she checked for understanding and provided small group instruction (Lewis Pre-1), provided one-to-one monitoring to check understanding (Lewis Pre-2), and offered guidance during independent work (Lewis Pre-3). For Lesson 3, Ms. Lewis believed students benefited from the ability to watch the video repeatedly.

Teachers identified interventions for students with LD after reflecting on a transcription of the 2-column note activity in Lesson 3. In this instance, their responses differed. Mr. Green identified "individual verbal prompts" as an intervention for students with LD and explained that it increased their participation. He said, "Students who were stuck or did not know what to write were able to complete their notes after individual prompting." Ms. Lewis identified two interventions she provided to all students in the class (a) providing students with a list of terms and (b) checking the setup of each student's 2-column note-taking chart. When asked what supports were offered to students with learning disabilities, she responded, “The same.”

When asked what they believed were the best supports for students with LD in science, both teachers repeated that “one-on-one” interaction with a teacher was best. Mr. Green added that the one-on-one interaction was “provided by the resource teacher in the room,” repeating the ideas he stated in the initial and pre-lesson interviews. However, in their reflections at the end of the study, both teachers identified interventions they had not mentioned in previous interviews. Mr. Green identified graphic organizers and presenting materials orally and visually as interventions for students with LD. Ms. Lewis wrote about the need to make sure students with LD understood the demands of the lesson and identified breaking down instruction “step by step” as additional interventions.

***Observed evidence-based practices for students with LD***. Observational data were used to identify evidence-based instructional practices that the teachers may or may not have identified. I observed two evidence-based instructional practices in the three lessons (a) use of graphic organizers and (b) vocabulary instruction, two instructional practices recognized as evidence-based by CEC. Ms. Lewis taught her students how to use a two-column notes graphic organizer to record information about science terms. She said, “Today we're going to organize your information, and we're going to use two-column notes.” She told students to use loose-leaf paper and gave step-by-step directions for setting up the paper. For example, after showing students how to fold the paper in half, she said,

> Write *Understanding Matter* across the top. Write the word Term on the left-hand side. Write Definition or Description or both on the right-hand side.

Then she said, “With the two-column notes, you have your term. You have your definition or description, and then what will we add?” A chorus of students replied, “A picture.” Ms. Lewis asked, “How will a picture help us? Why would I draw a picture?” After a student volunteered and answered the question, Ms. Lewis restated that a picture “helps you know what the word really is.”

After setting up the 2-column notes, Ms. Lewis told students how to describe the science terms. She reminded students to write a definition or description of each term in their own words and add an image to further describe the word. She said,

> We’re not asking you to get fancy. I draw stick pictures. If you have coloring supplies and want to add color, great.

The co-teachers identified a set of key terms and wrote them on the board. Ms. Lewis introduced the words before the students began to work independently.

> Lewis: What are the terms that we’ll be using today? Look at the board. In blue, in the center of the board, you see the first word, atom. Does everyone see the list in blue on the board? What's the second word?
>
> Many students: Proton.
>
> Lewis: What’s the third word?
>
> Many students: Neutron.

She continued to have the students chorally read each of the science terms. After reading them all, students started independent work.

**Summary of Findings**

In reference to language demands, both teachers indicated that reading was a challenge for their students, and therefore, they presented content through multiple modalities. For instance, they wrote key ideas on the whiteboard and used video to explain concepts.

Additionally, the co-teachers identified discussion as a means to clarify science concepts. I saw that when I observed as teachers used teacher explanation and video rather than text.

Regarding interventions, Mr. Green and Ms. Lewis stated that one-on-one conversations with students were a very effective intervention for all students. I observed that type of intervention in each of the three lessons. Additionally, at times research-based instructional practices (e.g., the group activity that lasted 12 minutes) and use of two evidence-based instructional practices (a) a two-column graphic organizer and (b) vocabulary instruction were used. Mr. Green stated that having a special education teacher in the classroom to monitor and check understanding was the main intervention for their students with learning disabilities. In addition to the interventions mentioned and provided to all students, I observed Ms. Lewis work with a small group of three students inside the classroom for 15 minutes as they practiced metric conversions. Regarding interventions used to teach NGSS practices, in my three observations, I saw no interventions explicitly linked to teaching students to ask questions, construct explanation, or argue from evidence. While vocabulary instruction and using graphic organizers to take notes are instructional practices with evidentiary warrant, those instructional practices are geared toward helping students learn conceptual science. In NGSS, that would be the disciplinary core ideas. The way in which those foci were used to teach the NGSS scientific practices remains unclear.

**Case B: Ms. Jones (Science Teacher) and Ms. Morgan (Special Education Teacher)**

Ms. Jones, the science general educator, and Ms. Morgan, the special educator, co-taught one period of eighth-grade science each day. They co-taught three years prior to the year of the study and then had a break for ten years because the district discontinued co-teaching in science classrooms. Science co-teaching was re-established during the year of this study, beginning in the fall when this unit was taught. The unit of study was *Fluids and Pressure*. Although the unit was designed prior to NGSS, the science teachers in the district were receiving PD with the expectation they would integrate NGSS into their science units during this school year. The *Fluids and Pressure* unit focused on Bernoulli's Principle, Pascal's principle, and Archimedes' Principle.

The unit lasted roughly six weeks, and I observed during the first through third weeks of the unit. I observed three lessons over a three-week period in September and October 2016. The observations took place on two consecutive Tuesdays and the following Wednesday. Each observation was an entire 50-minute class period. In Lesson 1, I observed Ms. Jones lead demonstrations aimed at illustrating the relationship between pressure and area and Bernoulli's Principle. In the second lesson, I observed students flying tetrahedral kites to apply Bernoulli's Principle, demonstrating how differences in air pressure cause lift and enable the kite to fly. In the third lesson, I saw Ms. Jones teach about density and use a Cartesian diver to introduce Pascal's Principle.

**Teacher perceptions of students.** Ms. Jones and Ms. Morgan taught science to 27 eighth-grade students. Five students had IEPs and four of those students had specific learning disabilities. Ms. Morgan shared two main concerns about the students with learning disabilities. First, she explained that many assessments required students to recall materials. She said, "For the students who have memory deficits, whether long-term or short-term, that always seems to come back and bite them." Both teachers stated that keeping students with LD on task in the science classroom was challenging. Ms. Jones explained, "I have toys in my class, and when [students] come in, they can play with the toys. I have some students this year who are just so distracted by that." The "toys" placed throughout the room were used to demonstrate scientific phenomenon. For example, on one countertop there were solar powered toys, a potato-powered clock, and a balancing bird. Ms. Morgan explained, "Although they are learning when they are playing with the little gadgets, it's not related to the lesson." She said her students needed her guidance to "channel their discoveries."

Additionally, Ms. Jones believed that many students, not only students with LD, lacked confidence in science. She stated that her goal for the year was to "get them to feel they can be successful and that it is okay to not get an answer right." Both teachers believed that many students needed to be entertained to stay interested during science instruction. Ms. Jones said her lessons had to be "entertaining and lively," and Ms. Morgan said, "[Students] have to be entertained. With all the video games that they use today, they have to be entertained." At the conclusion of the unit, both teachers explained that the students with LD performed better than their low-achieving students who did not have IEPs. Ms. Jones said. "I would say the greatest challenges in the class are not the kids with IEPs, but are the kids who are low, not on an IEP, and have come to not care."

**Teacher perceptions of language and literacy demands for learning science.** Ms. Jones and Ms. Morgan shared similar perceptions, with both citing the challenges students face using the expressive language skills of writing and speaking. Additionally, they indicated using science vocabulary was challenging. First I explore the teachers' comments and examples related to writing in science. In her initial interview, Ms. Jones spoke more about the challenges her students have with scientific writing than other language skills. She identified journaling to document an investigation or engineering project as the writing task most challenging to students. "You know what I'm looking for," she said she tells students over and over. "For each trial, what did you change?" Although Ms. Jones stressed that the journals must be legible, she did not expect properly formatted sentences and using "bullets" in the journals was fine. The overall purpose was, she explained, "being able to document a claim, use evidence and reasoning, and to write the CER." The CER, a specific way of writing in which students state a claim (C), cite evidence (E) that supports the claim and explain reasoning (R) or how the evidence supports the claim, was difficult for her students. “They just want to have the fun,” Ms. Jones said, “but I’ve worked in labs and, like one guy said, if you don’t document it, it didn’t happen. I love that. I keep repeating it to my kids.” She stressed that she continually reminds her students of her expectations, and one example is about taking notes. She said she tells her students, when you take notes “…you develop something. You should be able to pass it to someone else, and they should be able to follow it.”

Ms. Morgan reported similar concerns about students’ writing. She stated that the writing from students with LD was “all over the place” and often lacked organization.

> The size of the letters is bigger. There's no real organization to their writing. I can see that's where I will need to give lots of support, even with designs. They had to sketch the designs, list the materials [and] explain why they made the changes.

Staying focused on the task was especially a challenge during journal writing. Ms. Morgan reported using frequent direct guidance comments, e.g., “C’mon, write this down.” and “Put the bullet in there.” She explained that similar prompts were needed when students were sketching designs, listing materials, and explaining why design changes were made. She concluded, “They needed a lot of support to produce a legible journal. They needed a lot of guidance, but they got it done.”

In addition to writing in journals, Ms. Jones required her students to answer open response questions embedded in “notes” handouts. Ms. Jones did not use a science textbook and instead synthesized the information students needed to know about a topic into “notes packets” that each student kept in an organized binder. The notes included definitions of science terms, explanations of science principles, and questions with space for written responses. Ms. Jones explained that the notes she gives are main topics and students add to them. For example, she said the notes include questions such as “What do you think of this?” and space for students to “write down this little thing” presented in class.

Speaking was the second language and literacy skill teachers identified as challenging for students. When asked what challenges language presents, Ms. Morgan was very clear about this in statements like, “Trying to get them to understand that what they have to say is important.” Ms. Jones stated that her students mostly had opportunities to speak in small groups or speak to her and Ms. Morgan when they circulated to tables. When circulating, Ms. Jones said she would ask individual students to, “Explain it back to me. Now explain it back without using your notes” to check understanding during lessons. Ms. Morgan described how she guides students during small group discussions. She said, “They won't sit down and have a discussion on their own. I have to guide them and get the ball rolling, then they can.”

A third language challenge teachers identified was the comprehension and use of science vocabulary. Ms. Jones said, “Applying new (scientific) vocabulary to real life situations so they can make connections” helps students learn the vocabulary key to learning the science content. Ms. Morgan added at the same paired reflection interview that, “Visual demonstrations and conversations between teachers is a way to teach new vocabulary.” Yet she also reflected

> Less structured classes to allow for investigating can divert attention from concepts that are being presented and can result in loss of learning the meaning of vocabulary.

She explained that lack of vocabulary impacts students’ abilities to talk about science, commenting that, “Sometimes it’s hard for students to find the expressive language to describe their answers. They’ll say, “I don’t know how to explain it.”

**Stated outcomes, lesson overview and reflections.** The teachers’ outcomes for each observed lesson were different, though at times, related. For instance, the specificity and language they used to express the outcomes were different. In lesson 1, the teachers identified two different outcomes.  Ms. Jones focused on “explain how an airplane flies and why NASCAR cars have spoilers,” while Ms. Morgan focused on “relationships” amongst “area, force and pressure.”  While in Lesson 2 the outcomes were more similar in that both teachers referred to Bernoulli's Principle, Ms. Jones said students would apply their understanding to fly the kite, and Ms. Morgan said they would use the principle to explain why the kite did or did not fly.  One outcome focused on the activity, while the other was focused on how students would connect the activity to their understanding of Bernoulli’s Principle.  For Lesson 3, both teachers’ outcomes stated that students would understand Pascal’s Principle, but identified different aspects they would understand.  Ms. Jones wanted students to understand what it means to “multiply force” while Ms. Morgan identified specific scientific concepts about Pascal’s Principle (“how it relates to density, examine and continue discussion of density and component of pressure”) and how Pascal’s Principle related to those as well as related to prior studies (“previous demonstrations and explanations”).

Overall, Ms. Morgan’s outcomes were more specific in terms of the science concepts and the connections between them.  For example, Ms. Morgan said students would understand the “relationship” in Lesson 1, and “relate” prior learning to new learning in Lesson 3. Conversely, Ms. Jones’ outcomes did not include connections to prior learning and sometimes did not include the name or important components of the science principle.  The Lesson 1 outcomes are examples of that in which Ms. Jones said, “...explain how an airplane flies and why NASCAR cars have spoilers.”

A common feature of both teachers’ outcomes was their use of non-measurable verbs more than measurable verbs.  Ms. Jones used the verbs “understand and explain” in the first lesson outcome and the nouns “application” and “explanation” in the subsequent lesson outcomes, naming a topic rather than what students would do to demonstrate understanding of the topic. Ms. Morgan used the verbs “learn,” “apply” and “understand/gain knowledge” in her outcomes.

***Teachers' roles***. When asked to describe her role, Ms. Morgan described the functions she performs before, during, and after science class. She explained how she adapts materials for students with IEPs. She said that any materials used by the whole class are sent to her first. She makes “any adjustments or changes to the wordage” prior to the class. She also adapted assessments and did so by asking Ms. Jones to highlight questions that contained the most important information students needed to know. Then she looked at what students had to “pull from memory” and created word banks or multiple choice questions for her students with memory deficits.

During class, Ms. Morgan said she “will circulate the room” and “check to make sure students who have been identified [with disabilities] are on task and have in front of them what needs to be done.” Because the teachers do not have shared planning time, Ms. Morgan and Ms. Jones briefly discuss the lesson after class. Ms. Morgan provided an example of one discussion. She remarked that some students were not engaged while others in their group were making generators. She explained,

> They were in groups of four to six and generally two would do the hands-on of making the generator, and then I noticed that the other four were not at all on task. Especially for mine, they need something that's going to keep them focused. She [Ms. Jones] immediately came up with a journaling page and we were able to hand that out the next day.

Ms. Morgan believed her ideas about the science class were valued and she freely expressed her opinions to Ms. Jones.

Ms. Morgan reported that at times, she would take a small group of students who needed extra time and/or instruction to a small group review in another classroom. She indicated that happened when students were reading teacher-created notes or discussing the outcome of an activity, and the teachers perceived some students needed extra help. For example, Ms. Morgan worked with students in a small group to create vector diagrams after the kite flying activity. Additionally, science assessments were given by Ms. Morgan in a separate setting so she could read the questions aloud.

During the classroom-based lessons, I observed Ms. Jones lead instruction. She spoke approximately 110 of the observed 125 minutes in the science classroom. Ms. Morgan made interjections (e.g., reminding students of the formula for area, or asking a question during a demonstration). When students worked independently, both teachers circulated and provided individual help. During the second lesson, while students were outside with the kite-flying activity, both teachers interacted with the small groups.

***Instructional modes***. I observed two major ways of presenting science content, and in each way, Ms. Jones was in the lead. I observed that demonstrations were the instructional delivery model used most frequently. Altogether, 75 out of 150 of the observed minutes of instruction included teacher-led or student-led demonstrations. Teacher-led demonstrations in a whole group structure accounted for roughly 45 out of 150 minutes. Student-led demonstrations accounted for 30 out of 150 observed minutes.

Altogether, I observed seven demonstrations in which Ms. Jones took the lead. For example, During Lesson 1 she performed five demonstrations. After each brief demonstration, Ms. Jones stated that they were all "related" without explicitly stating how they were related to each other or any of the scientific principles key to the unit (e.g., Bernoulli's Principle).

Here is a description of five of the seven demonstrations, which all occurred in the first lesson I observed. Early in the lesson, Ms. Jones used a 3ft. by 5ft. bed of nails, which was a plywood board with nails protruding through the board at evenly spaced intervals. After she placed the bed of nails on the floor, she said,

> Jones: Remember, everything for science! What I'm going to do is take my shoes off, and I'm going to stand on it. Everybody good with that? Should I stand on it?
>
> (Students shout out. Some say yes, and some say no.)
>
> Morgan: She's not going to walk on it or stand on it. Think about why.
>
> Jones: I'm not going to stand on it, I can lay on it. (Ms. Jones lies on the bed of nails) I'm lying on it. See? Blood's not squirting all over the place. See, no blood. That is what we're going to think about. Think about why I can lay on it, but I can't stand on it.

The second demonstration was used to illustrate Bernoulli's Principle. Ms. Jones brought out two balloons that were hanging from strings placed about six inches apart on a horizontal rod. She asked the students to call out what they thought would happen when air was blown between the balloons. Most thought the balloons would spread apart. Then Ms. Jones called a student volunteer and said,

> I want you to blow gently between the balloons, and then we'll see them move apart and then we'll talk about it.

As the student blew on the balloons, they moved together instead of apart.

> Ms. Jones: They're not going apart. They're moving together. Let's try it again. Real gentle. Blow right between them now. (As the student blew between the balloons, they moved together).
>
> Ms. Morgan: Is she blowing gently enough?

Ms. Jones: Maybe it's a Valerie (student volunteer) thing. Let me try. (She blew between the balloons). Nope. It happens. They come together. Think about why that happens. Okay, here are a couple more demos. They're related.

Ms. Jones immediately moved on to the next demonstration. She had a small fan and placed a ping pong ball above it. For approximately 30 seconds, she showed that the ball spun in place above the fan. Ms. Morgan asked, "Why doesn't the ball fly off?" Ms. Jones said, "All of these are related" and introduced the next demonstration. She brought out a ten foot long tube-shaped plastic bag and asked for a volunteer who plays a wind instrument. The student blew into the bag. Ms. Jones pushed the air to the end of the bag to show how "windy" the student was. One additional student blew into the bag. The demonstration lasted about 90 seconds. Ms. Jones moved to the fifth demonstration and said, "We have one more related demo." She pulled out a large leaf blower machine and a roll of toilet paper. She blew air over the roll of toilet paper, which caused it to spin and unroll. She did that for about 15 seconds. She directed students to notice if the paper was moving up, down, or straight out as it came off the roll. Students called out what they saw happening to the toilet paper. Most students said it went down and a few said it went straight. Ms. Jones finished the demonstration seconds before the period ended and the bell rang. As students were packing up to leave the classroom, she said, "Tonight, think about how what you saw could possibly explain how airplanes fly and [why] race cars have spoilers."

Two demonstrations happened during Lesson 3. Ms. Jones demonstrated water displacement to calculate the volume of 2.7g of aluminum. She said, "I'm going to use water displacement to measure the volume. I have it at 15 ml. What should it go up to?" A few students called out, "16." She replied, "Yes, 16. Because I have 2.7 g." She added the aluminum to the graduated cylinder and said, "It did go up. It's up to 16 ml. It went up 1 ml. Let's move on."

The final demonstration took place during the last ten minutes of Lesson 3. Ms. Jones pulled out a “magic answering bottle” to introduce Pascal's Principle. It was a two-liter bottle nearly full of water and capped. Inside the bottle, a small plastic diver floated near the surface of the water. By squeezing the bottle, Ms. Jones increased the pressure inside the bottle and caused the diver to sink. She asked questions like should we study for science and squeezed the bottle to move the diver. At the conclusion of the demonstration, Ms. Jones explained that what they saw in the bottle connects to the brakes on a car, hydraulic lifts, and flaps on an airplane. She said, “Something is multiplying force. It’s hydraulics. They’re using fluids to put in a little bit of force and get out a lot.” She concluded by telling the students they would learn how that is done in the next lesson.

Student-led demonstrations occurred during 30 minutes of the observed 150 minutes. Prior to the balloon demonstration in Lesson 1, Ms. Jones and Ms. Morgan passed a strip of paper to each student. Students blew over the strip of paper to demonstrate Bernoulli’s Principle. Ms. Jones asked students to say the word that describes what the paper does. Students called out “elevate,” and “goes up.” After hints from Ms. Morgan, one a student called out “lift.”

By far, the longest student-led demonstration happened during Lesson 2 when students left the classroom to fly a tetrahedral kite. From start to finish of the activity, it took about 25 minutes although the length of time actually flying their kites differed. In self-selected groups of three or four, students had built one kite per group using tissue paper and straws. Each group went outside with only their kite. The co-teachers stood in the center of the field, and the groups of students spread out across the field. A few groups were able to fly the kite quickly and moved further away from the teachers while continuing to play with their kite. Student groups who struggled tended to stay near the teachers, and each teacher moved from group to group to assist. Ms. Jones had a “repair kit” and assisted groups by cutting string and making repairs to the kites as needed. Students returned to the classroom minutes before the bell rang. As they left the room, Ms. Jones said they would make “vector diagrams” to show why the kite did or did not fly.

In the remaining roughly 50 out of 150 minutes of the observed minutes, the instructional mode was mostly teacher-directed “lecture” (a term used by Ms. Morgan). The main example was a 40-minute lecture about density in Lesson 3. Ms. Jones defined density and directed students to locate it in their notes, and then introduced the formula Density = Mass/Volume. Interspersed through that the teachers directed students to independently write briefly in teacher-created notes.

Student independent work happened in Lessons 1 and 3 for an average of four minutes. It included students writing an answer to the question, “What would you do if you were walking on a frozen pond and the ice began to crack?” in their notes for three minutes during Lesson 1, and solving a density word problem in the notes for five minutes during Lesson 2. The remaining minutes of the observed lessons consisted of fifteen minutes of directions for appropriate behaviors and kite flying tips prior to the kite flying activity.

***Students’ language use and participation.*** I saw mostly attention to the receptive skill of listening in a whole group setting. It accounted for roughly 100 out of 150 of observed minutes. Students listened during demonstrations and while getting task instructions. During demonstrations, commonly Ms. Jones asked questions to the whole group (“Should I lie on it?” “What will happen to the balloons?”), directed student’s attention to an aspect of the demonstration (“Look, they’re moving together”) or prompted students to “think about” what they were observing. In another example of listening, at the beginning of Lesson 2, Ms. Jones gave oral directions for the kite flying activity during the first 15 minutes of the class period. In Lesson 3 Ms. Jones lectured as she reviewed density and directed students to add information to or locate information in the notes. For example, Ms. Jones prompted the students to write 1 ml=1 cc at the top of the notes page, and then locate the density of aluminum in a chart. Later in the lesson, Ms.

Jones used a projector and a document camera to model a process for solving density word problems. She directed students to write three steps (1. List your givens, 2. Write the formula and 3. Plug it in) and then modeled one problem before asking students to solve a different problem independently. Students worked independently for 5 minutes and then Ms. Jones modeled the solution to the word problem.

During the other roughly 50 out of 150 of the observed lessons, students expressed themselves orally in the following ways. They communicated with their group members as they flew the tetrahedral kite for 30 minutes, although it's unclear what the students talked about during the activity. In other examples, students volunteered to be called on (raising a hand) or called out answers chorally. In Lesson 1, Ms. Jones presented the question "What would you do if you were walking on a frozen pond and the ice began to crack?" Some students called out the wrong answer. Then Ms. Jones called on three students who volunteered by raising a hand to answer before one student said, "Lie down." When Ms. Jones heard that, she introduced the formula, Pressure = Force/Area.

***Teachers' reflections on outcomes.*** In reflecting on how well students met the lesson outcomes they had stated, Ms. Jones and Ms. Morgan differed in two ways. First, while Ms. Morgan's stated outcomes and reflections aligned, that was less the case for Ms. Jones. For example, in Lesson 1 she identified the outcomes of students learning how airplanes fly and why NASCARs have spoilers. Yet in reflection, she referred to one of the five demonstrations (lying on a bed of nails) and thought it helped students "understand the relationship between area and pressure." In Lesson 3, while she'd stated students would learn about multiplying force, the bulk of the lesson focused on density. She defined density, did the water/aluminum demonstration and had students solve problems. Ms. Jones commented that the lesson did not go as planned, but she was "trying something for the first time" (the water displacement demonstration). She said, "I'm always ready to try something. Sometimes it occurs to me in the middle of the lesson."

Secondly, to reflect on the lesson, Ms. Jones referred to work products students might produce in future lessons. For example, she said students would draw vector diagrams the next day, after the kite flying. She did not reflect on that day's lesson, the actual kite flying. In Lesson 3, Ms. Jones said she would refer to students' notes in their binder the next day because "this way each student must show understanding or not." On the other hand, Ms. Morgan referred to work completed during Lessons 1 and 2. In Lesson 1, she referred to the students' engagement during the discussions, saying that they "participated in the discussion and were successful in answering questions." In the second lesson, Ms. Morgan referred to students' abilities to fly their kites successfully, explaining that that showed students could "apply what they learned about lift and thrust to (fly) their kites." Similar to Ms. Jones, after Lesson 3, Ms. Morgan stated that students only met the lesson outcomes after "assistance" in a small group the following day.

**Interventions in an inclusive science classroom.** In the next section, I present the interventions I observed and the interventions reported by the teachers during the initial interview, pre-observation interviews and post-observation interviews. First I present the interventions teachers reported using to teach scientific practices, and then interventions used to help students with LD access the science lesson. I describe how I saw those interventions used during the lessons. Finally, I describe how EBP were used during the science lessons.

***Interventions for NGSS scientific practices*.** I asked teachers individually how their students engaged in the scientific practices of asking questions, constructing explanations, and arguing from evidence. In addition, they were asked how they provide supports as students engage in those scientific practices. Ms. Jones immediately said, "It's a work in progress," while

Ms. Morgan shared that they "hadn't gotten to that too much yet." Ms. Jones believed that students need to be "comfortable and interested" to ask questions, and that "knowing how to phrase a question" is difficult for her students. She gave her students a process for asking questions about concepts they did not understand. She tells her students,

> Come up with your question and put it on a sticky note. If it doesn't fit on a sticky note, you need to think about how to narrow it down. What is it that you don't understand? That in itself is hard. Think about it and put it on a sticky note.

Students then had the option of giving the note to one of the teachers or placing it on a Parking Lot answer chart designated as a place for students to post their questions. In her interview, Ms. Morgan also explained that students struggled to ask science questions and provided an example of how she modeled questioning during an engineering project.

> They had a great time making the turbines, but we had to talk about it. They couldn't come up with the ideas on they own, so I said, "What are some things that have blades?" They said, "Windmills," so I said, "Go look them up. Look at the blades. What else works with air?" I waited for the answers and many students said birds… "Alright. Then let's investigate the shape of the feathers." So they need guidance to get them going and then bring them back to focus on the task.

Concerning teaching scientific practices, both teachers described how students use a science journal. Ms. Jones said, "We're really working on their journals" and "especially with NGSS and communication, being able to document a claim, evidence, and reasoning, the CER." Ms. Jones provided time for students to review the journals and provided clear expectations when her students went "back to look at their journals." She did not grade the journals. Instead, they served as "a practice" for future engineering projects. She told her students, "You know what I'm looking for. For each trial, what did you change?" Ms. Morgan explained that in spite of the fact that "journaling is completed in bullets," her students need a great deal of individual prompting. She used prompts and guiding questions that enabled them to produce a "legible journal and be held accountable for whatever work they're capable of doing."

To provide additional opportunities for her students to explain scientific principles, Ms. Jones asked each of her students' parents to "give [her] five minutes each night" to listen to their child explain what he or she learned that day. For example, one night the homework was to "tell your parents how a generator works." She added that if students were not able to explain the homework, they were to write a question on a sticky note.

When asked about students learning the practice of arguing from evidence, Ms. Jones and Ms. Morgan reported that their students had not argued from evidence yet. Ms. Jones explained that she had facilitated arguments from evidence with students in previous years. Additionally, she shared that she didn't like to use the word "argue," and instead she asked her students to discuss in order to reach consensus. She said, "I keep using the word consensus. In order to get to consensus, you have to have justification."

***Teacher stated interventions for students with LD.*** Teachers stated that they provided two major interventions (a) Ms. Morgan monitoring for understanding and refocusing attention in the general education science classroom, and (b) Ms. Morgan taking selected students into small group instruction in a separate classroom setting. First I examine teachers' views about Ms. Morgan's intervention in the science classroom. Ms. Jones explained that Ms. Morgan would reinforce concepts presented during the demonstrations. She explained,

> For some of the students, the demonstrations sometimes, not sure how to say this, get them very excited and they may miss the point I am trying to make. Reinforcement and relying on Ms. Morgan will be crucial.

Similarly, before Lesson 3, Ms. Morgan said in her pre-lesson interview how she would interact with students with IEPs,

> Teacher support and redirection of attention during lecture will be provided, along with guidance for underlining or highlighting important information.

While observing, I saw Ms. Morgan circulate throughout the room and attend to individual students as well as to the whole group. I observed her looking over shoulders and having private conversations with students during Lessons 1 and 3. For example, after Ms. Jones directed students to "Open your binders to the page that has the duck on it," Ms. Morgan noticed a student flipping through her binder and repeated the directions. She remained with the student until the notes were open. She also had quiet conversations with individual students to check understanding. During Lesson 1, I saw her stand next to a student during the toilet paper demonstration. Although they were too far away for me to hear the conversation, I did see Ms. Morgan pointing to the toilet paper as she spoke to the student. She seemed to be tracing the movement of the paper with her hand, showing how it rose slightly before falling to the ground.

In the second intervention teachers articulated, Ms. Morgan explained that she pulled the students into to a separate setting to review and check for understanding. During the paired reflection interview, Ms. Jones explained that when the class read the teacher-created notes about density, Ms. Morgan took students with LD out to "chunk" the reading. Ms. Morgan added that because some of the students with LD had "memory issues," she directed them to the information that "needed to be highlighted" to focus on the "meat" of the notes. In addition to reading interventions, Ms. Morgan re-taught concepts as a reinforcer for students who needed it. She took them to a separate setting, explaining that doing so provided opportunities to check for understanding. She also believed that students were able to "demonstrate their learning." Ms. Morgan also shared that after the kite-flying lesson she took some students into a separate classroom and discussed the best place to tie the string to fly the kite. They also discussed connections between Bernoulli's Principle and the kite flying activity. Finally, she said she guided students to create vector diagrams to illustrate how Bernoulli's Principle applied to the kite flying activity.

Aside from those two interventions, Ms. Jones added that co-teaching with Ms. Morgan benefited all students. She explained that the co-teachers could get into discussions and use common language to explain the meaning of scientific words. She provided an example of a discussion that took place during a lesson on Pascal's Principle. The students were confused when she used the term "bleeding the brakes," and Ms. Morgan interjected, "It's like burping the brakes, to get the air out."

***Observed evidence-based practices for students with LD.*** Observational data were used to identify evidence-based instructional practices that the teachers may or may not have identified. During my observations, I saw use of one evidence-based practice. Ms. Jones introduced two mnemonic devices to aid students' memories of how to use two different mathematical formulas. In the first example, for the formula Pressure = Force/Area, she drew a triangle and wrote an F in the top section. She drew a vertical line to divide the bottom ½ of the triangle and wrote P in one section and A in the other. She called it a "magic triangle" and told students they were "going to be working with lots of formulas" and they would "learn to love the triangle."

Ms. Jones drew another mnemonic in Lesson 3 to help students remember the formula for calculating density. She wrote the formula for density, D = M/V on the board in a way that the M and V were vertically aligned. She then used the shape of the letters to form a heart. She said, "You'll never forget with the heart because we love density." She directed student to draw the mnemonic on their density notes page.

**Summary of Findings**

In reference to language demands, both teachers identified expressive language use to be most challenging. Ms. Jones explained that students struggle to write clear CER statements, while Ms. Morgan described the challenges students have organizing their writing. Both expressed concern about students' speaking skills in science, saying that problems they saw were due to lack of confidence or unknown vocabulary. I observed that the majority of instruction was teacher-directed, and delivered orally by Ms. Jones in a whole group setting. Additionally, students observed demonstrations, performed demonstrations, located information in notes (e.g., find the density of Al), or wrote short entries (e.g., 1 ml = 1 cc) when directed by Ms. Jones. They volunteered to answer questions by raising a hand or calling out.

The presence of Ms. Morgan, as she monitored student engagement and comprehension, was the main intervention provided to students with LD. She moved throughout the room, occasionally interjecting to ask a clarifying question or refocus a student's attention. An evidence-based instructional practice that was presented, although not with fidelity, was use of mnemonic devices. Ms. Jones briefly introduced two mnemonics without explicitly teaching students how to use them. The teachers also reported that Ms. Morgan worked with students with LD in a separate setting to read and review science concepts. Regarding interventions used to teach NGSS practices, in my three observations, I saw no interventions explicitly linked to teaching students to ask questions, construct explanation, or argue from evidence. Although I observed an inquiry-oriented activity (the kite flying activity), I observed that students did not collect evidence that might have been used to construct explanations or support arguments. Though I did not observe it, both teachers gave explanations about how their students used vector diagrams to explain the kite's flight and wrote claim-evidence-response journal entries after the Turbine Challenge, in which students designed blades for a turbine and measured output.

**Case C: Ms. Martin (Science Teacher) and Ms. Lacey (Special Education Teacher)**

Ms. Martin, the science general educator, and Ms. Lacey, the special educator, co-taught one period of seventh-grade science each day. The co-teachers were in their second year of co-teaching the science course. The unit of study, *Cells and Heredity*, was created several years ago by middle school science teachers in the district. This year, science teachers in fifth through eighth grades were integrating NGSS standards into their existing units. The *Cells and Heredity* unit focused on eukaryotic and prokaryotic cells, diffusion and osmosis, mitosis and meiosis, and concluded with genetics, focusing on Punnett Squares.

The unit lasted roughly 12 weeks, and I observed during the seventh through tenth weeks of the unit. I observed three lessons over a three week period in November 2016. The observations took place on a Thursday, the following Monday and then the Thursday of the next week. Each observation was an entire period, which was 40 minutes. In Lesson 1, I saw Ms. Martin guide students through teacher-created notes and a video to teach the stages of mitosis. In Lesson 2, I saw students work independently on the creation of a vocabulary “flipbook” and worksheet about mitosis. In Lesson 3, I saw Ms. Martin guide students through teacher-created notes and videos about meiosis, and I saw Ms. Lacey administer a pre-assessment to students with IEPs in a separate classroom.

**Teacher perceptions of students.** Ms. Martin and Ms. Lacey taught science to 26 seventh grade students. Seven students had IEPs and five of those students had specific learning disabilities. Ms. Martin explained that the students entered the middle school with IEPs that were written in the elementary school and both teachers had concerns about placement in an inclusion science class for some of the students. Ms. Martin said, “Some of the kids who have always been in self-contained [classes] are in science. They're extremely low so I don't think it's benefiting them." Ms. Lacey expressed a similar concern about placing some students in an inclusion science class. She said,

> I have a hard time with the fact that these kids have severe reading and writing learning disabilities and they're in a push-in science class, which is even harder than the literacy class. They're pulled out for literacy, and then in a push-in science and social studies class. Those are the two hardest reading and language subjects. The vocabulary in both is difficult. They're not expected to perform at that level in a reading class. How can they be expected to perform at that level in a science or social studies class?

At the conclusion of the unit, Ms. Martin reported that two of the students with LD performed well on the assessment, two students with LD performed slightly below non-disabled students and three students with LD or other disabilities underperformed. Ms. Lacey stated that the inclusion science class was not the correct placement for some of the students.

**Teacher perceptions of language and literacy demands for learning science.** Ms. Martin and Ms. Lacey shared similar perceptions about language and literacy in science. Both emphasized the importance of explicitly teaching literacy in science. In fact, all their responses related to language and literacy focused on the integration of literacy into science instruction and using multiple modalities in instruction. The teachers' foci on literacy skills centered on teaching unfamiliar vocabulary and providing guidance as students read science text.

First I explore teachers' ideas about reading. Both teachers explained how they guide students to read science text. Ms. Martin explained that she teaches students to read informational text and "pick out text features" at the beginning of the year. About reading in science, she explained that "most of the time we read together, we highlight and take notes. I rarely have them read alone. We read out loud, and then we discuss it. Ms. Lacey described how she guided students with LD to answers questions using the science textbook. She said,

> [Like] yesterday… they don't know that the questions that are on their homework follow the book step by step by step by step. So I pull them out and say, "We're on page 51, look at paragraph two, sentence number three. The words in your question are…." And I read the words to them and say look at the words in the sentence. Here are the words right in a row. What comes next?

A second commonly shared idea was that using a combination of language skills, including writing, helps students learn science. Ms. Martin explained,

> Since language is difficult in science, more time needs to be added to ensure understanding of materials. It is not enough to just say things once or twice. Students must hear it, write it, say it out loud. And this has to be done over and over...best way is a combination of modalities.

Ms. Lacey expressed the same ideals, saying that, "Reinforcing the language through multiple learning strategies helps improve [students'] comprehension." Ms. Martin stated, "You can't just lecture and expect them to know it. They have to read it for themselves." She further explained that when students write their own notes, they do better than when they are given notes and added, "So when they complain about writing notes, I tell them, this is what helps you remember – you actually writing it down." She concluded with the idea that "it has to be a combination of all four [language skills] to have anything stick."

Ms. Martin further stressed the idea of integrating modalities when she said, "We read, then write, I explain, then we do an activity to support what we just learned." As an example, Ms. Lacey described how they combine reading skills and writing skills in a vocabulary assignment that requires text and images. She said the students form "the definition from the context clues in the chapter" so that they "actually have to read something."

The third idea identified by both teachers was that learning unfamiliar vocabulary is challenging for all students. For example, Ms. Martin recognized in one lesson that there was a lot of vocabulary introduced (e.g., endocytosis, exocytosis, diffusion and osmosis). "That was all verbal," she said. "Today we're going to do a lab so they can see how that works."

The teachers explained that vocabulary terms with few real-world connections are more difficult for students to learn. For example, Ms. Martin said the vocabulary associated with mitosis and meiosis "doesn't relate to anything in their real life" and "are never used outside the science classroom." Ms. Lacey similarly stated that "science language is only heard in the 40 minutes they are in the science class." She explained that in English language arts, teachers "easily cross curriculum with social studies" but she had "never seen anything science related come up" so students "never see those words outside of the science classroom."

**Stated outcomes, lesson overview and reflections.** In this section, I compare the co-teachers' outcomes for Lessons 1 and 3. I describe Ms. Martin's outcome for Lesson 2; due to a personal emergency, Ms. Lacey was absent for Lesson 2 and could not share her planned outcomes.

The teachers' outcomes for Lessons 1 and 3 were very similar although they differed in levels of specificity. Both teachers identified the same lesson foci and used the verb "understand" for outcomes, although the co-teachers' outcomes differed slightly. Ms. Martin explained what students would learn about each of the cellular processes ("stages of cell division in mitosis," "phases of mitosis" and "the outcome of meiosis"), while Ms. Lacey stated broader outcomes, e.g., gain a "better understanding of cell division." In Lesson 3, Ms. Martin added an active verb and stated that students would "be able to tell the outcome of meiosis." Ms. Martin's outcome for Lesson 2 was for her students to "know the phases of mitosis." Non-measurable verbs were used by both teachers.

***Teachers' roles.*** When asked to describe her role, Ms. Lacey described the functions she performed before, during, and after science class. She explained that she modified assessments last year and planned to "add additional modifications that might be needed, like a word bank" to existing assessments. To describe her role in the classroom she said, "I float from one kid to another to another." She quickly added, "I teach vocabulary when I pull kids out. I also pull students out to a small group for anything written, for testing, and for studying." Ms. Lacey explained that she and Ms. Martin did not have common planning time, but that Ms. Martin shared the plans a week in advance. Ms. Lacey then reviewed them to determine which days she would pull students out of the general education science class for small group instruction. "During labs," she added, "they pretty much stay in there the whole time."

During the two lessons in which the co-teachers were present, I observed Ms. Martin lead teacher-directed instruction for more than 70 out of 80 of the observed minutes. Ms. Lacey stood at the side of the crowded room, occasionally looking over a student's shoulder or gesturing to refocus a student's attention on the lesson. She led instruction when she took a group of student to a separate classroom during the last ten minutes of Lesson 3 to administer a pre-assessment for the next unit. Over the two lessons, she was with the small group for nearly 10 out of 80 of the observed minutes.

***Instructional modes.*** I observed three major ways of presenting science content, and in all three ways, Ms. Martin was in the lead. Ms. Lacey assisted by standing on the side of the classroom and monitoring and re-focusing student attention with gestures (as observed in the lessons in which she was present, lessons 1 and 3). Ms. Martin guided students through teacher-created notes for nearly 30 out of 120 of the observed minutes. Teacher-created notes were used to explain the stages of mitosis and meiosis in Lessons 1 and 3. Then she used multimedia in the form of videos and interactive programs for 30 out of 120 of the observed minutes to reinforce the same concepts during those lessons. For roughly 25 out of 120 of the observed minutes in Lesson 2, the students used the mitosis notes and a science textbook to complete assignments independently while the Ms. Martin circulated and monitored their progress. During the remaining 35 out of 120 observed minutes students completed a pre-assessment for ten minutes at the end of Lesson 3. Ms. Martin explained directions for the independent practice, collected homework assignments, and explained homework assignments during the remaining time.

I first describe how Ms. Martin guided students through the notes. During Lessons 1 and 3, Ms. Martin led the instruction from the technology cart at the front of the room. She used a document camera to display science notes and directed her students to follow along and annotate their own papers. At the beginning of Lesson 1, she directed students to take out their highlighters and use them. She assured students that as they went through the notes and looked at images, she would point out everything they needed to know for the upcoming assessment. For example, at one point in Lesson 1, she said, "There are a few important details you need to know from each stage, so I highlighted those." At another time she said, "We start with interphase. This is the important part right here. At the end of interphase, the chromosomes are copied." Ms. Martin underlined "Chromosomes are copied." After describing each phase, Ms. Martin said, "You have the tools you need. Study ten minutes each day until the test." Ms. Martin passed out a new set of notes at the beginning of Lesson 3. With the notes displayed, she guided students to add annotations in the margins. For example, to explain fertilization, she drew an oval and wrote, "Egg-23" under it and a smaller oval with a tail and wrote, "Sperm-23" under it. Then she wrote, "Meet to create a fertilized egg." Under that statement, she drew another oval and wrote, “Fertilized egg-46” inside the oval. The students copied that on their own notes paper.

A second way of presenting science content was the use of multimedia. During Lesson 1, Ms. Martin showed a BrainPOP video to reinforce the stages of mitosis, and then she guided the whole class through a ten-question multiple-choice quiz. Ms. Martin introduced a BrainPOP video by saying, “It’s short, it is two minutes, but it gives us a visual.” The video presented information about the stages of mitosis and concluded with a ten-question multiple choice quiz. The quiz questions and answer choices were displayed, and Ms. Martin read them aloud. She prompted her students to say their answer choice aloud, selected the answer most students called out and moved to the next question.

Two videos were shown during Lesson 3. Ms. Martin explained, “The video yesterday was difficult to understand. This is simpler language.” The seven-minute video used animated drawings and text to describe the stages of meiosis by comparing them to mitosis. Before showing the second video, Ms. Martin asked, “Do any of you know twins, or have twins in your family?” After a couple of students raised a hand and told the class how they know twins, she showed the BrainPOP video, *Twins.* The video explained the difference between identical twins and fraternal twins.

Independent practice was the third type of instructional delivery I observed. For instance, students spent 25 minutes working independently on a list of assignments during Lesson 2. Assignments were listed on the board in the order they were to be completed. They were a) missing assignments, b) mitosis flipbook, c) vocabulary worksheet and d) extra credit mitosis worksheet. The students used their notes and science textbooks to complete the assignments.

***Students’ language use and participation.*** I mostly saw attention to receptive skills of listening and reading. Students listened to science instruction delivered by either Ms. Martin, Ms. Lacey or through multimedia for nearly 95 out of 120 of the observed minutes. In addition to listening to Ms. Martin explain science content, students listened to directions for the independent assignments, and they listened to the pre-assessment questions read by Ms. Lacey.

However, listening was often paired with reading text and writing or highlighting. Ms. Martin read and annotated the projected notes while students read and annotated their own. Also, the videos showed a large amount of text. For example, in one video a cartoonish sperm cell and egg cell were shown with the number 23 written next to each of them. As the narrator explained that they combine to form an egg with 46 chromosomes, the phrase, “With our powers combined, we form a fertilized egg” appeared on the screen. A third example happened when Ms. Martin talked through the directions for independent work. Students were to complete vocabulary flipbooks. She told students that her “modeling” was aimed at helping them “…check your flip book and make sure you have the right picture with the right phase, and then use your notes paper to write your own descriptions.” Ms. Lacey also engaged in the listening/reading/writing combination when she projected the pre-assessment on a large screen. Each student had their own copy, and as she read each question, students followed along and wrote their responses.

Lesson 2 required a different set of language skills. To meet the objective, students had to read and write independently for 25 minutes. They read the science textbook or their notes and then wrote a description of each stage of cell mitosis. Then they created a visual image of the stage. After completing it, they matched terms, definitions and images.

***Teachers' reflections of outcomes.*** In reflecting on how well students met the lesson outcomes they had stated, Ms. Martin and Ms. Lacey shared very different reflections. Ms. Martin relied on her observations of Lesson 1 and Lesson 3 to conclude that students met the outcomes. She based her reflection on student participation during the BrainPOP quiz in Lesson

1 and the discussion in Lesson 3. She stated that she would know more after grading student work. In contrast, Ms. Lacey believed her students gained an understanding of the Lesson 1 material only after receiving additional instruction she provided outside of the science classroom. Additionally, she did not think her students met the outcome for Lesson 3 due to the complex vocabulary that was introduced.

When reflecting on Lesson 2, Ms. Martin shared that her students created the mitosis flipbooks, but struggled to identify relevant text to describe the terms. She attributed the challenge to a lack of proficiency with the reading comprehension, identifying the skills of finding main idea and details as particularly challenging. She planned to review the reading skill in future lessons.

## Interventions in an Inclusive Science Classroom

In the next section, I present the interventions I observed and the interventions reported by the teachers during the initial interview, pre-observation interviews and post-observation interviews. First I present the interventions teachers reported using to teach scientific practices, and then interventions used to help students with LD access the science lesson. I describe how I saw those interventions used during the lessons. Finally, I describe how EBP were used during the science lessons.

***Interventions for NGSS scientific practices.*** I asked teachers individually how their students engaged in the scientific practices of asking questions, constructing explanations, and arguing from evidence. In addition, they were asked how they support students as they engage in those scientific practices. Ms. Martin explained that students typically answer her questions after a lab, and also have opportunities to ask their own questions. She explained that students use exit tickets to “elaborate what they didn't understand or have more questions about.” Ms. Lacey explained that students could ask questions, but the questions are “not necessarily what NGSS is looking for." Although students weren't generating NGSS-type questions yet, she said, "It will progress as time goes on."

Both teachers said that students explained their learning after labs. Ms. Martin said students would explain verbally and in writing. For example, she explained, students had just done a photosynthesis lab. She or Ms. Lacey would go around, and students would have to explain the lab to the teacher. For some labs, she added, students answered questions and explained their learning by writing answers to questions. Ms. Lacey explained that when needed, she assisted students with LD by writing as they dictated answers to the lab questions.

For the final scientific practice, arguing from evidence, both teachers said that the students had not done it much. Ms. Martin explained that she didn't "use claim and evidence forms" and she was "looking into starting to use them." She said most of the evidence her students used came from science text or an activity. Ms. Lacey shared that when Ms. Martin asks questions about a demonstration or something on the board, students "don't respond too much" and "have a hard time defending" their answers.

***Teacher stated interventions for students with LD.*** Three interventions described by the co-teachers were (a) adaptations to lesson requirements, (b) instruction in a separate setting and (c) multimodal instruction. Modified notes and assignments were a common interventions identified by Ms. Martin and Ms. Lacey. In fact, Ms. Martin identified adapted assignments for students with LD in each pre-lesson interview. Before Lesson 1, she stated that the co-teachers talked about modifying the amount of vocabulary the students with LD would be responsible for learning. She stated a similar support when describing the mitosis flipbook, explaining that Ms. Lacey reviewed the flipbook with her students in a separate classroom and provided the descriptions for the stages of mitosis. Additionally, the co-teachers reported that students with

LD were given meiosis notes that did not require them to write the information that their peers without disabilities had to fill in during the lesson.

An intervention identified by both teachers was instruction with Ms. Lacey outside of the science class. In the pre-lesson interviews and reflection guide, Ms. Lacey and Ms. Martin explained that Ms. Lacey pulled students out to read, write, and review vocabulary. Sometimes she pulled them into a separate class during the science period. Other times students reviewed science content during an academic block at the end of the day.

During the paired interview, Ms. Martin and Ms. Lacey were asked to describe the supports that best enable their students with LD to learn science. Ms. Lacey said, “Doing the notes for them and going over vocabulary.” Referring to the academic block, she added, “They have time at the end of the day where they are allowed to get together, and they do peer-tutoring.” Upon listening to that, Ms. Martin added that the curriculum “does move quickly, too quickly for kids with learning disabilities.” She then added that she believes the teachers

> …spend a lot of time on stuff. It’s hard because you have some kids who get it on the first day and some, well, are they ever going to get it? You know we modify their assignments. We talked about modifying even more to see if that will help.

When asked the best way to support all students and then students with LD to meet the language demands of learning science, Ms. Martin reflected that using a “combination of modalities,” is enough for some students with LD, but other need more. She wrote, “Some of the students with LD need additional support from another teacher, extra help with vocabulary, more visuals, and modified assignments.” Additionally, Ms. Martin wrote,

> I believe that students with LD struggle with science because they are not exposed to it as much as general ed students. Their focus is always on reading and math. Many haven’t been taught science with proper supports. Hopefully, that will change.

Ms. Lacey responded to the same prompt by writing that all students benefit from "reinforcement through multiple learning strategies like hands-on, auditory and visual learning that helps the students improve their understanding of the science vocabulary." She wrote,

> Students with LD benefit from the same supports and more assistance outside the science classroom. They need more help with not only reading the vocabulary but also understanding what the meaning is and how it is used.

***Observed evidence-based practices for students with LD***. Observational data were used to identify evidence-based instructional practices that the teachers may or may not have identified. I observed vocabulary instruction and mnemonic devices, two supports recognized as evidence-based interventions by CEC. Ms. Martin and Ms. Lacey spoke extensively about vocabulary instruction, however, they did not identify mnemonic as an intervention for students with LD. The three observed lessons focused heavily on vocabulary instruction. In Lesson 1, Ms. Martin used teacher-created notes, images, and the BrainPOP video to teach students the names for each stage of mitosis. In Lesson 2, students reviewed vocabulary by identifying context clues in the science textbook to complete the vocabulary flipbook. Then they matched statements and images on a vocabulary worksheet aimed at showing the correct stages of mitosis. In Lesson 3, Ms. Martin provided teacher-created notes to introduce terms related to meiosis and used a video to offer additional exposure to the vocabulary terms.

Mnemonic devices were used in Lesson 1 and Lesson 3. Two mnemonic devices were taught in Lesson 1. The sentence, *I probably might ace this test*, was designed to help students remember the names of the stages of mitosis in order. The first letter of each word in the sentence corresponds to the first letter of a stage (e.g., I- Interphase, P- prophase). When she introduced the sentence, Ms. Martin explained to her students that it was a "mnemonic" and it would help them remember the order. She suggested that they could create their own sentence if they did not like hers. The second mnemonic was a keyword that described the function of each stage. For example, interphase was linked to intermission and prophase was linked to pairs. The third mnemonic device was presented during the meiosis video. The narrator said, “You might remember from mitosis, the phrase PMAT,” as the letters appeared on the screen. Then PMAT appeared vertically and the names of the stages appeared next to each corresponding letter.

**Summary of Findings**

In reference to language demands, both teachers shared a view about the pivotal importance of vocabulary knowledge in teaching and learning science. They agreed that learning disciplinary keywords through use of visuals, video, and labs was important enough that they devoted large intervals of instructional time to teaching keywords. Moreover, they did so in a planned and purposeful way, e.g., creating vocabulary assignments, pulling small groups to focus on word study. Additionally, the teachers believed that students needed guidance to read science text. They chose videos and developed lessons and assignments in which students needed to read text that was often accompanied with ways to help them use context clues.

In addition to what I just reviewed, the teachers also provided multiple instructional interventions with explicit reasoning about instructional practices they chose, why and how they implemented them. They both emphasized use of multimodal instruction to supports science learning. The teachers shared a common belief that students with LD needed supports in order to access the ideas, and both agreed that students could benefit from small group instruction in a separate classroom provided by Ms. Lacey. I observed two evidence-based instructional practices specific for students with LD: used of mnemonic devices and vocabulary instruction.

Regarding supports used to teach NGSS practices, I saw no interventions explicitly linked to teaching students to ask questions, construct explanation or argue from evidence. While vocabulary instruction and using graphic organizers to take notes is good practice and has an evidentiary warrant, those practices are geared toward helping students learn conceptual science and what NGSS refers to as "disciplinary core ideas." The ways in which those practices were used to support learning the NGSS scientific practices were not observed.

**Cross-Case Analysis**

After examining each teacher pair, I looked across cases to respond to my research questions. In Table 5, I show the linkages between the research questions, case study sections and findings.

Table 5

*Research Questions, Case Sections and Findings*

| Research Question | Case Sections | Findings |
|---|---|---|
| Research Question #1 | ○ Teacher perceptions of language and literacy demands for learning science<br>○ Stated outcomes, lesson overview and reflections | ○ Within cases, co-teachers shared similar perspectives.<br>○ Perspectives on vocabulary, writing and speaking varied across cases.<br>○ Reading science text was perceived as challenging for students across cases. |
| Research Question #2 | ○ Interventions for NGSS scientific practices | ○ Two teachers modeled how to ask scientific questions.<br>○ Explanations tended to be repetition of taught content.<br>○ Students did not make scientific arguments from evidence. |
| Research Question #3 | ○ Teachers' roles<br>○ Interventions for students with LD<br>○ Observed evidence-based instructional practices | ○ Special education teachers were viewed as the main support.<br>○ Small group instruction consisted of reinforcement of content presented in general education classroom<br>○ EBPs were used but not explicitly named as interventions nor used with articulated fidelity. |

**Language and literacy.** The first research question refers to teachers' perceptions of language and literacy demands in science, and interventions/ instructional practices they used to help students meet those demands (See Table 6). All teachers commented on a need to teach science vocabulary, though in Cases B and C teachers raised concerns and described their attempts to help students without prompting from me. Case A teachers shared ways they taught vocabulary after I directly asked them about vocabulary instruction. In contrast to Cases B and C, they did not frame vocabulary as a challenge or concern. In the lessons I observed and in interviews, Case C teachers focused primarily on vocabulary in their instruction. Another key point about literacy was a concern about students reading of science texts, discussed especially by Case A and C teachers. Teachers in Cases A and C identified that as most challenging for students. They commented on how students' varying abilities affected their access to ideas. In multiple interviews, those teachers said they addressed the challenges by using multimodal instruction. In observations, I saw students access information visually and through auditor means using video (students did so individually in Case A and in whole group in Case C). Students in Case A individually wrote descriptions and drew images of parts of the atom after first viewing and discussing the video in whole group, while students in Case C engaged in large group discussions and used teacher-created guided note templates prior to the video. In Case C, teachers conjoined the reading of text with speaking, writing or watching a video with text that helped the students identify key information. Teachers in Case B did not share concerns about reading or identify multimodal instruction as a way to provide access to science content. However, I observed many teacher demonstrations, whole group discussion and use of teacher-created notes to present science concepts.

All teachers addressed writing in science, although they used writing for different purposes. In Cases A and C, students' writing activities seemed in service of learning vocabulary. For example, students in Case A described parts of an atom on their two-column notes, and in Case C students described the stages of mitosis in their flipbooks. However, in Case B, the teachers reported that students used writing to engage in the practice of science. They did that through the CER in which students documented a scientific claim, provided evidence to support it and their reasoning about how evidence supported the claim. The teachers' perceptions of writing varied. Teachers in Cases A and C viewed writing as opportunities to

Table 6

*Language and Literacy Supports across the Cases*

| Language/Literacy Foci | Identified by Co-teachers | Instructional actions |
|---|---|---|
| Science vocabulary | A - neutral<br>B - challenge<br>C - challenge | A: Video and two-column notes<br>B: Teacher conversations and real-world examples<br>C: Guided notes, flipbook, and matching worksheet |
| Reading science texts | A - challenge<br>B - neutral<br>C - challenge | A: Science World Magazine for content reading<br>B: Teacher-created notes<br>C: Multimodal instruction for reading guided notes |
| Expressive language and related literacy skills in writing | A - opportunity<br>B - challenge<br>C - opportunity | A and C: Writing focused on vocabulary teaching<br>B: Writing CER after engineering activity, brief answers in teacher-created notes<br>C: Annotating teacher-created notes, flipbook |
| Expressive language and related literacy skills in speaking | A - opportunity<br>B - challenge<br>C - challenge | A: Voluntary participation in whole group discussions, one-on one with teacher, small group during carousel<br>B: Voluntary participation in whole group discussions, one-on one with teacher, small group during kite flying<br>C: Voluntary participation in whole group discussions, one-on-one with teacher during flipbook |

reinforce science content. In contrast, teachers in Case B described the challenges students had writing clear, concise CER statements.

All teachers provided opportunities for students to speak openly in large groups and with a teacher. In all three cases, student participation in whole group discussions was voluntary and/or students answered chorally. Peer-to-peer discourse varied across the cases. Case A and B teachers planned activities that included peer interactions. For instance, in Case A, students participated in a carousel activity in teacher-assigned groups to discuss and record what they knew about matter. In Case B, students spoke in self-selected groups during the kite-flying activity. In Case C, students did not work with peers in the science classroom, however, Ms. Lacey said that when she pulled students out of the general education class, she had them work in small groups. Similarly, Ms. Morgan led small group discussions when she pulled students out of the science classroom. In all cases, students had multiple opportunities to speak one-on-one with their teachers, although it occurred more frequently and more systematically in Case A.

**Interventions for teaching NGSS scientific practices.** In perceptions and observations related to language and literacy, teachers in each pair had common views. However, in discussion of supports for helping students learn NGSS practices, co-teachers' perspectives differed. The NGSS practices are designed to teach students how to speak and think like scientists. While all teachers described how their students ask questions in science, they were not explicitly teaching students to ask *scientific* questions. Across all three cases students had opportunities to investigate, observe, and consider explanations. Yet both in teachers' comments and during my observations I saw little to no instruction about how to make "careful observation" or "clarify an explanation" or draw together in a systematic way questions that required "empirical evidence." For example, Ms. Jones (Case B) did over five demonstrations in one period. Students could have made observations. However, there was no explicit instruction in careful observation and no time given to clarifying evidence. It is unclear what happened in the days after the kite flying activity and if there was time given for students to ask a question or to explicitly learn the skills to do so. In my observations, students did not gather evidence.

Two teachers indicated that modeling is a way to teach questioning. In an interview, Ms. Morgan (Case B special educator) described how she asked questions to guide students as they designed blades for a turbine. Mr. Green (Case A general educator) discussed his belief that good modeling helps students ask scientific questions. However, I saw no specific evidence in observations. It remains unclear how students learned to ask questions in either of the three classes.

In the second NGSS practice I examined, that is, constructing explanations, each teacher described how their students explained their understanding of science concepts. Yet they did not share ways of explicitly teaching students to construct explanations that include “relationships between variables” or explanations based on evidence gathered through their “own experiments” or “theories and laws.” While interview and observation data indicated that constructing explanations is a practice that teachers seem to understand, I did not observe any instruction focused on developing their students’ ability to construct explanations. I noted that while all lessons I observed presented opportunities to make models, perform experiments, or learn theories and laws, it was not clear how students used those opportunities to engage in the practice of constructing explanations.

All teachers did identify talking to students and asking questions one-on-one or in a whole group discussion as the main way of teaching students to construct explanations. For instance, Mr. Green (Case C) explained that they hadn’t done it this year, but in previous years his students wrote explanations after observations. Then he would ask “silly” questions to guide his students to write better explanations. Better explanations included more detail about what they saw rather than connections to knowledge of science content or relationships between variables. In Case B, an opportunity to construct explanations followed the kite flying activity. Ms. Jones (Case B) explained that students would create vector diagrams as a model of their kites' flights. However, students did not gather data during the activity and I did not observe the vector diagram lesson, so it is unclear how or if they used the vector diagrams to construct explanations. While Ms. Jones (Case B) talked about writing CER statements when asked how her students construct explanations, she did not explain how she taught it or how or why she connected to explanation rather than argumentation. Ms. Jones said she restated her expectations and reminded students to write each step when they struggled to write concise CER statements. Ms. Morgan (Case B) explained how she focused on the organization of students' writing in the journal, but not their thinking about how to construct an explanation. Similarly, Ms. Lacey discussed the struggles some students have explaining their learning in writing after lab activities. Although Ms. Martin stated that students explain what they learned in lab activities, it is unclear if they are doing the critical thinking necessary to construct explanations or simply documenting their actions during the activity.

In the third NGSS practice of arguing from evidence, I saw no evidence in observations and heard little in interviews about teachers' knowledge and practice related to that practice. Arguing from evidence is a practice that teachers still seem to be defining and learning. For example, when I asked Ms. Lacey (Case C) how students argue from evidence in science class, she replied that they hadn't yet. She added that students had difficulty defending their answers to questions asked in class. She said, "[Ms. Martin] will ask questions. They don't respond too much. They never have to put it in writing." Mr. Green (Case A) talked about what he would like to do to teach argument with no additional explanation or definition. He said it would be easier to teach about argument from evidence with the new science curriculum he was teaching.

Ms. Martin (Case C) stated that she was familiar with CER, but she said she had not taught it to students yet. Ms. Jones (Case B) was the only teacher who could specifically discuss scientific argument from evidence. She said she had taught it last year, but it had not happened yet this year. She made quite clear that she does not like to use the word "argument" and instead uses "discussion" to reach consensus. However, whether Ms. Jones was talking about scientific argument remains unclear, especially since she does not want to use the word "argument" nor did she offer explanation of how she teaches it.

**Interventions for students with LD.** Similar to perceptions and observations related to language and literacy, the co-teaching pairs had great alignment in how they described instruction for students with LD. Therefore, I analyze across cases rather than individual teachers. I start by comparing and contrasting the co-teaching pairs perceptions about their students. The teachers in Case B reported that their students with LD outperformed the low-achieving students in the class. The teachers in the other two cases reported that the student with LD had "higher needs" (Case A) or were not able to keep up in the general education classroom due to "severe reading and writing learning disabilities" (Case C). To meet the needs of their students, the co-teachers in Case B agreed that Ms. Lewis, the special education, would deliver instruction at a slower pace and through a variety of instructional strategies. The co-teachers in Case C relied on small group instruction delivered in a separate setting by Ms. Lacey, the special education. To inform my observations of instruction for students with LD in the general education science classroom, I rely on the CEC Current Practice Alerts to identify and define evidence-based instructional practices. Table 7 displays the CEC description of each observed evidence-based practice and the ways the EBPs were observed.

Overall, the interventions for students with LD identified most consistently was individual attention provided by the special educator in the science classroom. In each case, the

Table 7

*"Go for It" Evidence-based Supports*

| Evidence-based Practice and definition | Use in Instruction | Findings |
|---|---|---|
| Mnemonics: structured ways to support the recall of information by combining information with explicit memory enhancing strategies. (Brigham & Brigham, 2001) | ○ Well suited to factual recall tasks and not "higher-order skills" and problem-solving<br>○ Provide abundant practice<br>○ Support students to develop their own<br>○ Generalization is essential to move toward independent learning<br>○ Keyword mnemonics - explicit phonetic and imagery links that promote recall | Case B: Pressure = Area/Force Triangle; Density = Mass/Volume Heart<br><br>Case C: I Probably Might Ace This Test; Mitosis Keywords |
| Vocabulary Instruction strategies vary and can be integrated into any subject area. How students learn new vocabulary is not universally agreed upon. (Berkeley & Scruggs, 2010) | ○ Direct instruction - scripted instruction for the explicit, systematic presentation of a word and its meaning, ongoing assessment<br>○ Fluency building vocabulary practice activities<br>○ Cognitive strategies - students categorize words | Case A: Students used a graphic organizer and video to independently describe teacher selected terms<br>Case B: Add brief descriptions to teacher-created notes<br>Case C: Teacher explanations, flipbook and worksheet |
| Graphic Organizers serve as visual cues designed to facilitate communication and/or understanding of information by showing how essential information about a topic is organized."(Ellis & Howard, 2007 p. 1) | ○ Informed - teacher provides a rationale for using a GO<br>○ Explicit - teacher overtly tells and shows students how the GO is used.<br>○ Intentional - students develop skill and demonstrate competency using the GO.<br>○ Scaffolded - coaching as students learn to independently use the GO tool, or a simplified version | Case C: Explicitly taught students to use two-column notes to describe vocabulary terms |

science teacher stated that the special educator was the main intervention for students with LD. In Case B and C, I observed the science educators deliver instruction while the special educator monitored individual students, redirecting their attention or having private conversations. The exception was Case A, where both teachers delivered instruction for nearly equal amounts of time, and equally interacted with students individually or in small groups. Furthermore, one-on-one and small group interactions with a teacher in Case A usually focused on deepening the students' understanding of the science concepts. In contrast, student interactions with the special educators in Cases B and C most often focused on redirecting students' attention to the whole class, teacher-directed lesson. For instance, Ms. Morgan (Case B) reported that she provided "redirection of attention" and Ms. Lacey (Case C) reported that during teacher-directed lessons, she floated from one student to another.

I observed three evidence-based instructional practices (a) mnemonics in Cases B and C, (b) vocabulary lessons in Cases A and C and (c) a two-column graphic organizer in Case A. The co-teachers in Cases B and C did not identify mnemonics as evidence-based instructional practices for teaching students with LD in any of the interviews. In fact, Case B teachers did not mention using mnemonics. In Case C, Ms. Martin mentioned the mnemonics when describing the lesson, but not as an intervention for students with LD. In addition to not identifying mnemonics as an intervention, they were not taught with the fidelity research shows is necessary. For instance, after Ms. Jones introduced the density heart for the formula, Density = mass/volume, students did not have opportunities to practice using the memory devices during the observed lessons. In another instance, Ms. Martin showed students what to highlight as she explained the mnemonic for mitosis, but students did not have an opportunity to use the mnemonic during the observed lesson.

The second evidence-based practice I observed was vocabulary instruction. None of the teachers identified vocabulary instruction as an intervention offered to students with LD, although the co-teachers in Case C strongly stated its importance in general terms. In Case A and C, I observed that co-teachers identified a set of words and provided opportunities for students to interact with the words, particularly in Case C. In Case C, I observed students had multiple opportunities to interact with the science terms through teacher-directed instruction with guided notes, multimedia, and independent practice (flipbook). In Case A, the teachers stated that they introduced the terms in the lesson prior to my observation. It is not known what that instruction involved.

The third evidence-based practice I observed was use of a graphic organizer. The co-teachers in Case A identified the graphic organizer as an intervention and introduced it in a way that met the CEC requirements for effective use. Ms. Lewis explicitly taught students to use a two-column graphic organizer. As students worked, the co-teachers monitored to ensure it was used correctly and offered guidance when it was needed. In this instance, the co-teachers did identify the two-column notes as an intervention for students with LD.

Finally, I observed that students in two classrooms worked in small group situations either in the classroom or a segregated setting, and all of the teachers reported that students worked with the special education teacher in a small group. Use of small group instruction has a strong research base related to certain instructional practices within them (e.g., peer-tutoring). Teachers' purposes and outcomes for small group instruction, and students' actions within them were not observed by me or described by the teachers. Therefore, I cannot link in a clear way the use of small group instruction or choices to use it to teachers' explicit knowledge about the research base.

# V. Discussion

The purpose of this multiple case study was to describe how general education science teachers and special educators considered the language demands of NGSS-based science instruction, and how they provided instructional support to middle school students, especially students with LD, to implement explicitly defined scientific practices. Specifically, my research questions were (a) How do science and special educator co-teaching pairs describe the language demands associated with asking questions, constructing explanations, and engaging in arguments from evidence for students with and without learning disabilities in inclusive middle school science classrooms? (b) What interventions do science and special educator co-teaching pairs provide as middle school students ask questions, construct explanations, and engage in arguments from evidence in inclusive middle school science classrooms? (c) How do science and special educator co-teaching pairs provide interventions to middle school students, targeting especially students with learning disabilities, within inclusive middle school science classrooms? My goal was to explore the interventions teachers used as students engaged in the language-intensive scientific practice of asking questions, constructing explanations, and arguing from evidence. Additionally, I sought to explore how the teachers described the interventions they provided to students with LD, and how those interventions were provided.

Through multiple interviews, observations and a reflection guide, I developed case studies for three pairs of co-teachers. The case studies presented the co-teachers' perspectives on how receptive and expressive language skills impact learning science core ideas and scientific practices. Additionally, I presented a summary of the observed lessons, focusing on the teacher stated outcomes, instructional modes and student participation. Then, I described the teachers' perceptions and my observations related to scientific practice and interventions for students with

LD. After fully describing each case, I presented a cross-case analysis to look for similarities and differences.

Overall, three themes emerged. First, all teachers recognized that language and literacy impacted their students' learning of science, and they frequently implemented instruction they believed could help students who had literacy-learning challenges. Second, science teachers and special educators had varied understandings of scientific practices and how to teach them. Third, although some EBPs were used, science teachers and special educators identified the special educator or service delivery model through which instruction was delivered as the main intervention for students with LD.

**Teachers' Perceptions of Language and Literacy in Science**

All teachers recognized language and literacy challenges students encountered while learning science, identifying vocabulary, reading and writing as concerns. When prompted in the paired interview, all six identified disciplinary vocabulary as an important component of science learning. They all identified key science terms critical to understanding the science concepts and provided instruction aimed at teaching those terms (e.g., flipbook, two-column notes). In addition to understanding the need to teach vocabulary, in the paired interview, all teachers identified students' struggles to learn science concepts through printed text. They used a variety of resources to make science content accessible to all students. Teachers in Case B and C developed teacher-created notes that described concepts and terms in simplified language. Teachers in Cases B and C used multimedia in the form of videos and educational websites. Additionally, those teachers provided multimodal instruction, providing opportunities for students to use a combination of modalities to learn science (e.g., viewing a video to define terms, reading and annotating notes with teacher modeling).

While all teachers recognized how reading and writing impacted students' science learning, they differed on whether they viewed the literacy-related skills as challenges or opportunities. Some suggested that the problems in writing, for instance, thwarted chances for students to write about science phenomena while others thought that learning to write notes in science could help students learn other content as well. Teachers also differed on how they addressed literacy skills, that is, to teach it explicitly (e.g., part of the lesson was learning to take two-column notes) or to provide multiple opportunities for students to respond as a group to multiple teacher-directed demonstrations (e.g., lying on a bed of nails.)

Though making content accessible through instructional practices to support learning science core ideas, teachers did not address the expectations for reading described in NGSS or CCSS. NGSS and the CCSS for science require students to read complex, informational text. In each case, however, teachers found ways to present science content without reading complex, informational texts. Although presenting content through other modes was effective for teaching science facts and vocabulary terms, that focus did not enable teachers to support students to wrestle with complicated and conflictual issues that are often associated with science. Furthermore, the instructional focus on facts and terms did not help students meet the expectations in NGSS practices which require middle school students to "gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication" (NRC, 2013 p. 428).

In contrast to their comments related to challenges associated with reading and writing in science and then planning ways to address those, teachers spoke much less about how they addressed speaking skills in science instruction. I did not observe how students learned to participate in scientific discourse central to engaging in the NGSS-promoted practices of asking questions, constructing explanations, or arguing from evidence. In each of the cases, when opportunities to engage in discourse arose, student participation was voluntary (e.g., call out answers chorally, volunteer to raise a hand and be called on). Also, participation was mostly in response to literal questions or to a review of content that had been explained by the teachers. For example, in Case B, when a student gave the correct response, “lie down,” to the cracked ice question, the discussion ended. In Cases A and C, most questions required students to simply repeat information (e.g., how to convert metric measures, the name of a stage in mitosis). Only one time did I see a teacher ask a student to respond to a classmate’s statement, and the student gave a one-word response. Before authentic scientific discourse can occur, Hackling, Smith and Murcia (2010 p. 20) claim, “students need to be introduced to the social conventions of active listening and speaking and some ground rules for discussion need to be established.” I saw no examples of scientific discourse that required all students to listen, speak, or think like scientists (as NGSS promotes) to ask questions, construct explanations, or argue from evidence.

**NGSS-based Science Instruction**

A second finding is that science teachers had liited understandings of the NGSS scientific practices or how to teach them. All lessons I observed focused exclusively on developing conceptual understanding and knowledge of academic vocabulary, which is one component of the NGSS (NGSS Dimension 3: Disciplinary Core Ideas). Furthermore, teachers’ perceptions about language and literacy and what instruction they implemented were linked to that same component. An overview of the assignments students completed reveals a focus on science text and vocabulary that was disconnected from scientific practices. Students read teacher-created texts that focused on core ideas in simplified language. Students wrote student-friendly meanings and illustrated terms with little connections to real world examples or natural phenomenon. Each activity was teacher-directed and allowed for little student autonomy. Even demonstrations were teachers directed in that the students had minimal opportunities to share their own ideas about the observed phenomenon. Teacher questions tended to be literal. Overall, students had few to no opportunities to talk about their understandings of the concepts (See Table 6). In contrast, in NGSS-based science instruction, core ideas should not be taught separately from Dimension 1: Scientific Practices. The standards call for the integration of science core ideas and scientific practices because "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" (NRC 2012, p. 218). In fact, one guiding principle of NGSS states

> Engagement in practices is language intensive and requires students to participate in classroom science discourse. (NRC, 2013, p. 392)

Teachers' lack of instruction that integrates core ideas and practices, and varied perceptions of how language and literacy can be useful in implementing that integration, may be a result of teachers' varied levels of understanding of the three NGSS scientific practices on which this study focused. For instance, engaging in scientific practice requires students to use expressive language skills to ask scientific questions. NGSS defines "scientific questions" as those answered with "explanations supported by empirical evidence, including evidence gathered by others or through investigation" (NRC, 2013 Appendix F p. 52). Scientific questions are different than the types of questions described by the teachers in this study. The teachers described how students asked questions about Disciplinary Core Ideas they did not understand. Although that metacognitive skill is important, it is not the type of questioning defined by NGSS. The teacher questioning described in this study was similar to the findings from a review of studies that explored student questioning reported by Chin and Osborne (2008). They found that more studies looked at teacher questioning rather than student questioning. Of the studies that looked at student questioning, the majority focused on asking questions about science text rather than learning to form inquiry-generated questions. Because I did not observe students generate questions in any of the observed lessons, it is not clear how, or if, teachers taught their students to ask NGSS-based scientific questions.

A second language-intensive practice in NGSS is constructing explanations. Students are "expected to construct their own explanations, as well as apply standard explanations they learn about from their teachers or reading" to explain natural phenomenon (NRC, 2013 Appendix F p. 60). In some of the interviews, teachers provided examples of how they perceived their students constructed explanations. However, the only explanation I observed was in Case B when students explained what they would do if they were walking on cracked ice. Because students were only asked to explain what they would do without explaining why, it was not apparent that they were relating their answer to the observed demonstrations or their understanding of a science principle.

Additionally, based on the teachers' descriptions, the explanations their students wrote were similar to the types of explanations Wang (2014) reported as common for middle school students. In a review of the literature on student constructed explanations, Wang found that middle school students' explanations tended to be summaries of observations and personal experiences. That is the type of explanation Mr. Green described when he said students wrote explanations after observations, the explanations Ms. Jones's students wrote about cracked ice and what Ms. Martin described when she said her students answered questions to explain what they learned during science labs. Only Ms. Jones referred to CER to construct explanation, although she did not require students to consistently use CER to explain phenomenon. The ways teachers in this study viewed student-constructed explanations did not reflect the literature on student-constructed explanations.

Teachers' understandings of and professional development about scientific explanation might reflect scholars in science education who remain divided on what it means to construct explanations and then how to teach them to students. Wang (2014 p. 240) defined as scientific explanation as "constituting three major components, specifically claims, evidence, and reasoning." Berland and Reiser (2009) identified three goals for engaging students in scientific explanation and argumentation. They are (a) sense making (b) articulating and (c) persuading. They argued that scientific explanation and argumentation should be combined, and that argumentation is the final step in the process that includes explanation. In contrast, Osborne and Patterson (2011, p. 629) argued that scientific explanation and argumentation are too often conflated and explained the difference between the two scientific practices as "[an] explanation … attempts to account for the given phenomenon, and an argument … examines the question of whether the explanation is valid." A major feature of explanation, they wrote, "is that the phenomenon to be explained is not in doubt." Conversely, when arguing from evidence, there is "always a substantial degree of tentativeness" as evidence is analyzed and weighed. The researchers identified several examples in science literature, and even in science standards, in which the terms *claim, evidence,* and *reasoning* are used to describe the process of constructing explanations. They argue that those terms are related to argumentation rather than explanation. They further argue that as teachers and their students are learning NGSS scientific practices, each practice needs to be clearly defined and isolated from the other.

In response to the clear distinctions between scientific explanation and argumentation presented by Osborne and Patterson (2011), Berland and McNeill (2012 p. 810) argue for the importance of "emphasizing the synergy and commonalities between the two practices" because both are critical to building knowledge in science. Similarly, Hsu, Chiu, Lin and Wang (2015) stated that explanation is part of argumentation and developed a structured argumentation scaffold, with one step being explanation. While the debate about definitions and linkages between scientific explanation and argumentation continues in science education research, teachers must still develop and implement NGSS-promoted practices. In this study, teachers overall limited understanding of the scientific practices and related possible instructional choices seemed apparent.

Teachers had the least to say about the final scientific practice explored in this study, which is, arguing from evidence. When arguing from evidence, students are "expected to use argumentation to listen to, compare, and evaluate competing ideas and methods based on their merits" (NRC, 2013 Appendix F p. 62). When asked about that practice, all of the teachers reported that the students had not done it yet. The science teachers in this study used the terms "debate," "discussion," and "justification" when they described how students engaged in this practice in the past, or how they anticipated students might engage in future lessons. Overall, the purpose of the debates or discussions described by all teachers in this study seemed to be about swaying others to agree with an argument rather engage in an exercise in evaluating evidence. That is similar to the findings reported by Berland and Reiser (2009 p. 31) who described argumentation as a discourse to "persuade others of their understandings." But after a review of 54 articles that described interventions for argumentation, Cavagnetto (2010) reported a different use for argumentation. He found that the purpose of most scientific arguments made by students was to advance understanding of a concept. Recognizing that teaching students to analyze and evaluate multiple sources of evidence is a complex task that requires explicit instruction, Chin and Osborne (2010) developed a protocol to teach students how to argue from evidence in science. The protocol included a series of clearly defined steps and organizers to scaffold students as they learned the practice. The teachers in this study reported that their students were not arguing from evidence and I did not see it, so it remains unknown how these teachers will teach their students to argue from evidence, or how they differentiate explanation and argumentation.

**Interventions for Students with LD**

Both science teachers and special educators identified the co-teaching service delivery model, and specifically the special educator, as the primary intervention for students with LD. Each science teacher identified the presence of the special educator and working with her as a major way to help students with LD. It was not clear to what extent or in what ways teachers planned together or shared assessment data because none of the co-teaching pairs had shared planning time in their schedules. While in the science classroom, science and special educators described how the special educator role was to monitor students to refocus attention or to have one-to-one conversations with students to assess their understanding.

All teachers, however, identified the importance at times of separate settings for students with LD to access and review content. The special educators each spoke about activities they led with students in small groups, either in the same classroom or in a separate setting. For instance, they said they read science texts, reviewed concepts, led discussions and reviewed vocabulary. I did not gain information about how they provided the instruction; that is, they did not explain their instructional processes. In that way, they described the small group structure and the location of the instruction, but they did not offer a description of how they delivered instruction. Additionally, though the teachers did use evidence-based instructional practices (mnemonics, graphic organizer, vocabulary instruction) that have been shown to be effective for students with LD, they were inconsistent in identifying those as specifically used as interventions for students. Furthermore, mnemonics and vocabulary instruction were not implemented with the fidelity required for the evidence-based practices.

Special educators’ comments in interviews and actions during observations revealed their focus on individual students. The lesson outcomes they articulated, their lesson reflections during post-observation interviews and their responses in the three-part Reflection Guide provided evidence of that emphasis. Additionally, at times, teacher comments were suggestive of challenges in helping the science teacher understand ways to differentiate the lesson to support a range of students' learning (especially in Case B). The special educators' comments further showed some uneasiness about the fast-pacing and teacher-centered nature of the science instruction. Those concerns were most prevalent in Case C. Ms. Martin and Ms. Lacey expressed concerns over the placement for some of their students with disabilities, not only LD. When their students transitioned from elementary school, all students with IEPs were placed in an inclusion science classroom. The teachers believed the placement was not appropriate for some students with severe reading and writing disabilities who had been in self-contained special education classrooms in elementary school. Although each student is to be educated in the least restrictive environment appropriate for him or her, and the general education classroom may not have been the appropriate placement for all of the students, the lack of shared planning time may have also influenced the teachers' ability to provide appropriate instruction within the general education classroom.

The findings from this study support other research findings as well. One instance is findings from Magiera, Smith, Zigmond, and Gebaner (2005) who reported that co-teachers had minimal time to prepare for co-teaching and most instruction was delivered to the whole group, with the special educator interacting with students with disabilities while the general educator had little interactions with them. I observed similar co-teaching in Cases B and C. In those classrooms, the general education science teacher-delivered instruction while the special educator circulated, monitored for attention and checked in with individual students. The roles and work of those special educators are consistent with research about typical roles of special educators in co-taught classrooms. In another study examining the work of 71 co-teaching pairs, Kilanowski-Press, Foote, and Rinaldo (2010) reported that 89% of the teachers they interviewed relied on the “consultant model” in which the special education teacher is present but delivers very little instruction. Weiss and Lloyd (2002) found that the special educator in the co-taught classrooms they studied frequently assisted in a way similar to an instructional aide. One exception was a lesson I observed in which the special educator delivered science instruction to the whole group. Notably, however, the instruction that day was focused on two-column notes.

In spite of having little opportunity to provide instruction in the science classroom (Cases B and C), all of the special educators reported that they delivered instruction to students in small groups as an alternative to the large-group instruction. One special educator worked with a small group in the classroom during the science period, while the two others pulled students out to a separate setting during the class period. All teachers thought the small group structure was useful for students (and it was not clear whether it was all students with LD, though teachers described the small groups as useful for all students). I had limited opportunities to observe small group instruction and special educators did not explain the instructional practices or interventions they used during small group instruction, therefore it is not possible to explain the roles the special educators took on during instruction. However, when small group instruction is implemented with clear expectations and explicit instruction, research has indicated worth and benefit to students’ learning (Bennett, Hogarth, Lubben, Campbell, and Robinson, 2010; Datchuk, 2017; Ledford, Lane & Wolery, 2015). Marston (1996) shed light on the benefits of the small group practices particularly similar to those used in this study. He looked at the effects of using a combination of co-teaching and pull-out services and compared the effectiveness of pull-out only, co-teaching only, and the combination of co-teaching and pull-out. He concluded that the combination of pull-out and co-teaching produced the largest gains in learning for students with disabilities.

**Conclusion**

All of the teachers recognized that disciplinary vocabulary and the ability to read science text impacted science learning. They all could articulate what they perceived they implemented to support NGSS practices and students with LD. Yet findings reveal that purposeful attention to the NGSS practices and their definitions, and to the range of evidence-based practices to support students with LD, could enhance teachers' science instruction. Additional knowledge to identify rationales for instructional choices and possible adaptation of evidence-based practices for students with LD could enhance teacher support for students, especially differentiation of instructional practices focused on students with LD. Likewise, enhanced understandings about the NGSS practices and the integral integration of literacy skills promoted by NGSS could help students.

The overall findings seem especially compelling given that teachers in this study were highly accomplished and arguably could be best suited to implement NGSS-based practices and evidence-based practices to support students with LD and language-based challenges. All held advanced degrees, and 4/6 held multiple science endorsements and were nominated by their principals. Science teachers had an average of more than 19 years of experience (range 13-25 years), and special educators had an average of 25 years of teaching experience (range 12-35). Yet they grappled with the complicated tasks of integrating the new language-intensive NGSS science practices into their traditional science instruction while attending to the unique learning needs of their diverse group of students, including students with LD. An intentional focus on language and literacy skills when teaching disciplinary content could be a key feature in professional development and potentially considerations about teacher preparation.

## Limitations

This study had several limitations. Selecting the participants through purposeful sampling is one limitation of case study design (Creswell, 2011). Because the participants were selected by the researcher, the results may not be generalizable. Additionally, for this study, the grade level and science content were not considerations in selecting participants. Therefore, different Disciplinary Core Ideas were being taught at three different grade levels. Each topic of study presents unique complexity in terms of vocabulary, concepts, and integration of scientific practices. Those make it complicated to draw conclusions across cases. Not considering the context of the co-teaching partnerships was another limitation. Literature on co-teaching highlights the necessity to participate in regularly scheduled co-planning meetings. Additionally, the middle school philosophy relies on regularly scheduled team meetings. None of the teachers reported participating in those team meeting together. The teachers in this study did not have that opportunity built into their schedules. Therefore, the cases do not serve as an ideal model of co-teaching in middle school science classrooms.

The timing and frequency of the observations was another limitation. The data collection took place early in the academic year. It may be that scientific practice, such as arguing from evidence, was introduced and taught later in the year. Also, I observed only three lessons in units that ranged from six to twelve weeks. That provided only a snapshot of instruction at three points in time. Additionally, while I did not observe scientific practices, in interviews teachers described other lessons in which they perceived scientific practices were used.

Another limitation is that the students with LD were not participants; therefore, they were not identified to me. That impacted my ability to comment on specific interventions aimed at students with LD. As I did not know who they were, I did not know when the special educator or general educator was assisting a student with LD in the science classroom.

To address threats to reliability, a variety of data types were collected, that included multiple interviews with each participant, classroom observations, and a reflection that involved individual reflections and a paired interview. Additionally, intercoder reliability was established by having a second coder code one-third of the data. Inter-coder reliability was adequately established. Finally, peer/colleague review was in place as I discussed each step of the design, data collection, and analysis with my dissertation chair. To address issues of validity, I provide context-rich and meaningful descriptions of the results. The results emerged from triangulation of multiple data sources. Finally, areas of uncertainty due to lack of data are clearly identified.

## Implications

**Implications for practice.** NGSS-promoted science may be different from how teachers taught before, learned science themselves and learned to teach science. Therefore, one implication evident from this study is that teachers may need to "unlearn" how they have thought about science core ideas and teaching science to students in order to make space for learning NGSS-based ideas. They will need to consider how they integrate teaching core ideas and scientific practices. Additionally, they need to consider how they will generate in their classrooms the scientific discourse required to develop those scientific practices in a diverse student population. This is similar to the early work related to teachers' adoption of National Council of Teachers of Mathematics reform standards in the early 1990s. Ball (1988, p. 26) asserted that knowing what teachers bring as background knowledge and then "developing ways of challenging, changing, and extending what they know, believe, and care about" could lead to changes in their practice. While that study focused on pre-service teachers, the same could be true for practicing teachers as they expand their knowledge to implement new instructional practices for teaching language-intensive NGSS scientific practice to students who bring diverse levels of language abilities.

Another implication is the focus of professional development (PD) that could be intentionally aimed at helping educators gain a deeper understanding of the NGSS and language demands. PD is believed by many to be the lever that can change teacher practice and thereby increase student achievement (Blank, de las Alas, & Smith, 2008; Desimone, 2009; Yoon, Duncan. Lee, Scarloss & Shapley, 2007). Empirical research findings indicate that effective PD provides active learning that is content-specific and linked to student learning (Andree, Richardson, & Orphanos, 2009; Blank et al., 2008; Cronen & Garet, 2008; Wayne, Yoon, Zhu, Wei, Darling-Hammond,) and that develops a community of learners (Brand & Moore, 2011). Although there are many models for delivering PD, professional learning communities (PLCs) could be the best model for science teachers to work together with special educators as both learn to implement language-intensive NGSS. PLCs are based on the assumption that a teacher's experiences and reflection on those experiences, when situated in a collaborative group of professionals, has the potential to increase professional knowledge and thereby increase student learning (Vescio, Ross & Adams, 2008).

Another implication of this study is the potential PD focus on the use of academic language inherent to learning science. Attending to both language use and content knowledge has been shown to increase students' knowledge and skills in both areas (Brown & Ryoo, 2008; Brown & Spang, 2008). Jung and Brown (2016 p. 851) taught pre-service teachers to write "clear and measurable language objectives in concert with science content objectives." The researchers developed a lesson planning tool that required the pre-service teachers to consider seven components of the lesson: "Content Objective, Tasks, Discourse, Syntax, Vocabulary, Language Objective and Language Supports." That type of planning for co-taught science instruction has the potential to lead to the more consistent use of evidence-based practices as teachers identify language objectives and how their instruction and interventions allow all students to meet the objective. The science teacher could have primary responsibility for planning the science content and lesson structure, while the special educator in addition to attention to helping students meet IEP goals, could have primary responsibility for making adaptations related to the language demands and aligning with individual students' assets and challenges. Clearly identifying those language demands through a language objective could help enable clear roles and work between co-teachers to be identified. A body of research already exists that identifies some literacy strategies and interventions shown to be useful in science classrooms (Chin & Obsborne, 2008, 2010; Herrenkohl, 2006; Wang, 2014). By teaching teachers about those, we could enhance their research-based wisdom and capacities to implement language-based intervention that could help all students. Special educators could focus on also gaining knowledge and skills in supporting the learning of language and literacy, which is very often the focus on IEP goals.

**Implications for research.** Roughly 68 percent of students with disabilities spend 80% of their days in general education (Kena et al., 2016) and science is often the subject in which they are included (Cawley et al., 2002). Research that includes descriptive studies that could lead to quasi-experimental work could help the field identify additional literacy evidence-based practices to support students with diverse learning needs to access science that includes NGSS language-intensive scientific practices. Although there are evidence-based practices that are effective for teaching science content (mnemonics, graphic organizers, vocabulary), they are not readily applicable to the scientific practices.

In addition to identifying evidence-based practices for scientific practices, teachers will need to develop the knowledge of how to link literacy and science practices that will include how to effectively select EBPs and adapt them to meet students' challenges. Cook, Tankersley and Harjusola-Webb (2008, p. 110) explain that researchers are charged with identifying EBPs, and then special education teachers must "skillfully and creatively using their professional wisdom" to decide how to use the EBP. Similarly, Spencer, Detrich and Slocum (2012) argue that teachers must use professional judgment to identify the best EBPs for their "clients" in their particular contexts. Therefore, we need research not only about what needs to be taught but also how teachers make the decisions. Palincsar et al. (2001) offer a roadmap for this type of study. Over a two-year period, Palincsar et al. (2001) showed how science teachers taught literacy intentionally and explicitly within inclusive science classrooms with students with LD. They led discussions around vignettes to prompt teachers to reflect on their instruction for students with LD and then guided them as they developed interventions for their students. The teachers made choices of how to do that based on their knowledge of the students and settings. It could be argued that a similar process, paired with PD related to NGSS-based science, could guide teachers to develop the interventions some students need to fully participate in inclusive science classes.

Additionally, as students with LD are increasingly expected to engage in language-intensive NGSS practices, researchers in the field of special education could be developing and evaluating interventions that build on students' varied strengths. NGSS implementation could offer a unique opportunity to create new curricular resources and instructional practices. There is a growing body of research that demonstrates the effectiveness of using protocols or strategies to teach all students the skills of asking questions (Chin & Obsorne, 2008, Bulgren & Ellis, 2015), constructing explanations (Wang, 2014), and arguing from evidence (Chin & Osborne, 2010). However, those protocols and strategies are not adapted for students with LD. Researchers now have an opportunity for interventionists to "focus on the child's development in terms of their abilities to use compensatory processes" (Vygotsky, 1978) and develop tools that will allow them to participate in scientific discourse with peers.

**Implications for policy.** The findings from this study have implications for the structure, nature and use of standards policy creation and document creation. The NGSS are designed to provide high-quality science and engineering instruction to *all* students. In fact, NGSS Appendix

D, named “All Standards, All Students” clearly states that all students are expected to meet the “increased cognitive expectations” of the three NGSS dimensions. To assist teachers as they plan and deliver instruction to their students who may present a range of unique learning needs, Appendix D presents a set of vignettes that highlight the connections between the dimensions and suggestions for providing instruction to non-dominant groups of students, one of which is students with disabilities. In an attempt to explain how to adapt NGSS-based instruction, Appendix D explains,

> Two approaches for providing accommodations and modifications are widely used by general education teachers in their classrooms: (1) differentiated instruction and (2) Universal Design for Learning (NRC, 2013 Appendix D p. 31).

That statement and potentially others, could be amended to provide background knowledge, suggested evidence-based practices and adaptations to teachers in how to make NGSS accessible to students with disabilities. Vignettes of teaching that include students with LD could be developed.

Beyond the standards documents, policies about PD and resources to support it could be developed to support teachers like those in this study. As teachers are being asked to change the way they are teaching science while providing all students access to instruction, they will gain from purposeful PD focused on identifying evidence-based practices linked to NGSS science practices specifically for addressing the academic language demands. They will benefit from knowledge and skill to adapt content to ensure access to both core disciplinary ideas and scientific practices. If the U.S. is truly committed to science for all, a commitment needs to be made for research, resources and teacher development.

# Appendix A: Participation Criteria Checklist

## General Education Science Teachers

Seeking middle school science teachers and the special educators with whom they co-teach to participate in a study. Participation will include interviews, observations, and a reflection meeting. Participants will receive a $95 gift card and a professional resource as compensation for their time.

Directions: Please check yes or no to answer each question below.

| | Yes | No |
|---|---|---|
| Are you a state licensed general education teacher? | | |
| Do you have a science endorsement? | | |
| Do you teach science to students in grades 6-8? | | |
| Do you have at least 5 years of teaching experience? | | |
| Are at least 2 students with learning disabilities enrolled in at least one of your science classes? | | |
| What is the name of the special education teacher with whom you co-teach or collaborate? | | |

If you replied yes to each question and would like to participate in this study, please complete the information below.

| | |
|---|---|
| Your Name | |
| Phone Number | |
| Email | |
| Best Time and Day to call | |

Research being completed by:
Kathleen Barabasz - UIC doctoral student [redacted])
Michelle Parker-Katz - UIC faculty and research supervisor [redacted]

Email [redacted] or call [redacted] for additional information.
Interested teachers should complete the checklist and return it to Kathleen Barabasz.

Thank you!

## Appendix A: Participation Criteria Checklist (cont.)

### Special Educators

Seeking middle school science teachers and the special educators with whom they co-teach to participate in a study. Participation will include interviews, observations, and a reflection meeting. Participants will receive a $95 gift card and a professional resource as compensation for their time.

Directions: Please check yes or no to answer each question below.

| | Yes | No |
|---|---|---|
| Are you a state licensed special education teacher? | | |
| Do you co-teach science to students with learning disabilities in grades 6-8? | | |
| Do you have at least 5 years of teaching experience? | | |
| Are at least 2 students with learning disabilities enrolled in the science class referred to in the second question? | | |

If you replied "yes" to each question and would like to participate in this study, please complete the information below.

| | |
|---|---|
| Your Name | |
| Phone Number | |
| Email | |
| Best Time and Day to call | |
| Name of the general education teacher with whom you co-teach or collaborate. | |

Research being completed by:
Kathleen Barabasz - UIC doctoral student [redacted]
Michelle Parker-Katz - UIC faculty and research supervisor ([redacted]

Email [redacted] or call [redacted] for additional information.

Interested teachers should complete the checklist and return it to Kathleen Barabasz. Thank you!

## Appendix B: Teacher and Class Profile

General Education Science Teacher Profile

1. Teacher Name:

2. School:

3. Subjects taught each day:

4. Total years of teaching:

5. Total years of teaching the science course:

6. Highest degree attained/area:

7. Area(s) of endorsement (list all):

8. Describe the coursework or professional development related to teaching students with LD you participated in during the last 2 years. Include an approximate number of hours.

9. Describe coursework or professional development related to teaching science you participated in during the last 2 years. Include an approximate number of hours.

Daily Schedule

Complete the schedule for each science class you teach.

| Start time- End time | Room Number | Grade Level | Number of Students | Number of Students with Learning Disabilities | Science Discipline (Life, Physical, Earth) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## Appendix B: Teacher and Class Profile (cont.)

Special Education Teacher Profile

1. Teacher Name:

2. School:

3. Subjects taught each day:

4. Total years of teaching:

5. Total years of teaching special education:

6. Total years of teaching the science course:

7. Highest degree attained:

8. Area(s) of endorsement (list all):

9. Describe the coursework or professional development related to teaching students with LD you participated in during the last 2 years. Include an approximate number of hours.

10. Complete the schedule for science classes that you co-teach.

| Start time-End time | Room Number | Grade Level | Number of Students | Number of Students with Learning Disabilities | Science Discipline (Life, Physical, Earth) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

## Appendix C: Initial Interview Protocol for Science Teachers

Introduction: Hello. Thank you for meeting with me today and for volunteering to participate in this study. I want to begin by introducing myself and giving you a bit of history about how this study developed. I began my teaching career in middle school science, and it remains a passion of mine. After 15 years as a classroom teacher, I began a Ph.D. program in special education because I was interested in learning how to provide effective instruction to students with learning disabilities. I am currently working as an instructional coach with student teachers and new teachers. This study if a requirement of the Ph.D. program in special education. It combines my interest in science instruction and special education.

During the interview, I will be taking notes. I am also going to audio-record the interview to use in cases where my notes are not sufficiently clear. I will send the notes to you by email within five days of the interview. Please read the notes and add additional information or clarify information that doesn't accurately reflect your thoughts about the question.

Participant ______________________________ Date ______________

Location ______________________________ Time ______________

1. For the first few questions, think about the unit you taught during the past two weeks. What topic did you teach? What learning outcomes were you expecting?
2. Thank you. Next, I want to talk with you about what your science teaching looks like? What do you do during a typical lesson? What do students do?
3. Now, tell me how you decided what to teach in terms of core ideas? Did you add or change anything from the required curriculum?
4. As you know, for this study, I'm focusing on the NGSS. I'm particularly interested in how you engage students in scientific practices. Tell me about the scientific practices you focused on over the last two weeks.
5. Can you tell me more about how you promote student questioning as part of your science instruction?

a. How do you know it when you see it?

b. How do you know your students are developing the skill of asking scientific questions?

6. Can you tell me more about how you promote student explanations as part of your science instruction?

a. How do you know it when you see it?

b. How do you know your students are developing the skill of generating scientific explanations?

7. Can you tell me more about how you promote student argumentation from evidence as part of your science instruction?

a. How do you know it when you see it?

b. How do you know your students are developing the skill of arguing from evidence?

8. Language demands can be described as receptive skills of listening and reading, and the expressive skills of speaking and writing. What language demands did students experience while engaging in those practices over the last two weeks? Can you give examples of how students used language? How did you support students as they used language during scientific practices?

9. Now let's focus on your students with identified learning disabilities. Over the last two weeks, tell me about the particular supports those students received. Think of supports as any adaptations to the science curriculum or consultation or instruction provided by the special education teachers.

a. In what ways did those supports help the students?

b. What changes would you make?

c. What additional supports or different kinds of supports would be helpful? Why?

10. With respect to the practices of asking questions, generating explanations, and arguing from evidence, in what ways were the supports helpful or not?

11. In the last two weeks, in what ways, if any, have you collaborated with a special education teacher?

## Appendix D: Initial Interview Protocol for Special Educators

Introduction: Hello. Thank you for meeting with me today and for volunteering to participate in this study. I want to begin by introducing myself and giving you a bit of history about how this study developed. I began my teaching career in middle school science and it remains a passion of mine. After 15 years as a classroom teacher, I began a Ph,D. program in special education because I was interested in learning how provide effective instruction to students with learning disabilities. I am currently working as an instructional coach with student teachers and new teachers. This study if a requirement of Ph.D. program in special education. It combines my interest in science instruction and special education.

During the interview, I will be taking notes. I am also going to audio-record the interview to use in cases where my notes are not sufficiently clear. I will send the notes to you by email within five days of the interview. Please read the notes and add additional information or clarify information that doesn’t accurately reflect your thoughts about the question.

Participant ______________________________ Date ______________

Location ______________________________ Time ______________

1. I want to talk with you about teaching science to students with learning disabilities. First, talk to me about your role in teaching science to students with LD? Generally, what do you do before, during, and after the lesson?
2. Think about science instruction over the past two weeks. How did you support students during science classes? Outside of science classes? Can you give examples?
3. The NGSS, the new science standards, call for students to engage in practices, or the work of science. Students are expected to ask questions, generate explanations and engage in arguments from evidence about the topics they study. How did you support students with LD over the past two weeks as they “did” science?
4. One practice is asking questions. Scientists ask questions about the natural world they study or observe. How did you support students to ask questions about the topics they were studying?

5. Another practice is constructing explanations. Scientists generate explanations about the natural world they study or observe. How did you support students to construct explanation about the topics they were studying?
6. The final question is about the practice of engaging in arguments from evidence. Over the past two weeks, did your students have opportunities to engage in arguments from evidence? How did you support them?
7. Language demands can be described as receptive skills of listening and reading, and the expressive skills of speaking and writing. What language demands did students experience while engaging in those practices over the last two weeks? Can you give examples of how students used language? How did you support students as they used language during science?
8. In the last two weeks, in what ways, if any, have you collaborated with a special education teacher?

# Appendix E: Pre-observation Interview Protocols

Pre-observation Interview for Science Teacher

Teacher: School:

Date of Lesson: Room Number:

Observed Lesson # (circle 1) 1 2 3

Start Time: End Time:

Total number of students in the class ___________

Total number of students with IEPs in the class _______

Total number of students with LD _______________

Please answer the following questions.

1. What are you working on in science?
2. What are the learning outcomes for the lesson?
3. I want a sense of the flow of the lesson. What's the first thing I will see? Then what?
4. How will students use language during the lesson? Will they use receptive skills of listening and reading, and the expressive skills of speaking and writing?
5. What challenges do you anticipate the language demands will present to students with and without LD?
6. How does this lesson fit in with what you did yesterday and what you'll do in the future?
7. As you're moving through this unit, what challenges have you seen for students with LD? What, if anything have you been doing to help them. How have you been doing that?
8. How might what you just discussed align with your students' IEPs.

Pre-observation Interview for Special Educators

Teacher: School:

Date of Lesson: Room Number:

Observed Lesson # (circle 1) 1 2 3

Start Time: End Time:

Total number of students in the class ___________

Total number of students with IEPs in the class _______

Total number of students with LD _______________

Please answer the following questions.

1. What are the learning outcomes of the lesson for students with LD?
2. If we think of language demands as the receptive skills of listening and reading and the expressive skills of speaking and writing, what opportunities do you anticipate the language demands will present to students with LD during this lesson?
3. What challenges do you anticipate the language demands will present to students with LD during this lesson?
4. What supports will students with LD receive to meet the language demands?
5. How will those supports be provided?

## Appendix F: Post-Observation Interview Protocol

Post-observation Interview for Science Teachers and Special Educators

1. Tell me what you think went very well during the lesson?
2. What would you do differently next time?
3. Did students meet the learning outcome(s) for the lesson? How do you know?
4. What scientific practice(s) were students' engaged in? Do you think the students learned the practice, If yes, how do you know?
5. Describe the language demands students experienced during the lesson. How well do you think your students met the language demands of the lesson? How do you know?
6. What supports were offered to students with LD?
7. Do you think the supports provided to students with LD were effective? How do you know?

## Appendix G: Science Instruction Observation Guide

| | | |
|---|---|---|
| Teacher: | School: | Observer: |
| Date: | Time: | # Students: |

| | |
|---|---|
| Lesson Objective(s): | Materials: |

| **Time** | **Descriptive Field Notes** (Scientific practices: asking questions, constructing explanations. engaging in arguments from evidence, or Language and Literacy: expressive and receptive language, vocabulary instruction) | **Reflective Field Notes** (personal thoughts, insights, questions) |
|---|---|---|
| | | |

Record participant structure and communication mode every 8 minutes

| Time (Min.) | Participant Structure | | | | | Communicative Mode | | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | Whole Group | Small Group 3-5 | Pairs | Independent Work | | Interpersonal | Interpretive | Presentational | |
| 0 | | | | | | | | | |
| 8 | | | | | | | | | |
| 16 | | | | | | | | | |
| 24 | | | | | | | | | |
| 32 | | | | | | | | | |
| 40 | | | | | | | | | |
| 48 | | | | | | | | | |
| 56 | | | | | | | | | |

## Appendix H: Reflection Guide Instrument

Name ____________________________________ Date ____________________

This meeting will provide an opportunity for you, as co-teachers, to reflect on your students' use of language in science during one segment of a lessons I observed. You will read a transcript of the lesson segment and independently answer six questions about the segment. Consider how your students used language during this segment. For this activity, think of language demands as the receptive skills of listening and reading and the expressive skills of speaking and writing. Then we will have a discussion to share your thoughts about language demands and scientific practices for your students, and especially your students with LD. After the discussion, you will have an opportunity to write a final reflection.

Part 1: Lesson Segment Reflection

1. What science/scientific practices were students learning during this lesson?

2. Describe the language demands in this part of the lesson.

3. How did language demands impact your students' ability to learn the science/scientific practices? Provide examples.

4. What supports were offered to all students?

5. What supports were offered to students with disabilities?

6. How did the supports increase participation in science/scientific practices for students with LD? How do you know?

Part 2: Discussion

1. What opportunities do language demands present for all students while learning science/scientific practices?
2. What opportunities do language demands present for students with LD while learning science/scientific practices?
3. What challenges do language demands present for all students while learning science/scientific practices?
4. What challenges do language demands present for all students with LD while learning science/scientific practices?

Part 3: Written Reflection

1. How do language demands impact learning of science/scientific practices?
2. What do you think is the best way to support all students to meet the language demands they experience while engaging in science/scientific practices? Provide examples to explain your response
3. What do you think is the best way to support students with LD to meet the language demands they experience while engaging in science/scientific practices? Provide examples to explain your response.
4. What additional thoughts would you like to share?

## Appendix I: Institutional Review Board Approval

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

**Approval Notice**

**Initial Review (Response To Modifications)**

February 19, 2016

Kathleen Barabasz, MA
Special Education
[redacted]

RE: Protocol # 2015-1237

"Supporting Students with LD to Question, Explain, and Argue in Inclusive Middle School Science Classrooms"

Dear Ms. Barabasz:

**Please remember to submit letters of support from each school site prior to accessing/analyzing identifiable information and/or recruiting/enrolling subjects at those sites. Letters must be on letterhead, briefly outline the research activities the school agrees to host, provide explicit approval if a waiver of parental permission is being sought, and be signed by the school principal/authorized official. Letters must be accompanied by an Amendment form when submitted to the UIC IRB.**

***Please note that stamped and approved .pdfs of all recruitment and consent documents will be forwarded as an attachment to a separate email. OPRS/IRB no longer issues paper letters and stamped/approved documents, so it will be necessary to retain the emailed documents for your files for auditing purposes.***

Your Initial Review (Response To Modifications) was reviewed and approved by the Expedited review process on February 8, 2016. You may now begin your research

Please note the following information about your approved research protocol:

**Protocol Approval Period:** February 8, 2016 - February 7, 2017

**Approved Subject Enrollment #:** 10

**Additional Determinations for Research Involving Minors:** The Board determined that this research satisfies 45CFR46.404)', research not involving greater than minimal risk. Therefore, in accordance with 45CFR46.408 ', the IRB determined that only one parent's/legal guardian's permission/signature is needed. Wards of the State may not be enrolled unless the IRB grants specific approval and assures inclusion of additional protections in the research required under 45CFR46.409 '. If you wish to enroll Wards of the State contact OPRS and refer to the tip sheet.

**Performance Sites:** UIC

**Sponsor:** None

**PAF#:** Not applicable

**Research Protocol(s):**

a) Revised Protocol; Version 2; 12/28/2015

**Recruitment Material(s):**

a) Participation Criteria Checklist (Special Education Teacher); Version 2; 12/27/0215
b) Participation Criteria Checklist (Science Teacher); Version 2; 12/27/2015
c) Supt. Letter; Version 1; 12/29/2015
d) Invitation Email Script; Version 1; 01/24/2016
e) Recruitment Session Script; Version 2; 01/24/2016
f) Principal Letter #2; Version 2; 01/24/2016
g) Principal Letter #1; Version 2; 01/24/2016
h) Recruitment Flyer; Version 3; 01/24/2016

**Informed Consent(s):**

a) Teacher Consent; Version 2; 12/27/2015
b) A waiver of documentation of informed consent has been granted under 45 CFR 46.117 and an alteration of consent has been granted under 45 CFR 46.116(d) for recruitment purposes only; minimal risk; verbal consent to screening/eligibility questions will be obtained; written consent/ will be obtained at enrollment.
c) Waiver of informed consent granted [45 CFR 46.116(d)] for the identification of potential subjects in the recruitment phase of the research.

**Assent(s):**

a) A waiver of assent has been granted under 45 CFR 46.116(d) for children as secondary subjects who may be captured on audio tape; minimal risk; impracticable to obtain assent.

**Parental Permission(s):**

a) A waiver of parental permission has been granted under 45 CFR 46.116(d) for children as secondary subjects who may be captured on audio tape; minimal risk; impracticable to obtain permission; school site explicitly agrees to the waiver of parental permission.

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific category(ies):

(6) Collection of data from voice, video, digital, or image recordings made for research purposes., (7) Research on individual or group characteristics or behavior (including but not limited to research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

**Please note the Review History of this submission:**

| Receipt Date | Submission Type | Review Process | Review Date | Review Action |
|---|---|---|---|---|
| 11/25/2015 | Initial Review | Expedited | 12/01/2015 | Modifications Required |
| 01/06/2016 | Response To Modifications | Expedited | 01/07/2016 | Modifications Required |
| 01/25/2016 | Response To Modifications | Expedited | 02/08/2016 | Approved |

Please remember to:

→ Use your **research protocol number** (2015-1237) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the OPRS website at,

"**UIC Investigator Responsibilities, Protection of Human Research Subjects**"
*(http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)*

**Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.**

**Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.**

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 355-0816. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Alison Santiago, MSW, MJ

Assistant Director, IRB # 2

Office for the Protection of Research Subjects

Enclosure(s):

1. **UIC Investigator Responsibilities, Protection of Human Research Subjects**
2. **Informed Consent Document(s):**
   a) Teacher Consent; Version 2; 12/27/2015
3. **Recruiting Material(s):**
   a) Participation Criteria Checklist (Special Education Teacher); Version 2; 12/27/0215
   b) Participation Criteria Checklist (Science Teacher); Version 2; 12/27/2015
   c) Supt. Letter; Version 1; 12/29/2015
   d) Invitation Email Script; Version 1; 01/24/2016
   e) Recruitment Session Script; Version 2; 01/24/2016
   f) Principal Letter #2; Version 2; 01/24/2016
   g) Principal Letter #1; Version 2; 01/24/2016
   h) Recruitment Flyer; Version 3; 01/24/2016

cc: Norma Lopez-Renya, Special Education, M/C 147
Michelle Parker-Katz (Faculty Sponsor), Special Education, M/C 147

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

**Approval Notice**

**Continuing Review**

January 24, 2017

Kathleen Barabasz, MA

Special Education

[redacted]

**RE: Protocol # 2015-1237**

**"Supporting Students with LD to Question, Explain, and Argue in Inclusive Middle School Science Classrooms"**

Dear Ms. Barabasz:

Your Continuing Review was reviewed and approved by the Expedited review process on January 19, 2017. You may now continue your research.

Please note the following information about your approved research protocol:

**<u>Protocol Approval Period:</u>** February 7, 2017 - February 7, 2018

**<u>Approved Subject Enrollment #:</u>** 10 (6 Subjects enrolled to date)

**<u>Additional Determinations for Research Involving Minors:</u>** The Board determined that this research satisfies 45CFR46.404, research not involving greater than minimal risk. Therefore, in accordance with 45CFR46.408, the IRB determined that only one parent's/legal guardian's permission/signature is needed.

Wards of the State may not be enrolled unless the IRB grants specific approval and assures inclusion of additional protections in the research required under 45CFR46.409. If you wish to enroll Wards of the State contact OPRS and refer to the tip sheet.

**Performance Sites:** [redacted]

**Sponsor:** None

**Research Protocol(s):**

b) Revised Protocol; Version 2; 12/28/2015

**Recruitment Material(s):**

i) Participation Criteria Checklist (Special Education Teacher); Version 2; 12/27/0215
j) Participation Criteria Checklist (Science Teacher); Version 2; 12/27/2015
k) Invitation Email Script; Version 1; 01/24/2016
l) Recruitment Session Script; Version 2; 01/24/2016
m) Principal Letter #1; Version 3; 04/21/2016
n) Principal Letter #2; Version 3; 04/21/2016
o) Supt. Letter; Version 2; 04/21/2016
p) Recruitment Flyer; Version 4; 01/21/2017

**Informed Consent(s):**

d) Teacher Consent; Version 3; 01/21/2017
e) Waiver of informed consent granted [45 CFR 46.116(d)] for the identification of potential subjects in the recruitment phase of the research.
f) A waiver of documentation of informed consent has been granted under 45 CFR 46.117 and an alteration of consent has been granted under 45 CFR 46.116(d) for recruitment purposes only; minimal risk; verbal consent to screening/eligibility questions will be obtained; written consent/ will be obtained at enrollment.

**Assent(s):**

b) A waiver of assent has been granted under 45 CFR 46.116(d) for children as secondary subjects who may be captured on audio tape; minimal risk; impracticable to obtain assent.

**Parental Permission(s):**

b) A waiver of parental permission has been granted under 45 CFR 46.116(d) for children as secondary subjects who may be captured on audio tape; minimal risk; impracticable to obtain permission; school site explicitly agrees to to the waiver of parental permission.

Your research continues to meet the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific categories:

**(6)** Collection of data from voice, video, digital, or image recordings made for research purposes., **(7)** Research on individual or group characteristics or behavior (including but not limited to research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

**Please note the Review History of this submission:**

| Receipt Date | Submission Type | Review Process | Review Date | Review Action |
|---|---|---|---|---|
| 01/03/2017 | Continuing Review | Expedited | 01/19/2017 | Approved |

Please remember to:

→ Use your **research protocol number** (2015-1237) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the guidance document,

"**UIC Investigator Responsibilities, Protection of Human Research Subjects**"
*(http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)*

**Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.**

**Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.**

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 355-2939. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Jewell Hamilton, MSW

IRB Coordinator, IRB # 2

Office for the Protection of Research Subjects

Enclosure(s):

**Please note that stamped and approved .pdfs of all recruitment and consent documents will be forwarded as an attachment to a separate email. OPRS/IRB no longer issues paper letters and stamped/approved documents, so it will be necessary to retain the emailed documents for your files for auditing purposes.**

cc: Norma Lopez-Renya, Special Education, M/C 147
Michelle Parker-Katz, Faculty Advisor, Special Education, M/C 147

APPROVAL
STARTS 02/07/2017 — EXPIRES 02/07/2018
UIC UNIVERSITY OF ILLINOIS AT CHICAGO INSTITUTIONAL REVIEW BOARD

**University of Illinois at Chicago**
**Research Information and Consent for Participation in Social Behavioral Research**

**Supporting Students with LD to Question, Explain, and Argue in Inclusive Middle School Science Classrooms**

You are being asked to participate in a research study. Researchers are required to provide a consent form such as this one to tell you about the research, to explain that taking part is voluntary, to describe the risks and benefits of participation, and to help you to make an informed decision. You should feel free to ask the researchers any questions you may have. Your decision whether or not to participate in this study will not affect any relationship or employment with the school or employer.

Principal Investigator Name and Title: Kathleen Barabasz, Doctoral Student
Department and Institution: Special Education, UIC
Address and Contact Information: [redacted]
Sponsor: Michelle Parker-Katz, UIC Professor

**<u>Why am I being asked?</u>**

You are being asked to be a subject in a research study about implementing the Next Generation Science Standards in inclusive middle school science classrooms. The NGSS scientific practices require students to "do" the work of scientist while learning specific science content. Three language intensive scientific practices are asking questions, constructing explanations, and arguing from evidence. In light of these increased language demands and the impact that a learning disability might have on receptive and expressive language, it is important to know how general education teachers and special education teachers might support their students, especially those with LD, in inclusive science classrooms as they engage in scientific practices.

You have been asked to participate in the research because you are a general education science teacher who provides science instruction based on NGSS to students with learning disabilities in a middle school inclusive classroom, or you are the special education teacher who co-teaches or consults with the general education science teacher.

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future dealings with the University of Illinois at Chicago. **If you decide to participate, you are free to withdraw at any time without affecting that relationship.**

Approximately 10 subjects (5 general education science teachers and 5 special education teachers) may be involved in this research at UIC.

**What is the purpose of this research?**

This study will focus on how middle school science teachers and the special education teachers with whom they co-teach or consult describe the language demands students encounter when asking questions, constructing explanations, or arguing from evidence in science. It will also investigate what supports are provided, and how the supports are provided as students, especially students with learning disabilities, engage in those practices.

**What procedures are involved?**

This research will be performed at your school and will include interviews and classroom observations. The study will follow this procedure:

- Each participant will complete a 2-page teacher and class profile.
- Each subject will participate in one 30-40 minute initial interview.
- Three classroom observations will be completed in each general education science classroom.
- A 15-20 minute pre-observation telephone interview with the general education science teacher and special education teacher will occur before each observation.
- Each observation will be one class period and will be audio-recorded to capture the teachers' instruction.
- Each participant will participate in a 15-20 minute post-observation telephone interview with the researcher.
- Pairs of general education teachers and special education techers will meet with the researcher for a 45 minute session to reflect on the observed lessons and discuss the supports provided to students with LD.

**What are the potential risks and discomforts?**

There is a risk that a breach of privacy (others might learn you are participating in a research study) or confidentiality (accidental disclosure of identifiable data) may occur.

**Are there benefits to taking part in the research?**

There are no direct benefits to participating in this study.

**What other options are there?**

You have the option to not participate in this study.

**What about privacy and confidentiality?**

The people who will know that you are a research subject are members of the research team, the school principal, the co-teacher, and others in the school. Otherwise information about you will only be disclosed to others with your written permission, or if necessary to protect your rights or welfare (for example, when the Illinois State Auditors or UIC Office for the Protection of Research Subjects monitors the research or consent process) or if required by law.

Study information which identifies you and the consent form signed by you will be locked up at the principal researchers' home. The Participation Criteria Checklist will be the only document with identifiable information. It will be secured in a locked cabinet in the PI's home. Once subjects are enrolled in the study, pseudonyms will be used for all data collection, storage, analysis, and reports. A list of corresponding names and pseudonyms will be stored separately from all other documents in a locked file cabinet in the PI's home. Additionally, the school district and the school will not be identified or described in a manner that might lead to identification.

The general education teachers' instruction captured on the audio recording will be transcribed by the researcher. Then the audio recording will be destroyed.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity.

Interviews and classroom observations will be audio recorded. The audio files will be named with the pseudonym and stored on a password protected computer in the PI's home. All audio recordings will be destroyed after they are transcribed.

**What are the costs for participating in this research?**

There are no costs to you for participating in this research.

**Will I be reimbursed for any of my expenses or paid for my participation in this research?**

If you complete the study, you will receive a $95 gift card and a professional reference book as compensation for your time. If you are complete some, but not all of the research tasks, you will receive a professional resource. The principal investigator will deliver the compensation after the final meeting is complete.

**Can I withdraw or be removed from the study?**

If you decide to participate, you are free to withdraw your consent and discontinue participation at any time.

The Researchers also have the right to stop your participation in this study without your consent if changes in your class or schedule do not meet the participation criteria.

**Who should I contact if I have questions?**

Contact the researcher, Kathleen Barabasz, Doctoral Student at [redacted] or email address: [redacted] OR Michelle Parker-Katz, UIC Professor at [redacted] or email [redacted]

- if you have any questions about this study or your part in it,
- if you have questions, concerns or complaints about the research.

**What are my rights as a research subject?**

If you feel you have not been treated according to the descriptions in this form, or if you have any questions about your rights as a research subject, including questions, concerns, complaints, or to offer input, you may call the Office for the Protection of Research Subjects (OPRS) at 312-996-1711 or 1-866-789-6215 (toll-free) or e-mail OPRS at uicirb@uic.edu.

**Remember**:

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University. If you decide to participate, you are free to withdraw at any time without affecting that relationship.

**Signature of Subject**

I have read (or someone has read to me) the above information. I have been given an opportunity to ask questions and my questions have been answered to my satisfaction. I agree to participate in this research. I will be given a copy of this signed and dated form.

______________________ ______________
Signature Date

______________________
Printed Name

______________________ ______________
Signature of Person Obtaining Consent Date (must be same as subject's)

______________________
Printed Name of Person Obtaining Consent

## Appendix J: Codes, Definitions and Examples

| Code | Operational Definition | Example |
|---|---|---|
| | | |
| Attention | Teacher refocuses students' attention on lesson | Ms. Lacey used a gesture to prompt a student to add to the notes (Case C) |
| Graphic Organizer | Students use an organizational structure to show relationships between concepts | Two-column notes (Case A) |
| Individual | 1:1 support provided to a student | Mr. Green and Ms. Lewis checked each students' online quizzes before they submitted them (Case A) |
| Mnemonic/Memory Device | Teacher presents memory device | "I probably might ace this test" for phases of mitosis (Case C) |
| Multimedia | Content delivered through videos or web sites | BrainPop video on parts of the atom Case A) |
| Pull Out | Students receive instruction in a separate room | Students took a pre-assessment in a separate classroom (Case C) |
| Small Group | Students receive instruction in a small group (3-5 students) in same room | Special educator worked with three students at a table inside the classroom (Case A) |
| Students Listen | Students access science content aurally | Students listened to lecture about density (Case B) |
| Students Read | Students access science content through text | Students annotated teacher created notes about meiosis (Case C) |
| Students Speak | Students communicate their ideas orally | Student explained how to convert a metric measure (Case A) |
| Students Write | Students communicate their ideas by creating text | Students wrote short answer to cracked ice question in notes (Case B) |
| Teacher Demonstration | Teacher presents a scientific phenomenon | Teacher used bed of nails to demonstrate relationship between area and pressure (Case B) |
| Teacher: Teacher Discourse | Conversation between co-teachers explains a phenomenon or concepts | Ms. Jones and Ms. Morgan talk about "bleeding the brakes" (Case B) |
| Vocabulary | Instruction directly focuses on learning the meaning of scientific terms | Students used notes and texts to complete vocabulary flipbook (Case C) |

# VI. Cited Literature

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# Kathleen Barabasz

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## Education

Ph.D. in Special Education (In Progress)
University of Illinois at Chicago

M.A. Educational Administration
Governors State University, University Park, IL

B.A. Elementary Education
University of Illinois at Chicago

## Professional Experience

2012-present Mentor-Resident Coach-AUSL
Coach pre-service teachers, new teachers, and mentor teachers; provide professional development; observe teaching and give feedback based on Danielson Framework

Summer 2012 Adjunct Teacher-National Louis University
Taught SPE 500 Introduction to Exceptional Children and Adolescents to students pursuing a master's degree in elementary education

2005- 2011 Mentor Teacher: 5th Grade Homeroom
Performed duties of a classroom teacher, mentored pre-service teachers through a yearlong teacher preparation and certification program

Fall 2010 Adjunct Teacher University of Illinois
Taught SPED 465, Cognitive Development and Disabilities, in a blended format to students pursuing a master's degree in Special Education.

2005 – 2009 Mentor-Chicago Public Schools National Board Certification Program
Mentored candidates in Early and Middle Childhood Literacy, led weekly cohort meetings

1993 – 2005 Teacher-Nathan Hale Elementary School
2001 – 2005 Teacher: 4th grade science
1998 – 2001 Teacher: Second grade self-contained
1993 – 1998 Teacher: Junior High science

## Presentation

2009 Council for Exceptional Children Teacher Education Division
TED Kaleidoscope poster presentation
"How do mentors working with resident teachers respond to hypothetical classroom situations?"

2018 Council for Exceptional Children Convention and Expo (anticipated)
Poster Session
"Supporting students with learning disabilities in inclusive middle school science classroom"

## Certification

Illinois Master Elementary
- NBPTS Middle Childhood Generalist
- Self-Contained K – 9
- General Science
- General Social Studies

Illinois Administrative Type 75
- General Administrative

## Professional Affiliations

The Council for Exceptional Children
- Teacher Education Division
- Division for Learning Disabilities