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Promoting Vocabulary Knowledge In Inclusive Science Classrooms: Comparison Of Instructional Methods

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PROMOTING VOCABULARY KNOWLEDGE IN INCLUSIVE SCIENCE CLASSROOMS:
COMPARISON OF INSTRUCTIONAL METHODS

By

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Bachelor of Science - Special Education
University of Nevada, Las Vegas
2012

Master of Education - Special Education
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ABSTRACT

PROMOTING DEPTH OF VOCABULARY KNOWLEDGE IN INCLUSIVE SCIENCE CLASSROOMS: COMPARISON OF INSTRUCTIONAL METHODS

by

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A sustained trend in the overall enrollment in the United States has seen classrooms reflect more student diversity. This diversity has included increased rates of participation in general education classrooms from both students from culturally and linguistically diverse backgrounds and students with disabilities. While the increase in student diversity in general education classrooms is certainly a positive step in increasing inclusive education, shifting student demographics have presented teachers with new and evolving instructional challenges. The diverse academic, cultural, and linguistic backgrounds students represent also come to characterize the unique learning needs teachers should address. This is particularly true in science, where recommendations and evidenced-based practices differ for different student populations (i.e., students with disabilities, students learning English).

As technology has become more mobile (e.g., personal computers, tablets) teachers are increasingly able to provide individualized instruction and supplement traditional classroom instruction with technology. While there is great potential for technology-based tools to provide flexible and personalized instruction that addresses the diverse learning needs of students, there is little empirical investigations that describes specific ways students interact with technology to
learn. To support the development of sound instructional technology, research that describes specific design elements and their impact on student learning is needed.

This study aimed to compare teacher-led and technology-based instructional interventions designed to teach students academic vocabulary in inclusive science classrooms. The vocabulary instruction delivered in the study was delivered by teacher-led instruction (TLI) or personalized mobile instruction (PMI) and oriented around specific inquiry assignments. Additionally, student and teacher perceptions of these interventions were collected through surveys. The results of this study suggest that teacher-led interventions that utilize evidence-based practices and personalized learning tools that are well designed can have similar impact developing students’ depth of vocabulary knowledge. Additionally, teacher and student perceptions of the helpfulness and impact on student learning did not differ between treatment groups, though teachers rated the interventions as more helpful and impactful for students’ depth of vocabulary knowledge.
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CHAPTER ONE

INTRODUCTION

Interest in preparing students to be fluent in science has continually increased as aspects of science and technology become more integral to daily life. Long-term research and development initiatives like *Project 2061* (Americans for the Advancement of the Sciences, 2009) and multiple science education reforms attempt to develop curricula and interventions to prepare young adults for a rapidly changing world driven by science and technology (National Research Council, 2012). Employment in the areas of science, technology, engineering, and mathematics (STEM) are outgrowing and replacing manufacturing jobs at higher rates than in previous decades, highlighting the need to prepare science literate individuals who can sustain the economic success of developed countries (Carnevale & Smith, 2011).

Unfortunately, when compared to other developed nations, the United States ranks 27th in student science achievement (National Center for Education Statistics, 2016). To address this underachievement in science, the *Next Generation Science Standards* (NRC, 2012) set forth a new vision for science education and the skills students should master to be considered science literate. This view of science literacy revolves around students' ability to acquire essential information from the core science areas (i.e., life, earth, physical) and subsequent application of this information in science and engineering practices to solve problems (Duschl, 2012). As part of a larger educational reform aimed at preparing students to be college or career ready (i.e., *Common Core State Standards*) the NGSS are designed to prepare students to be science literate and have the skills necessary to work in science related fields or pursue a science-based major in college.
Science Literacy Defined

Science literacy is a multifaceted construct that includes academic knowledge and the use of applied skills. To be science literate, it is not enough to simply know science, but rather be able to apply scientific methods to create new knowledge (Bybee, 2011; Lederman & Lederman, 2004). Specifically, the NGSS want students to engage in hands on activities, develop knowledge, and have a scientifically-based view of the world (Reiser, Berland, & Kenyon, 2012). Scientific literacy is the ability to use core knowledge in science and the application of these skills to ask questions using the scientific method to ultimately explain natural phenomena (Woodcock, 2014). To develop science literacy, models of science instruction suggest that students should first be able to engage with concepts through hands-on and applied experiences and explore scientific phenomena that are reinforced with traditional academic activities such as classroom discussions, lectures, or reading assignments (Brigham, Scruggs, Mastropieri, 2013; Bybee, 2011).

This view of science literacy is a shift from previous thoughts held by the science education community. Specifically, the NGSS (NRC, 2012) move away from previous standards that emphasized the memorization of factual science knowledge and the use of linear science inquiry, to a multidimensional view of science literacy (i.e., cross-cutting concepts, science and engineering practices, disciplinary core ideas) that focuses on a more relevant application of scientific methods in dynamic hands on activities (Krajcik & Merritt, 2012). This shift is meant to align with the skills that individuals in STEM fields require and to increase student achievement on standardized tests in science (Jang, 2016). Additionally, while not every individual will obtain employment in a STEM related field, increased scientific literacy provides
individuals with skills that enable them to come to informed decisions related to policy, being a wise consumer, and individual health and wellness (Marino & Hayes, 2012).

Science Instructional Models

Along with changes to how scientific literacy is viewed, the role of science in developing college and career readiness skills also has been a major focus of educational reform (Duschl, 2012). As part of a holistic framework for preparing students to be college and career ready in science, standards related to English Language Arts (ELA), speaking, and listening play a prominent role in the NGSS (NRC, 2012). While it has been suggested that students can learn science content without the use of text-based activities, focusing only on hands on activities may leave students unprepared for traditional science assessments, STEM careers, and postsecondary science education (Jang, 2016; Reed, Whalon, Lynn, Miller, & Smith, 2017). Outlined in the NGSS are standards related to reading expository text, communication, and collaboration. While typically reserved for ELA classrooms, these skills play an essential role in science instruction and in STEM fields (Jagger & Yore, 2012; Kaldenberg, Watt, & Therrien, 2015; Lee, Miller, & Januscyk, 2014). With the focus shifting from preparing students to memorize science content to engaging in scientific and engineering practices, the role of literacy in explaining and clarifying scientific phenomena cannot be ignored (Norris & Phillips, 2003).

Even as science education shifts to focusing on hands on activities to explore concepts, literacy, language, and discourse still play a large role in developing and expanding student knowledge (August, Artzi, & Barr, 2016; Jung & Brown, 2016; Weinburgh, Silva, Smith, Groulx, & Nettles, 2014). Built on constructivist learning theories, many science teachers focus on active student participation to gain experiences that facilitate learning (Mastropieri & Scruggs, 2007; Savasci & Berlin, 2012). Often this approach is built
around student engagement with a hands-on learning experience (e.g., labs) that build student curiosity and experience. This is later reinforced through literacy-based activities, classroom-based discussion, and lectures (Brigham, et al., 2013; Wilson, Taylor, Kowalski, & Carlson, 2010). However, the current reform in science education aims to increase relevance for students by aligning learning targets and classroom practices with college and career demands in science, current models of science instruction, and related standards (i.e., NGSS). Yet as this shift occurs, these changes can widen the achievement gap experienced by traditionally underperforming student populations (Brigham, et al., 2013; Johnson, Balshakova, & Waldron, 2016; Lee, et al., 2014).

**Trends in Inclusive Science Classrooms**

Increasingly, the student population in general education classrooms in the United States is becoming more diverse. This includes science classrooms in which students come from different backgrounds in terms of cultural and linguistic diversity (CLD), academic abilities, and disability status (Lee, et al., 2014). Science educators need to meet the diverse academic, social, and language needs of students. This includes students with disabilities who receive their instruction in general education environments (McLeskey, Landers, & Hoppey, 2012) and students learning English who represent the fastest growing student population in the United States (National Center for Educational Statistics, 2017). However, science educators often feel unprepared to meet the needs of an increasingly diverse student population (King-Sears, Brawand, Jenkins, & Preston-Smith, 2014; Lee, 2014). For general educators, struggles stem from language barriers, student lack of foundational science knowledge, and educator knowledge related to language acquisition and special education strategies (Cho & McDonnough, 2009; Jung & Brown, 2016; Kahn & Lewis, 2014).
Similar problems exist for special educators. In inclusive science classrooms, special educators often feel unprepared to teach science content, creating difficulties for general and special educators in the alignment of content, pedagogy, and co-teaching to best meet the needs of all students (King-Sears, et al. 2014; Kirch, Bargerhuff, Cowan, & Wheatley, 2007:). Ideally, teachers share the responsibility of identifying content to teach, deciding what instructional strategies to use, and sharing instructional responsibilities. Unfortunately, most observations of co-teaching pairs suggest that co-taught classrooms often mirror the typical Tier 1 instruction, where instruction is not differentiated for groups of students (Magiera & Zigmond, 2005; Scruggs, Mastropieri, & McDuffie, 2007; Vannest, Mason, Dyer, Brown, Maney, & Adiguzel, 2009).

With a main goal of the NGSS focused on ensuring all students are science literate, exploration of methods shown to be effective for diverse learners in inclusive science classrooms are needed (Jagger & Yore, 2013). As directed by the Every Student Succeeds Act (ESSA, 2015), these methods should be evidenced-based and shown to support student achievement. However, educators often find that evidenced-based practices identified for the various groups in science are difficult to implement within science teaching models (Lee & Buxton, 2013; Ryoo, 2014; Zwiep, Straits, Stone, Beltran, & Delgado, 2011). Issues then arise for educators related to the determination of when and how to provide instruction that supplements hands on activities that make content accessible and reinforce the science knowledge of all students in their classrooms (Brigham, et al 2013; Garza, Huerta, Lara-Alecio, Irby, & Tong, 2016).
Science Education for Students with Disabilities

General education science classrooms may be unaccommodating to students with diverse learning needs, leading to negative academic outcomes (Gottfried, Bozick, Rose, & Moore, 2016). For students with disabilities, contemporary science instruction may create multiple barriers to success through its emphasis on embedded literacy activities, inquiry-based learning, classroom discourse, and the intersection of learning from multiple content areas (Brigham, et al. 2013). While educators address these barriers, doing so in a way that aligns effective pedagogy for individual groups of students may prove to be difficult, due to the conflicting nature of recommendations in the literature for how science should be taught to different student populations (Mastropieri & Scruggs, 2007). These issues are compounded by a lack of effective co-teaching occurring in science classrooms, with many special educators feeling underprepared to teach science and often serving in assistance roles during the planning and implementation of instruction (McDuffie, et al. 2009).

Additionally, while students with disabilities often are successful in science classrooms grounded in hands on activities, they require a more structured and guided approach to learning science material (Mastropieri & Scruggs, 2007; Therrien, Taylor, Hosp, Kaldenberg, & Gorsh, 2011). This guided-inquiry approach involves activating student prior knowledge, pre-teaching essential skills, providing students supports and accommodations (e.g., graphic organizers, prompts, guided notes) while they engage in inquiry-based settings. This involves supporting students through coached elaborations so that students can describe scientific phenomena (Brigham, Scruggs, & Mastropieri, 2011; Scruggs, Mastropieri, & Okolo, 2008). This structured guidance of learning often detracts from traditional science instruction in which students independently explore concepts and build science knowledge. However, research
suggests that guided inquiry approaches facilitate the achievement of students with disabilities in science (Therrien et al., 2011).

Another significant barrier for students with disabilities in science is the use of expository text (King-Sears & Duke, 2010; Mason & Hedin, 2011). Often, text-based activities are used to reinforce understandings of key science concepts before and after inquiry-based activities (Kaldenberg, et al., 2015). Due to the text structure and high concentration of domain specific academic vocabulary words, students with disabilities often struggle to acquire foundational content knowledge presented in text (Botsas, 2017; Dexter, Park, & Hughes, 2011). This also has the adverse effect of making it difficult for students to participate in classroom discussions that further reinforce their knowledge (Brigham, et al., 2011). Rather, educators often rely on differentiated curricular enhancements and other strategies (e.g., mnemonic instruction, teaching text structure, graphic organizers) to help students acquire foundational content knowledge (Lumin & Polloway, 2017; Scruggs, Mastropieri, Berkely, & Marshak, 2010).

**Science Education for Students Learning English**

Like students with disabilities, students learning English can face multiple barriers to participating in science. The most discernable issue being that this population is trying to learn language in tandem with content. The increased focus on the use of discourse and other language intensive learning activities can amplify the struggles faced in science and alienate them during classroom discourse (Lee et al., 2014). While hands on-activities have the potential to engage individuals in novel learning experiences as they explore science concepts, struggling with language components (e.g., expository text, classroom discourse) of academic portions of science instruction can marginalize student interest and become a barrier to learning (August et al., 2016; Lee, 2005). Additionally, while students learning English can be successful
in science, effective approaches integrate specific language, vocabulary, and academic supports into the inquiry and instructional portions of science that support student acquisition of language and content in tandem (Bunch, 2013; Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Proctor, Dalton, Grisham, 2007). To meet these specific needs, effective instructional approaches often require that educators anchor their instruction to language objectives, provide students the opportunity to acquire and use new academic vocabulary, and provide guidance in accessing academic texts (Richards-Tutor, Baker, Gersten, Baker, & Smith, 2016; Silva, Weinburgh, Malloy, Smith, & Marshall, 2012). However, teachers often find embedding these activities and supports into science difficult when trying to deliver instruction to the multiple, diverse student groups in science classrooms (Jackson & Ash, 2012; Lee et al., 2008).

**The Role of Vocabulary in Science**

With the goal of science literacy (NGSS Lead States, 2013), it is important that effective methods for meeting the diverse learning needs of all learners be identified. This includes finding interventions that (a) are manageable for educators and (b) fit within contemporary models of science instruction. For students to effectively learn in science, they must be able to gather information from a wide variety of sources, including printed text. For students with disabilities and those learning English, spending instructional time supporting access to text can improve overall achievement in science (Shyyan, Thurlow, & Liu, 2008; Thurlow & Kopriva, 2016). One area of focus is the domain specific academic vocabulary that all learners use as an anchor to hands-on activities, text comprehension, and classroom discourse.
Problems with Vocabulary Approaches

Teaching science is a complex process that requires the teaching of a variety of content specific skills and knowledge. However, for students with disabilities, students learning English, and their teachers, the more structured and guided inquiry processes they require may be difficult to implement and contradictory to traditional science education practices rooted in the use of hands-on activities to explore science concepts (Cho & McDonough 2014; Rizzo & Taylor, 2016). Often providing different or enhanced curricula, aligned to the needs of individual groups of students, is very time intensive in terms of creating materials and establishing a scope and sequence of content delivery (Mastropieri et al., 2006). Additionally, there is debate as to when vocabulary instruction should take place in science for both students with disabilities and students who are learning English (Kennedy, Rodgers, Romig, Lloyd, & Brownell, 2017; Lee, 2014). While suggested models of science and language instruction support the approach of teaching core language and concepts prior to hands-on activities, others suggest that instruction be embedded as students explore science concepts (Krashen, 2013; Therrien et al., 2011). This often results in contradictory and confusing views on when and how to embed language in science instruction (Weinburgh et al., 2014). However, with the importance placed on the ability of students to understand and use content specific terms in science, more research is needed on effectively embedding vocabulary instruction in inquiry-based science instruction.

The Promise of Focusing on Vocabulary

It is understandable that science teachers and special educators cannot focus on literacy alone. However, to support the needs of all students, areas of instruction that have a high level of utility in supporting student success in science should be prioritized and embedded within other science instruction. Vocabulary is an area that is appropriate to pursue. For students
learning English, it is an anchor to participating in a wide range of curricular activities (i.e., reading, classroom discussions, learning language) to support their overall academic success (Gottardo, Mizra, Koh, Ferreira, & Javier, 2017; Richards-Tutor et al., 2016). Similarly, focusing on academic vocabulary aids students with disabilities in recalling key information, leading to success in inquiry-based science education, and accessing expository text (Kuder, 2017; Scruggs & Mastropieri, 2007; Therrien et al., 2011). This approach, when embedded in inclusive science classrooms, also supports the acquisition of academic vocabulary of general education students (Crevecoeur, Coyne, & McCoach, 2014). The existing research suggests that focusing on academic vocabulary can support the diverse needs of students in science. However, with many teachers feeling uncomfortable differentiating, teachers need tools, resources, and guidance to support the diverse academic and language needs of students in science (Jagger & Yore, 2012; Kahn & Lewis, 2014; Kennedy, et al. 2017).

The Role of Technology in the Classroom

An increasingly popular option for educators is the use of technology in the classroom to differentiate instruction (Xie, Basham, Marino, & Rice, 2018). As technology continues to advance, there is a call to use digital learning tools to individualize learning for an increasingly diverse student population (National Education Technology Plan, 2016). For both students with disabilities and students learning English, digital tools have been used as effective teaching methods in a variety of areas (Kim, McKenna, & Park, 2017; Macaruso & Rodman, 2011; Weng, Maeda, & Bouck, 2014). With the diverse learning needs of students in science, instructional interventions that are delivered digitally may serve the purpose of supplementing science instruction while supporting the individual needs of each student (Marino, 2010; Smith & Okolo, 2008). In a review of interventions used in science, Slavin et al. (2014) concluded that
technology-based interventions produced high levels of student achievement. In their conclusions, they maintained that technology provides the ability for science phenomena to be displayed as a concrete visual, rather than as an abstract concept.

However, definitions and methods for providing personalized learning tools are still developing in various areas of research and practice and the role of technology in tiered classrooms still needs to be defined (Basham, Hall, Carter, & Stahl, 2016). Included in the Every Student Succeeds Act (ESSA, 2015), Universal Design for Learning (UDL) is a common theme in the literature used as a recommendation for making science content more accessible for students with diverse learning needs (Marino, 2010; Marino, Gotch, Israel, Vasquez, Basham, & Becht, 2014; Price, Johnson, & Burnett, 2014).

**Universal Design for Learning**

UDL is an approach to the development of instructional materials that are meant to address the diverse learning needs of students in classrooms (Hall, Meyer, & Rose, 2014). With the goal being to provide students flexibility and options in their learning materials, specific guidelines for UDL focus on three areas: (a) how material is presented, (b) how mastery of material is measured, and (c) how materials engage and sustain student motivation in the learning process (Rose & Meyer, 2002). This includes accounting for the presentation of material to promote understanding across languages, clarify vocabulary, and ways to communicate understanding (CAST, 2011). UDL is meant to guide proactive approaches to student diversity, in which educators consider student needs and align teaching practices and materials to address barriers to learning prior to instruction (Meo, 2008). While it has been suggested that these practices can be implemented without technology, true personalized learning is delivered through the multiple presentation and input options technology provides (Edyburn, 2010; Smith &
Basham, 2014). However, to be sure that these guidelines are applied through technology-based tools appropriately, it is important to ensure they follow evidenced based multimedia practices. The principles outlined in Mayer’s (2009) Cognitive Theory of Media Learning may help provide guidance in developing universally designed tools that are backed by research. Adherence to these principles supports the development of tools that align to UDL tenets and ensure that the multimedia features embedded support student learning (Kennedy, Newman Thomas, Meyer, Alves, Lloyd, 2014). By applying the principles of UDL and embedding them into technology-based tools, teachers can supplement student needs in language and reading as they relate to science.

**Statement of the Problem**

Many teachers, both general and special educators, often struggle to meet the needs of diverse student populations in science (Kahn & Lewis, 2014; King-Sears et al., 2014; Lee et al., 2014). With data suggesting that most students struggle in science, particularly in the secondary grades (NCES, 2016), methods are needed to address the various needs of all students. This includes considering the linguistic and academic needs of both students with disabilities and students learning English. However, meeting the needs of these student populations in inclusive science classrooms can prove to be difficult (Helman, et al. 2015). For students with disabilities, a guided inquiry approach, in which concepts are pre-taught through explicit instruction, is considered best practice (Brigham et al., 2013), whereas for students learning English, recommendations are for concepts and language to be embedded within activities and reinforced after hands on experiences (Lesaux et al., 2011; Shyan et al., 2008)

Research indicates that science co-teachers find it difficult to integrate instructional practices to support diverse populations within the inquiry-based frameworks generally expected
in science instruction (King-Sears et al., 2014). This includes how these adaptations impact the scope and sequence of instruction. Therefore, many of the strategies students with disabilities and students learning English require are not integrated effectively (Brigham et al., 2013; Khan & Lewis, 2014; Lee et al., 2014). A promising solution to meeting the needs of all students is the use of technology designed to address learner variability by adhering to the principles of UDL (Hall, Cohen, Vue, & Ganley, 2015). This study was designed to compare the delivery methods (i.e., teacher-led, instruction delivered on personal mobile devices) of vocabulary instruction designed to support student participation in classroom discussions, text-based activities, and inquiry-based activities. Specifically, the study was guided by the following research questions:

Research Question 1: Is there a statistically significant difference in the depth of word knowledge of students with disabilities participating in treatment conditions compared to students in the control condition?

Research Question 2: Is there a statistically significant difference in the depth of word knowledge of students learning English participating in treatment conditions compared to students in the control condition?

Research Question 3: Is there a statistically significant difference in the depth of vocabulary knowledge of SWD and SLE based on the timing of their vocabulary instruction?

Research Question 4: Are there differences in teacher perceptions of student learning based on the treatment group they participated in?

Research Question 5: Are student perceptions of their own learning different based on the treatment group they participated in?

**Significance of the Study**
While teaching and learning in science is grounded in the exploration of science concepts through hands-on activities, text-based activities play a large role in preparing students and reinforcing concepts experienced during hands-on activities (Kaldenberg et al., 2015; Mason & Hedin, 2011). However, direct instruction of components of literacy are not often a part of instruction in general education science classrooms (Reed et al., 2016) and without this instruction students with the most intensive learning needs (e.g., students with disabilities, students learning English) will fail to make progress in science. Students enter science classrooms with large gaps in reading achievement and often require intensive reading interventions (Vaughn, Roberts, Schnakenberg, Fall, Vaughn, & Wexler, 2015). While teachers are tasked with covering large amounts of science specific content, this can be difficult without first addressing aspects of students reading needs. Recommended for many struggling readers, a focus on developing academic vocabulary can be an intervention targeting literacy for older students (Leko, Handy, & Roberts, 2017). This is particularly true in science in which texts are even more complex, and contain very content specific vocabulary, concepts, and theories in the upper grades (Mason & Hedin, 2011; Seifert & Espin, 2012).

Additionally, this study was designed to provide initial evidence that clarifies the most effective methods for embedding vocabulary instruction in science at the secondary level. Contradictions with how science educators, special educators, and teachers of English as a second language define the role of vocabulary and vocabulary instruction within science can prove to be confusing for educators in inclusive classrooms. This study attempted to clarify the most efficacious methods for addressing vocabulary instruction in science. This includes disaggregating the effects the timing of vocabulary instruction has on student
acquisition and use of terms, as well as responding to calls in the literature to clarify the effects of instructional tools aligned to UDL principles (Rao, Ok, & Bryant, 2014).

**Definitions**

**Academic vocabulary.** Terms or concepts that are not utilized in typical daily interpersonal communications but are instead used to convey specialized meanings in specific academic contents (Lesaux, Kieffer, Faller, & Kelly, 2010).

**Cognitive theory of media learning.** Theory that posits individuals have a limited capacity for taking in different sources of information through visual and auditory channels and that learning occurs when information is presented in a way that allows it to be filtered, organized, and integrated (Mayer, 2009).

**Explicit instruction.** Direct and systematic instruction that segments complex skills, highlights key content, and provides opportunities for frequent student input and feedback (Hughes, Morris, Therrien, & Benson, 2017).

**Expository text.** Text that is meant to inform readers about a topic and is structured to contain text, tables, glossaries, indexes, and diagrams.

**Guided inquiry.** An approach to teaching scientific concepts where teachers pre-teach key concepts to students prior to their engagement with independent hands on learning experiences (Therrien et al., 2011).

**Inclusive classroom.** Classrooms that serve students with disabilities, students learning English, and their English-speaking peers without disabilities.

**Instructional technology.** Technology and media used for the purpose of delivering instruction.
**Inquiry-based learning.** A learning process where students are provided a question to independently explore through hands on learning activities.

**Mobile device.** A portable device with computing power and access to the internet (e.g., smart phones, tablets, laptops).

**Personal mobile instruction.** A mode of instruction where students self-pace themselves through instructional presentations delivered through personal devices such as tablets or laptops.

**Students learning English.** Individuals who have limited English proficiency and are learning English as a second language. This includes students with emerging bilingualism, with limited academic and social skills in English, and are often referred to as English learners or English language learners.

**Teacher led instruction.** Instruction that is characterized by teacher guided lectures and student participation in paper-based notes.

**Universal design for learning.** A guiding framework to plan ways to present instructional content to students while providing multiple ways for students to remain engaged in learning and demonstrate knowledge (Rose & Meyer, 2002).

**Limitations**

The limitations to this study include:

1. The students sampled in this study came from a confined geographical area, limiting the generalization of the findings from the study.
2. The schools used in the study were chosen from a convenience sample. The findings may not generalize to other schools due to this sample.
3. This study looked at a component skill of literacy (i.e., academic vocabulary acquisition) and did not measure the overall impact this has on other aspects of literacy such as fluency, comprehension, and written expression.

4. While baseline equivalence related to student vocabulary knowledge was established, other areas of literacy skills were not measured and could potentially have contributed to student success in science.

5. The students identified as students learning English who participated in the study were not disaggregated into groups based on language proficiency, which may influence the findings of the study.

6. The students identified as students with disabilities who participated in the study were not disaggregated into groups based on disability status, which may influence the findings of the study.

7. This study only controlled a portion of the instruction that occurred during the 4-weeks of instruction the vocabulary instruction was built into, leaving the potential for incidental teaching of vocabulary to have occurred in classrooms.

8. Observations were not conducted on during all days with no intervention, leaving the potential for unaccounted vocabulary instruction to have occurred.

9. Small samples of the targeted student populations in this study were recruited, limiting the ability of the findings to be generalized and increasing the likelihood of a Type I or Type II error occurring.

10. While the lessons and materials in this study were implemented within the same portion of district assigned curricula and set of standards, implementation did not occur
simultaneously as the classrooms sampled in this research progressed through their curriculum at different rates.

11. A business as usual comparison group was not utilized in this study, therefore limiting the comparisons these findings have when compared to traditional classroom instruction.
CHAPTER TWO

REVIEW OF RELATED LITERATURE

Contemporary Science Education

Literacy in science requires individuals to be able to piece together and evaluate many sources of information to describe phenomena and solve problems. This approach is meant to align with current educational reforms aimed at preparing students to be college and career ready. In this case, this means preparing students for STEM majors or careers. However, for SWD and SLE, science can prove to be a difficult academic area with its dependence on math, complex texts, domain specific vocabulary, and cross-cutting concepts. With both student populations increasingly participating in general education science classrooms, identifying educational practices that work for these student populations and that can be delivered in a feasible way by teachers is imperative.

Approaches to Science Instruction for Students with Disabilities

In preparing students to be college and career ready, it is important that students be prepared with the skills that are required in STEM fields and entry-level college courses. In science, this includes preparing students to implement scientific methods and engage in inquiry that allow them to observe the world around them in scientific terms. A key to this is implementing inquiry based activities in classrooms that allow students to explore and engage with scientific phenomena. Teachers have a variety of inquiry-based models they can use to support student exploration of science concepts, but should pair those methods with instructional strategies shown to support student learning.

In a study that looked at how the scientific method could be taught to students with learning disabilities (LD), Mc Cleery and Tindal (1999) investigated how concept anchoring and
explicit instruction could support student investigation of scientific concepts. The purpose of this study was to measure the effects of explicit rule based instruction anchored around conceptual knowledge on student explanations of a scientific problem. A total of 57 students recruited from two general education classrooms participated in this study. This included 14 students with LD.

Two experimental conditions were utilized. A pull-away group/Period A, and the comparison group, Period B. In period A, most students received hands on constructivist instruction from their teacher, while 6 students who were deemed “at risk for failing science” by their teacher also received the pull-away instruction from a teacher who was trained to provide this instruction. This consisted of five sessions of 40 minutes each (over a 6 week period) where students were provided instruction by one of the investigators in explicit rule based instruction, that was supplemented by hands-on activities meant to support the application of the scientific method. In these sessions, each concept was taught explicitly and guided by a lesson outline that guided the construction of a scientific response and application of the scientific method through explicitly defined rules. Period A also had a separate experimental condition where the remaining students in the period (n=23; 6 girls, 17 boys, with 6 remaining receiving special education services) where all lessons but the final were taught by their teacher. The final lesson was taught by a volunteer teacher who had been trained to implement the explicit rule based instruction. Period B, the comparison group received their traditional classroom instruction, guided by hands on activities, and did not receive explicit instruction in rules or concepts. Additionally, use of concepts during instruction were measured during the intervention. Within 60 second intervals, teacher use of concepts related to the scientific method were measured. One hundred nine intervals were recorded for Period A and 19 occurrences were recorded with concepts being covered. In the pull away session, 84 intervals were recorded and 81 intervals
 contained concepts being covered. Observational data related to student engagement was also collected in Period A and the pullout group. This involved observing successive students in 10s intervals during instruction. In period A 1,243 intervals were recorded and 469 during pull away instruction. Engagement was measured as being active, passive, unengaged, or disruptive.

At the end of the 6-week period, a final lesson topic/experimental problem solving activity was given, “How does heat affect/change the molecular structure of various liquids?” All 57 students received this experimental problem. The problem was based around students using each element of the scientific method. The experimental forms by each student were then collected and coded. The scoring included receiving one point for including an explanation, and then qualitatively for the richness of their response, with three points available, one each for the inclusion of an explanation related to the three elements in the experimental prompt. In analyzing student responses, 100% of students in the pullout group included explanations in their lab report, 78% did so in Period A, and 35% did so in Period B. This is an increase from zero students including these elements in the pretest condition across all groups. From this, the authors concluded that the groups that received concept anchored and explicit instruction had significant differences in terms of quality of scientific explanations, had more exposures to concepts related to the scientific method, and had higher levels of engagement in class. However, the authors do note limitations in their study including: lack of a formal definition of “at risk”, only six students being included in the pull away group, a complex and unrefined treatment package consisting of many uncontrolled aspects of instruction, and a post measure only approach that does not compare equal groups.

An additional study conducted by Scruggs, Mastropieri, Bakken, and Brigham (1993) looked to compare the effects of textbook based approaches for learning to hands on learning
experiences in science classrooms. The purpose of this study was to investigate the use of textbook based approaches, inquiry based activities, with four classrooms of students with learning disabilities. Subjects included 26 students with LD in four junior high classes taught by one teacher. The authors report using a within-subjects crossover design. So, for one unit, two classes (i.e., one 7th grade, one 8th grade) received an activity oriented approach and a textbook based approach in successive units. The comparison groups would then receive instruction in the reverse order. In this experiment, each subject served as their own control, and differences between classrooms were controlled for through this design.

Two weeks of instruction were covered in this study. The first week was on electricity and magnetism and the second on rocks and minerals. The amount of material covered (i.e., vocabulary, concepts, time) were aligned as much as possible between conditions. Within the activities oriented sections, FOSS kits were implemented for Magnetism and Electricity Modules, and the Earth science Module. For the textbook based activities, students worked within a textbook that covered parallel content covered in the FOSS kits. The difference here being that students in the textbook activities were presented materials and examples, and students in the FOSS Kits were able to actually manipulate and observe the phenomena. Classes were stratified and assigned to receive the condition they would be placed into in the two weeks. Each condition received structured lessons (i.e., intro, review, guided practice, independent practice, assessment) during 50 minute periods. Instruction was delivered by two special education teachers who both taught textbook and activity oriented lessons during the study. In each unit, students received three days of instruction and a unit test on the fourth day, as well as one week after the last day of instruction for that unit. The tests included recall measures of students orally
stating everything they could recall from the week’s instruction and recorded on a response sheet. Then students would take a 24-item test.

Following instruction and during assessment settings, students were given the opportunity to let a recorder know everything they could recall about their instruction. Following this, they would be given a 24-item test that had equal numbers of vocabulary, factual recall, and application questions. Students would also take a delayed-recall test one week later. Scores on these tests were compared using a t-test. On both immediate and delayed recall measures, students mean scores were better when they were in the activity oriented condition. When compared through the t-test, student scores were not found to be significantly different in terms of their factual recall and application. For vocabulary however, significant differences were found. Surveys also revealed that students preferred the hands-on activities, with 25 of 26 students reporting a preference for them. The authors concluded that when appropriately structured, activity based instruction can facilitate acquisition of content by students with LD. However, the authors highlight that effective teacher led instruction can also be just as effective at aiding students in acquiring knowledge. Therefore, instruction should be balanced to meet instructional objectives.

In another study, McCarthy (2005) looked to compare the efficacy of hands-on activities to a textbook-based approach in science. The purpose of the study was to determine whether there were any differences in behavior and achievement of students with emotional behavioral disorders (EBD) who receive instruction in science from a textbook or activity-oriented program. Eighteen students with EBD from two self-contained classrooms in a partial hospitalization setting were recruited for the study. Students were assigned to the hands on or textbook based sections at the classroom level. Prior to the study, scores on initial measures of science
achievement (i.e., multiple choice, short answer, hands-on) did not indicate any significant differences between the students in either group.

In the textbook condition, students covered four chapters of content that included Properties of Matter; Matter and Heat; Changing Matter; and Mixtures and Solutions. The textbook was designed for 5th grade use. Each textbook lesson was taught by a classroom teacher and followed a teacher’s edition. Each lesson followed a general format with 5–10 minutes of review, a 10-minute teacher demonstration, 15–20 minutes of textbook reading and discussion, and 10 minutes of independent practice. All lessons were read aloud to students to prevent reading difficulties from influencing the effectiveness of the lessons. In the hands-on condition, previously developed hands on materials that were developed for students in grades 3-8 were used. These materials were previously developed by experts in science and special education. The topics covered were the same as those used in the textbook condition. Each of the activity-based lessons included 5–10 minutes of review, 30–40 minutes of students conducting experiments in groups of two or three while the teacher provided guided practice, and 5–10 minutes of review of the concepts and results of the experiments. The author described the differences in the treatments where the students in the hands-on group were manipulating materials and discovering new concepts in small groups, while the students in the textbook condition were passively learning concepts by watching the teacher, listening to the reading, and responding to questions both verbally and in written format at the end of the lesson.

Student classroom behavior in both settings (i.e., hands-on vs. textbook) was recorded. Teaching assistants were trained to chart, record, and describe individual student behavior via a classroom goal sheet during structured academic time periods. For each science lesson, the teaching assistants kept individual student records of behavior and work effort. The assistants
first transferred these scores to a data sheet that reflected the class’s earned points out of 100 total possible points. Levels of behavioral infractions were coded into three levels. Level 1 infractions involved: cursing; refusal to work; instigating; and engaging in negative attention-seeking behaviors. Level 2 infractions included: rude or obscene gestures and/or verbalizations; disrespect; lying; stealing; continuous disruption; insubordination; and throwing materials. Level 3 infractions: physical or verbal aggression toward peers or adults and leaving class or building. Specific behaviors that were of special concern or interest were those that were positive (e.g., participation, on-task, effort, and cooperation) or negative (e.g., defiance, off-task behaviors, and poor social interactions with their peers or their teacher). Scientific knowledge was measured using one of three pre–post assessments: multiple choice, short answer, and hands-on activities. Four experts in science education pertaining to test development and adequate representation of science concepts in each of the respective tests reviewed content validity. The multiple-choice test consisted of 16 items, each with four possible choices. There were 20 short-answer questions that were scored on a 0–2 scale. Students were given directions to carefully listen to the question and then to give their best possible science answer for each question. A score of ‘‘0’’ indicated that the answer was wrong. A score of ‘‘1’’ was given for a simple explanation, and a score of ‘‘2’’ was given for a scientific explanation. The hands-on assessment format consisted of two performance-based assessments. In the first task, the students were instructed to change an ice cube in as many ways as possible using the materials in front of him/her, such as a hot plate, pan, and hammer. During the second task, the students were instructed to show that air has weight and takes up space using some of the materials presented such as a balloon and scale. The examiner scored one point for each way of completing the task correctly, though there was no predetermined amount for this.
To compare the effects of the interventions a multivariate analysis was conducted. The within-subject factor or dependent measure was achievement with three levels: hands-on, multiple choice, and short answer. Univariate tests were conducted to determine group differences on the three individual measures. The between-group factor was type of teaching method with two levels: hands-on and textbook. Overall, students who received instruction in the hands-on condition performed significantly better on measures of achievement than the students who received textbook instruction. On the multiple-choice measure, there were no significant differences between the students in the hands-on condition and the textbook condition. Students who received instruction in the hands-on program performed significantly better than the students who received instruction in the textbook condition. Students in the hands-on portion increased their scores 21 points on average from pre to post tests, while the textbook group averaged an increase of 4.7 points. Overall, the students in the hands-on instructional condition performed significantly better than the students in the textbook condition. Student Behavior Scores recorded for student behavior were not statistically different between the conditions. The authors do suggest that anecdotal reports from the teaching assistants suggests that students in the textbook condition required slightly more teacher attention and direction than the students in the hands-on condition, though they did not lose points in terms of their behavioral records. The author concluded that students with disabilities can master concepts in science that are usually taught in regular science classrooms when hands on activities are appropriately implemented. While students performed as well on MC measures, students who had received hands-on instruction far outperformed those in the textbook based instruction in their ability to apply scientific knowledge.
In a study that looked to compare multiple methods of direct instruction to teach science facts to SWD, Mastropieiri, Scruggs, and Levin (1986) compared direct instruction to mnemonic strategy instruction. Two studies were used the first with students with LD and the second with students with intellectual disabilities. The results from the first study that included 56 students with LD are included in this review. To compare the instructional methods, these students were divided into 12 groups, with six groups each assigned to direct or mnemonic instruction.

The lessons that were implemented as part of the study taught mineral hardness levels of 17 minerals in either a mnemonic based instructional setting or in a direct instructional setting. Six groups of students were randomly assigned to the treatment (mnemonic instruction) or control groups (direct instruction). In mnemonic instruction groups, students were taught a keyword-pegword mnemonic technique for learning the hardness level of 14 minerals. Students were taught rhyming pegwords for hardness level (1-10). This was accomplished through the use of displaying a card that had a pegword (one associated with the mineral), the picture of the pegword, and its rhyming number on one side. On the corresponding was the mineral and its actual word on the back used for corrective feedback as necessary. Students were then taught how to relate the pegwords and pictures to recall mineral information (e.g., remember box means bauxite, and buns means one. So, a box of buns tells you the mineral bauxite has a hardness of 1). Students in the direct instruction conditions were provided direct and explicit instruction that presented them with minerals and their hardness levels, as well as multiple opportunities to recite and recall this information through teacher led activities. This included seeing a picture of a mineral that was labeled with the mineral name and number. Then students were presented the picture and name of the mineral on a card with the number on the back for feedback purposes.
This process took place for sets of 5 minerals and then 10 when those were mastered, and finally all 14.

Following the mnemonic or direct instruction (DI), students were asked to write the hardness level of the 14 minerals that the experimenter called out. Students recorded their responses on lined paper. For the mnemonic groups, recall of the 14 hardness levels were 12.6, 12.6, 11.8, 11.4, 10.8, and 8, with an average of 80% recalled. For the DI groups it was 8.7, 8.0, 7.7, 6.0, 6.0, and 5.6 for an average of 50%. With the small sample size, a two-sample permutation test was run that resulted in a significant difference suggested between the two methods. The authors concluded that mnemonic instruction tailored for small group instruction supported higher fact recall of science content for high school students with LD.

A study conducted by King-Sears, et al (2014) looked at the effect of direct instructional practices and learning materials aligned to the tenets of UDL had on the learning of chemistry concepts by students in inclusive science classrooms. The purpose of the study was to investigate the effects of a universally designed curriculum in science on students with high incidence disabilities and students without disabilities. Students and teachers from four co-taught chemistry classes participated in the study. Students from these classes were assigned to a UDL condition and a comparison condition.

Classes assigned to the UDL conditions were provided materials designed by the researchers. Four types of materials made up the UDL Modules. These included video clips of the science material covered, a self-management strategy (IDEAS) with guided practice workbooks, laminated strategy sheets with key elements of information needed (periodic table and an example of how to solve a problem), and answer sheets for students to check their work. While all classes were co-taught, special education teachers lead instruction in both groups. Prior
to implementation, all students were pretested on the material to be covered. For the UDL instruction, teachers were provided an 11-step script to be followed for three days of instruction. This included modeling of the self-management strategy, and when to utilize the student workbooks. Across the three days, teachers were instructed when to play the video clips, and when to pause them to allow students to complete their mole-conversions in their workbooks. Students in the comparison groups received instruction as their teachers traditionally taught it. This varied across settings, teachers, and schools.

To measure the effectiveness of the interventions, three equivalent versions of Mole Conversion Tests were developed by the researchers. A different version was used as the pre-, post-, and delayed measure. Each test contained five mole conversion problems, using a rubric to score student answers. Students were required to show their work for the conversions, with the rubric weighted to reflect the work students showed in solving each problem. A total of 153 points was possible for the pre-, post-, and delayed measures. Interrater Agreement was collected for scoring on each, with 99%, 98%, and 99% agreement reported for each. Students in the UDL treatment also completed a social validity questionnaire that contained Likert Scale and open ended questions. After the last day of instruction, students completed a post-test. Four weeks later, students took a delayed-post test.

A 2x2 ANOVA was run to compare UDL versus comparison and general education students versus SWD. On post test measures, there were no significant differences found for condition. However, there were significant differences found for population and a significant interaction effect between condition and population. Students with disabilities in the UDL condition outperformed students with disabilities in comparison groups; general education students in the UDL condition performed worse than comparison. On the delayed test, there were
no significant differences for condition, but significant results for population and an interaction effect between condition and population. Student results were similar to previous research findings, where SWDs felt they learned better from UDL materials. Results suggest that each type of instruction proved to similarly effective for SWD, though ES suggest that the UDL interventions were effective at increasing post and delayed test scores of SWD.

Mastropieri and colleagues (2006) looked at the effects enhanced and tiered materials had on the performance of students in middle school science classrooms on classroom and high-stakes tests. The purpose of this study was to determine: (a) whether differentiated curriculum enhancements relevant to the study of scientific materials could be created for inclusive eighth-grade science classrooms, (b) if these materials could be implemented in a classwide peer-mediated format, (c) whether this implementation would increase classroom and high stakes test scores, and (d) if students enjoyed the materials and if they improved their attitudes towards science. In total, 13 sections of science classrooms were recruited, and represented five inclusive classrooms, two segregated classrooms, and six general education only classrooms. A total of 213 students participated, including 37 students with LD and seven with EBD.

Both conditions used the same textbook and high stakes assessment adopted by their state to guide content instruction. Materials were differentiated for 8 activities covered as part of the assigned science curriculum. Materials in the control condition consisted of teacher lecture, class notes, labs, and supplementary textbook materials. In this condition teachers led all instruction. This condition revolved around daily reviews, presentation of new content, guided/independent practice, and lab activities. In this condition, students took notes, completed worksheets, and performed lab work. In the intervention condition, leveled materials were made for use in the classroom. For each area, three levels of materials were created. Each level was represented by
the different color folder they were in. Yellow for level 1 (required the identification of science concepts from an array of alternatives and contained supports and prompts to assist students), level 2-blue folder (required production responses of the information and had some prompts to assist students), and level 3-red folder (required responses, but provided no prompts). In this condition, teacher led content instruction was identical to those presented in the comparison group, but the time spent on worksheets was instead spent having students work in groups of 2-3, based on teacher assignment of ability levels, on the differentiated science materials. Teachers also assigned the levels of materials students were to work on. All students were directed to work on the assigned materials and worked towards proficiency at all levels.

Measures of science content and attitudes toward science were developed for this study. These measures included pre and post measures that were made to measure science content, and consisted of a 34-item multiple choice tests. End of year high stakes tests were also used as data points. For students in the treatment group, an eight item survey was administered to measure student attitudes toward specific instructional activities.

Posttest data were run through a 2x2 ANCOVA with posttest data compared between treatment and control groups and students in general and special education. Pretests were used as covariates, and classrooms nested as a nested factor within condition. Effects for condition were considered significant. The effects for group and condition by group were not statistically significant. Effects for classroom nested within treatment were also not considered significant. High-stakes test data were entered into a 2x2 ANCOVA with pretest as a covariate with classrooms as a nested factor within treatment, which yielded significant effects for condition, and for group. Condition by group interaction effect was not statistically significant. Students reported neutral feelings towards the implemented activities, and reported greater interest in
game like activities. Teachers reported liking the experimental materials, and found them to be valid and helpful for learning. Most felt the materials increased student learning, though reported it was difficult to find time to implement the materials. The authors report that the use of curriculum enhancements that are peer mediated can increase S performance on classroom and end of year high stakes tests. The findings suggest that in inclusive environments, students can work with their peers collaboratively to learn and apply science content.

Rogevich and Perin (2008) conducted a study to discuss the effects of a reading comprehension intervention on the summarization of science content. The study was designed to measure the effectiveness of the think before reading, while reading, and after reading (TWA) strategy for students with behavioral disorders. Participants included students with behavior disorders aged 13 to 16 who are attending a long-term program for students with behavior disorders.

Students were assigned to treatment or comparison groups based on matched sampling where students were placed in the group based on their IQ age and reading level with similar students placed in the opposite group. Students were placed in four groups: students with behavior disorders receiving the intervention, students with behavior disorders and ADHD receiving the intervention, and the same groups in control conditions where students received literacy instruction as usual. The study of 13 passages, twelve related to science and one related to social studies from fourth grade text. Students in the intervention phase were taught the nine steps in the strategy through five sessions of instruction. these lessons focused on the three phases (i.e., before, during, and after reading). Students in the comparison condition received additional instructional time and sessions and given passages to read and engage in brief group
discussions using the same text. Students were then instructed to write a summary at the end of each section.

Following the intervention, five written summarization assignments were collected at pre-test and post-test as well three transfer and maintenance tests. For these assessments students had to read a passage and create a summary of it. Rated on scoring rubrics by multiple raters. the scoring rubrics were created by the researchers and included a list of all key facts presented in the passage. Soon to receive points for fully supporting the idea partially supporting the idea or not mentioning it all. A repeated-measures multivariate ANCOVA was used to compare the four intervention groups on all four outcome measures (post-test and transfer tests). Intelligent quotient scores, reading ability, and age served as covariates. Results from this included significant differences between groups so no interactions. student to and receive the intervention score better on all four post-test and transfer tasks, and student behavior disorders and students with comorbid ADHD who received the intervention did not differ in their scores. The results of the study suggests that additional components need to be added to strategy instruction running to support the comprehension and summarization of science material by SWD.

**Instructional Approaches in Science for Students Learning English**

Helman, et al (2015) conducted a study that looked at improving the science vocabulary of SLE with reading disabilities. This study investigated the effects of a combined contextual and morphemic analysis strategy to increase the acquisition of science vocabulary words by three high schools identified as SLE with reading disabilities. A multiple baseline across participants design was used. Intervention included student use of the clue word strategy and dependent measure used examined the use of the clue word strategy, morpheme, and reading comprehension of science materials. Each student was given a vocabulary binder that contained
the following sections: (a) three CWS graphic organizer sheets for each lesson, (b) a sheet containing the list of CWS steps, (c) answer key sheets, (d) guided note sheets for the pre-training lessons, and (e) blank note sheets. During Baseline procedures students completed a minimum of three clue word strategy probe they received every other day. For the intervention phase, students were taught the clue word strategy strategy. The strategy involves the following steps: (a) read a sentence with a target vocabulary word, (b) look for context clues that surround the unknown word, (c) re-read the sentence, (d) write the target vocabulary word, (e) break the vocabulary word into its morphemes (i.e., prefix, suffix, root), (f) write the meaning of each morpheme, (g) predict and write the meaning of the targeted science word, and (h) check the dictionary or the answer key sheet for the correct meaning. Students participated in 45-min clue word strategy instructional lessons over three weekly sessions.

Clue word strategy probes, were administered to each student during baseline, intervention, and maintenance phases. Each probe included one sentence with an unknown science vocabulary word and a clue word strategy graphic organizer. Science words with common Greek and Latin roots were used during clue word strategy instruction and for assessments. Based on the science (e.g., biology and life science) curriculum, 50 roots were selected from biology texts and curricular sources. The TORC-4 was also administered prior to and following intervention to see if the strategy had any effect on reading ability. Measures of strategy use were also included in the study and measured how many steps students correctly completed using the clue word strategy.

Based on the results presented in the multiple baseline design, from baseline to intervention there were immediate increases and sustained increase in overall strategy use (i.e., morphemic analysis), written strategy knowledge (i.e., writing down the steps of the strategy),
and oral strategy knowledge (i.e., retelling the strategy steps). Mixed results were noted on the

test of reading comprehension with two students increasing their abilities and one student
decreasing across all five subtests. The authors concluded that the study provides initial support
for the use of strategy instruction support students analysis of science morphemes and breaking
down unknown science terms.

In another study, Llosa, et al (2016) investigated the impact of a large-scale science
intervention (i.e., P-SELL) that focused on providing support for SLE. The focus of this study
was to measure the impact a science curricula paired with teacher professional development had
on the language and science learning outcomes of SLE. This study included 123 teachers who
were assigned to the treatment group and 135 who are assigned to the control group. A total of
6,673 students were recruited for the study as well. Student participants were classified into four
groups: (a) English Language Learners (ELL) who receive instruction through English for
Speakers of Other Languages (ESOL) programs, (b) recently reclassified ELLs who had exited
ESOL programs within two years and are monitored for a two-year period, (c) former ELLs who
had exited ESOL programs over two years ago, and (d) non-ELLs who had not previously
received ESOL services.

The treatment package (i.e., teacher professional development, science curricula)
incorporated student curricular materials and teacher development materials. Teacher
components included a comprehensive teacher’s guide and professional development workshops.
The teacher’s guide was designed to assist teachers with the implementation of the curriculum
and strategies that support SLE. This included explanations for teachers for how the curriculum
promoted student mastery of science standards and the role of inquiry into facilitating students
understanding of science. Additionally, for each chapter in the curriculum, the guide provided
science background information explanations for the concepts under investigation, and provided teachers content specific teaching strategies for each topic. This included language development strategies for science learning for SLE in particular. The teacher workshops focused on developing teacher science knowledge in teaching practices that promoted the use of scientific inquiry in classrooms that also supported English language development. Workshops were offered during the summer prior to the school year and throughout the school year for participants in the P-SELL condition. Teachers were also given time for collaborative planning to develop goals, share materials, and exchange ideas. The ultimate goal these workshops was to familiarize teachers with science standards and assessments, hands-on inquiry activities, science content, and language development strategies. The student components of this intervention included a comprehensive standalone year-long fifth grade science curriculum. This curriculum includes student workbooks, science supplies, and supplementary materials provided on a website. The curricula was meant to be standards-based and inquiry focused for all students, with special features provided for SLE. The curricula covered 18 big ideas based on four bodies of knowledge in science, including the nature of science, Earth and space science, life science, and physical science. Additionally, the curriculum focuses on inquiry oriented activities that support science learning and the development of scientific thinking. Student books were designed to follow a progression from teacher lead to student initiated inquiry. Finally, special considerations for SLE are included by providing guidance and scaffolding for English language development. This includes starting chapters with key science terms provided in three languages. Then introducing these concepts and terms by connecting them with students prior knowledge or experience through the use of multiple representations in textual and graphic format. The end of
each chapter includes summarizations of key concepts in multiple languages with multiple online resources meant to support language development provided on a supplementary website.

Across three school districts, 66 elementary schools were randomly selected to participate in the study. In the recruited schools, all fifth-grade science teachers and their students in the participated in this study. These classrooms were split into treatment and control conditions, with 33 schools in each condition. This included a total of 258 teachers and 6673 students. Across a year of instruction, the participants either engaged in the P-SELL curriculum and professional development or conducted instruction as business as usual.

For the study, student science achievement was captured through two measures, researcher developed science assessments and state standardized science assessment. State assessments were given only once at the end of fifth grade and researcher developed assessments were used as pre-and post-measures. The researcher developed assessments were composed of public release items from the National Assessment of Educational Progress (NAEP) and the Trends in International Mathematics and Science Study (TIMSS). Each assessment had 25 multiple choice and three short answer response items that covered Earth and space science, life science, physical science, and the nature of science. For the short answer response items, a NAEP rubric associated with each question was utilized by the research team. The state science assessment covered the same for bodies of science knowledge, and included 60 multiple-choice items administered over the course of two days in 80 minutes sessions at the end of the school year.

To evaluate the impact of the P-SELL intervention, hierarchical linear models were established with condition used as a dummy variable in pre-test scores as a covariate. The data was organized into three levels with students at level one, their teachers at level two, and school
sites at level three. An initial analysis suggested that students identified as ELLs had the lowest mean scores on post measures, followed by ELLs who had recently been reclassified, and ELLs exited from ESOL programs scoring slightly higher than non-ELLs. Utilizing the three level model, the researchers reported they found significant and meaningfully sized average intervention effects on both the researcher developed assessments and the state science assessments, indicating that students in the treatment group outperform students in the control group on both measures. Further subgroup analyses were based on language classification and revealed that the P-SELL had significant and meaningfully sized effects for all language groups, again suggesting the treatment groups outperformed the control groups. Intervention effects were not statistically significant however for students classified as ELLs. These results suggest that a large-scale science curriculum with embedded supports for SLE can support the development of science knowledge for students with a wide variety of language proficiencies, particularly when teachers have training and materials that support their instruction.

In another study, Lara-Alecio, et al (2012) investigated the impact of an intervention on the science and English reading achievement of SLE in middle school. The researchers utilized a quasi-experimental design in this study, with the purpose to evaluate the effectiveness of a literacy integrated science intervention on the reading outcomes of SLE on high-stakes state assessments. This study was derived from a larger longitudinal field-based project and followed students from the fifth to sixth grade. In total four intermediate schools were recruited for the study and were assigned to treatment or comparison conditions. With assignment at the school level, teachers from each site were assigned to conditions. In all, a total of 12 teachers and 246 students were assigned to treatment and control conditions.
The intervention utilized in the study included two main components. The first component was a teacher professional development that included ongoing training workshops for teachers and their instructional assistants that were provided by research coordinators across multiple sessions. During these training sessions teachers reviewed and practice upcoming lessons, discuss science concepts, reflections of student learning, assessing pedagogical progress, conducted the required inquiry activities for their interventions, and were provided instruction for ESL strategies that included question strategies, and language scaffolding, visual scaffolding, the use of manipulatives and realia, and integrating technology. To support implementation teachers were also given scripted lesson plans during the sessions. The second component and this intervention included the instructional activities used in treatment classrooms. These included 85-minute daily science lessons that followed a general routine of daily oral and written language in science activities, warm-ups, in academic sequences that followed a 5-E instructional cycle. The cycle typically included an engage activity that garnered student interest in science concepts, an explore activity that had students working groups to explore science content, an explain activity where students gained deeper understanding of science concepts through direct instruction of science vocabulary, an evaluate activity in which students used science journals to demonstrate their understanding of concepts, and an elaborate activity that allowed students to extend their learning of concepts through additional activities. A major component for these activities focused on developing student science vocabulary and extending their science related knowledge through the use of expository text. To make this possible students were provided direct instruction in vocabulary that included the pronunciation of the words, student friendly definitions, and visual scaffolding. This instruction occurred before reading to support students understanding of text. Additionally, students were provided science journals in which they could
use their new science vocabulary in writing and were structured so that students could have multiple opportunities to make observations, label scientific diagrams, organize information, record vocabulary, and develop writing skills in science. In addition to the instructional components of the intervention, students were also provided enrichment opportunities in which students in treatment classrooms were provided additional technology supports for teachers to use to implement the augmented science curricula used in the study. Following the implementation of the study materials, a battery of assessments forgiven the student participants to measure the effectiveness of the intervention. These included criterion-referenced district benchmark tests that determine if a student passed or met standards administered in 6-week intervals, state standardized tests, the Dynamic Indicators of Basic Literacy Skills (DIBELS), and fidelity measures to ensure Science teachers were implementing interventions appropriately.

Utilizing chi-squared tests in their analysis, the researchers reported statistically significant differences in the percentage of passing scores on district benchmark assessments in science, with significantly more students passing in the treatment group. However significant differences were not identified on the state assessment. Similar to the benchmark assessments in science, students in the treatment group perform significantly better on benchmark assessments in reading then did students in the control group. Finally, an ANCOVA that utilized pretest scores as a covariate, indicated that on the DIBELS assessments, all students demonstrated significant growth from beginning to the end of the school year in literacy skills, a statistically significant difference was observed between student in the treatment group and students in the control, with students in the treatment outperforming students on the control on the post-test measures. The findings from this study suggests that well-crafted science curriculum can meet the needs of diverse learners, and support learning outcomes in both science and literacy.
Another study focusing on methods that support science achievement of SLE, Ryoo and Bedell (2017) looked to explore the effects visualizations of content hat on student understanding of science concepts. The study explored the effects of interactive dynamic and static visualizations on student understanding of abstract energy and matter of transformation concepts in life science. This research utilized a mixed-methods approach with quantitative data collected to discuss the impact of each intervention and qualitative data used to describe how students make sense of the science content covered in the study. Sixteen classrooms taught by four teachers at two schools were recruiting for the study and assigned to use either dynamic or static visualizations in their instruction. Overall 331 students in seventh grade were included in the research, including 154 students learning English.

As part of the research, students were paired to work through the online inquiry assignments in this study. These pairs included one students learning English and one native English speaking student. Students in dynamic and static conditions completed web-based inquiry projects as part of the regular science instruction across two weeks. The only difference between the two web-based inquiry projects between the conditions was whether these projects utilized dynamic or static visualizations when learning about energy or matter transformations. During the inquiry and instruction aligned with this project, students in both conditions explored how energy and matter interact and transform during biological processes. Other than differences in how molecules and energy move through the visualizations, students were provided with identical information in the dynamic and static visualizations. The authors report developing these visualizations based on previous research done with multimedia learning tools and effective instructional practices for SLE. Each condition was meant to provide interactive learning supports and allow students to self-pace themselves through the modules and
visualizations. The dynamic visualizations provided continuous animations that explicitly showed Energy transformations that occurred during chemical reactions while the static conditions included and still pictures of the same content. Across both conditions, 17 pairs of students were videotaped during the study to capture how they reasoned with and understood matter transformations. Students in both conditions spent the same amount of time working on each unit.

Prior to the study all students completed online pretests. Pretests included six open ended items aligned with the instruction provided. These items tasked students with integrating their ideas of energy, chemical reactions, and transformations into specific biological processes. Researchers utilized a developed rubric two scores do not ideas and answers. Scores ranged from no answer and a score of zero to advanced complex answers linking ideas and a score of six. The same items were used as post measures following the study. For the 17 pairs of students, the video tape sessions of students working through the content were also analyzed. These videos were collected through webcam recordings and screen capturing technology. These videos were reviewed and fully transcribed. Two researchers then independently coded all 34 transcripts.

To compare student performance across conditions and measures, a 2x2 ANOVA was conducted. The results of this analysis suggests that a significant effect across time was evident, suggesting that students benefited from both types of visualizations and a significant effect was found for condition, with students participating in dynamic version being able to better describe the processes of matter and energy transforming on open ended questions. In the qualitative analysis that described how SLE made sense of science content using the visualizations in pairs, it was noted that hairs who participated in the dynamic condition Took more turns to interact and engage in discourse with their partner then students in static condition. This includes increased
student activity engaging in discourse that was focused on specific science content. This suggests that the use of dynamic visualizations can create situations and learning environments where students engage in increased academic discourse with their peers. The findings of this research suggest that interactive visualizations, either static or dynamic, can improve science learning for SLE and their peers, though dynamic visualizations can support increased classroom discourse and an improved Scientific understanding and learning outcomes.

**Integrating a Variety of Approaches to Support Diverse Learners in Science**

Combined, the literature describing effective science practices for SWD and SLE highlight multiple important instructional practices and considerations. Most importantly, this combined research suggests that both groups of students can be successful in both direct instruction and inquiry-based approaches to science. What this research suggests is that teachers who are provided training or professional development in implementing instruction that is tailored to address specific elements of student needs (i.e., language, academic) can significantly influence the learning outcomes of all students. Additionally, the role of tools and curricula that are aligned to student needs are highlighted as critical in supporting student outcomes. As demographics in inclusive classrooms continue to shift, the proactive planning and development of curricula responsive to the needs of SWD and SLE will be critical for the success of teachers and students in inclusive classrooms.

**Content Area Vocabulary Instruction for Diverse Learners**

A common thread across both student groups (i.e., SWD, SLE) and instructional formats (i.e., direct instruction, inquiry, combined) in science is the role academic vocabulary has as an instructional component in interventions tailored for the diverse learning needs of these populations. However, considering their intensive learning needs, it is important to identify
elements of instruction that support the development of academic vocabulary for SWD and SLE. Specifically, common elements of vocabulary instruction that can be delivered as a Tier I intervention should be identified. Additionally, the impact these interventions have on student reading outcomes and access to other content area instruction are important to understand.

Teaching Vocabulary to Students with Disabilities

A study conducted by Seifert and Espin (2012) investigated ways to improve the reading of science text by SWD in high school. The purpose of the study was to examine three comprehensive types of reading interventions on science text comprehension of students with learning disabilities. These interventions looked at the effects of text reading, vocabulary learning, and combined approaches to instruction on reading outcomes. Twenty 10th grade students with learning disabilities participated in the study.

Three different instructional approaches were utilized in this study. Text reading, vocabulary learning, and text reading plus vocabulary learning. The design employed in this study was a within-subject design in which each student participated in four conditions (i.e., three intervention and one control condition). The text reading intervention began with a word recognition activity. 10 vocabulary words were selected from the passage and rehearse with students. Following this activity students completed a read-aloud activity reading a passage from a textbook. Students read the passage aloud for five minutes while the instructor recorded errors. At the end of the 5 minutes the instructor pointed to and read aloud any word that had been read incorrectly and the student repeated the word in isolation. After this, the student would read the passage again for five minutes. The vocabulary learning condition began with a word definition activity. Ten words were selected for the vocabulary learning condition in the same manner as those used in the text-reading condition. The student was shown each word one of the time while
the instructor read the definition. students were asked to repeat the definition as best they could. following this the instructor would read a sentence with the word in it. Student then repeated the sentence followed by responding to two probing questions provided by the instructor. if the students cannot answer the question the instructors provided the answer in the student repeated it. In the combined condition (i.e., text reading plus vocabulary) Students completed the word recognition activity, completed the vocabulary activity, and then read the passage. In the control condition, students read the passage, took a vocabulary measure, and then a comprehension measure. No additional instruction was provided.

Reading fluency was measured using the passages from the textbook that students read. A multiple choice assessment for each passage was used as a means for measuring comprehension. Vocabulary was measured using a matching activity where students matched terms and definitions. Analysis was conducted using multiple one way ANOVAs for each of these areas. Students read significantly more words in the text and combined approaches than the vocab only and control, and the vocab approach performed significantly better than the control group as well. Repeated measures ANOVA that were run suggest that vocabulary matches were significantly higher in the vocab condition and combined approach than the text only approach and control. Text only and control were not found to be significantly different on the measures included in this study. The authors concluded that specific treatments (i.e., text reading, vocabulary) were effective at increasing the elements their treatments revolved around. The authors support a combined approach, however, with more intensive interventions focused on vocabulary and reading occurring separately. This claim is supported by other findings that text reading alone is not enough to support comprehension of science material.
In another study, King-Sears, Mercer, and Sindelar (1992) compared multiple instructional methods impact on the recall of science definitions. The major purpose of this study was to compare the science vocabulary definition recall of students under three treatment conditions: (a) systematic teaching, (b) systematic teaching with teacher-provided keyword mnemonic, and (c) systematic teaching with student-provided keyword mnemonic. The subjects for this study were 30 students with LD and seven students with EBD in the sixth, seventh, and eighth grades. The authors describe students across grade levels as not being significantly different from one another on intelligence and achievement tests, outside of IQ. Three teachers in each grade level provided the intervention in a RR. Each teacher taught two classes, with each having one randomly assigned as treatment and control. All students were taught the same four units of 12 vocabulary words (total of 48 words) each week over a period of 4-weeks. The authors report six controls for the instructional components of this study: (a) all students spent the same amount of time learning the terms and definitions; (b) all students were taught by their special education classroom teacher; (c) the same words were used for all conditions; (d) all students were assessed in the same manner with identical materials (and teacher directions as given in teacher scripts) for daily quizzes, weekly written tests, and weekly matching tests; (e) effective teaching techniques and teacher behaviors, described in this study as systematic teaching, were used in all conditions; and (f) all teachers followed scripted lesson formats.

In the Imposed Keyword Condition students were provided two cards, one with the word and definition, and the other with the keyword, the vocab word, the definition, and an interactive illustration of the term and keyword. On Day 1, three minutes were spent demonstrating three practice words, and 12 minutes were used for practicing the actual words on days two and three. First, the teacher presented the vocabulary term and keyword to the students using the first card.
that had the term on one side and the keyword on the other. Then the teacher used the second card containing the term, the term's definition, the keyword, and interactive illustration to demonstrate the way to remember the term's definition. In the Induced Keyword Condition students received the same materials and instruction as students in the imposed keyword condition for the first week of instruction to become familiar with mnemonic strategies.

Beginning the second week of instruction, these student were taught a strategy (IT FITS) to help them make up their own keywords and interactive illustrations of their keywords. The strategy (i.e., Identify the term; Tell the definition of the term; Find a keyword; Imagine the definition doing something with the keyword; Think about the definition doing something with the keyword; Study what you imagined until you know the definition) was posted in the classroom for students in this condition throughout the study. During the first 3 minutes on Day 1, the teacher used sample terms and imposed keyword mnemonics to review the end product for the students. Then, each step in the IT FITS strategy was reviewed. Next, the targeted words for the week were presented using cards that provided the term and definition. Students were then left to independently complete the FITS portion of the strategy.

Assessment materials for all students were identical, with two weekly tests, one required writing definitions from memory (production), and the other required matching definitions to terms (recall). These tests were given six times, one day after each week's instruction, one week after all instruction had ended, and three weeks after all instruction had ended. Weekly tests included all 48 items measured across the intervention. Daily quizzes were given immediately following the 3 days of instruction for each week, and listed each of the 12 terms targeted for instruction that week. Students were required to write as many definitions as they could within a five-minute time limit.
Fidelity of implementation was collected, with an average of 94% of intervals (measured every 30 seconds) across two observers, suggesting that the teachers implemented the interventions correctly. Additionally, the scoring of tests was observed by two scorers with the reliability of graded definitions at 97%. Data were analyzed in two ways. First, group means on the last three weeks of instruction were analyzed using repeated measures ANCOVA. IQ was the covariate, and written and matching performances were analyzed separately. Additionally, data were analyzed was using the 12 words taught during the fourth and final week of instruction. Three scores (initial scores on the fourth week measures, and two follow up tests one and three weeks after) for the students were analyzed in a repeated measures ANCOVA. On the written measures, there was no significant difference noticed in the type of treatment or week analyzed. On the matching measures from the second, third, and fourth weeks there were no significant main effects for treatment or week. There was however an interaction effect that favored the imposed keyword condition over the other two conditions. On the measures derived from the 12 words taught during the fourth week, there were no significant main effects for the treatment on either written or matching measures. There was also no effect noticed in the initial follow up on the written measure, though on the matching test, scores for the imposed and induced keyword strategy were greater than the systematic teaching strategy. No effects were noticed at the 3 week follow up across all conditions. The authors concluded that while significant findings across conditions were not found in the analysis, the limited findings suggest that implementation of keyword mnemonics support the recall of definitions and terms.

Mastropieri, Scruggs, and Fulk (1990) described the effects the keyword mnemonic strategy had on student acquisition of abstract vocabulary. As part of the research 25 students with LD who attended resource rooms were included in this study. Students were compared
across multiple conditions, including a keyword condition and direct instruction condition. The overarching purpose of this research was to determine whether or not the keyword mnemonic method could be used to teach both abstract and concrete information and whether or not this method could be used to teach students high utility vocabulary words.

Vocabulary words used in this investigation included eight concrete and eight abstract words. In the keyword condition, materials included 18 index cards. On the top of each card was the vocabulary word, a keyword provided in parentheses, and the definition of each term. In the middle of each card the keyword what was included in a visualization depicted the keyword interacting with a definition. For concrete words the keyword was seen performing an action that would help students recall the word while abstract words the keyword was seen interacting with an instance of the definition. In the direct instruction rehearsal condition Materials were the same except all keywords or picture references were not included on the index cards. Additionally, two tests were used to measure the effectiveness of each intervention in the setting. One had students recall definitions orally for each term and the second was a comprehension test where students had to match appropriate terms two example of a term.

In the keyword condition students were taught through mnemonics and pictures for each new vocabulary word that was then explained by the experimenter. Sixteen terms were taught in a random order and students were shown each index card with their pictures for 30 seconds while the researcher described the keywords and the strategy for recalling them. At the end of the session students were given recall test followed by the comprehension test. In the rehearsal condition In the rehearsal condition students were provided drill and practice and direct explicit instruction for the terms and then provided the recall and comprehension test. Instruction for
both conditions included equal time and were both followed by the recall and comprehension test. Both tests were read aloud to students and students could orally recite their answers.

Answer sheets were scored by researcher blind to the study, and 100% agreement was obtained. These scores were compared using a repeated measures ANOVA. Results from this analysis suggest that students who participated in mnemonic instruction significantly outperform students in the direct instruction rehearsal condition. This includes significant differences on the production and recall tests. The findings of this study suggests that mnemonic keyword instruction can support the acquisition and recall of both concrete and abstract vocabulary words that can be generalized and used across content areas.

Harris, Schumaker, and Deshler (2011) looked to describe the impact of multicomponent vocabulary interventions for students in inclusive classrooms. Participants were 230 students enrolled in ninth grade English classes. This included students with and without disabilities. Three teachers who taught nine classes were also recruited for the study. Six of these classes were randomly assigned to one of two groups the word mapping group in the vocabulary LINCS group. The remaining three classes served as a comparison group.

In the word mapping group, students were taught a set of cognitive and behavioral steps to use to predict the meaning of an unknown word. Students were taught a mnemonic device, MAPS, to learn and remember words. MAPS guide students through breaking words into their morphemic parts (i.e., prefixes and suffixes), attaching meaning to word parts, making predictions about the meaning of unknown words, and checking the dictionary for definitions. Along with the students were provided a word map where they could breakdown the word into its component parts using the MAPS strategy. In the vocabulary strategy students were provided instruction for how to memorize and recall the meaning of vocabulary words. This involve using
a set of mnemonic strategies included the keyword strategy, visual imagery strategy, a story strategy to link known words in information to new vocabulary words and their definitions, and a self-testing method for recalling the meaning of words. The mnemonic LINCS was used to help students memorize these steps. In implementing this strategy themselves, students write the word and its definition, identify word that they will use to remind them of the target term that sounds or looks like it, creating a linking story where students include the reminding word and the terms definition, and finally dry picture that includes the important parts of the story they developed. Students then say the words themselves think of the reminding word the linking story and a picture, and remember the definition. To do this students were provided a LINCS table to complete.

Instruction for each group took place across 10 lessons, with each lesson lasting forty-five minutes. Each lesson followed a common format, that occurred in three phases: orientation, instruction of vocabulary word list one, and vocabulary instruction for word list two. In the word mapping condition students are invited for lessons focused on identifying prefixes, suffixes, routes, and the steps of the word mapping strategy. Each lesson included activities that had students identify morphemes, and practiced looking up morpheme meaning. In phase 2 of the word mapping strategy instruction, students practiced using the word mapping strategy for target words on the first vocabulary word list. This included direct and explicit instruction in breaking down words using word maps in using these words maps to determine word meaning. These procedures were repeated for terms on the second vocabulary words list. In the vocabulary strategy and instruction, lessons also took place in three phases. The first set of lessons covered use of the vocabulary LINCS strategy and follow direct and explicit teaching procedures. For the following phases of instruction use of this strategy to determine the meaning
of words on the first and second word list also occurred. Students in the business as usual or comparison group received their traditional classroom instruction during this time.

Across the two intervention conditions, fidelity checklist for use to assess the quality teacher performance in conducting the interventions. These checklists included 10 items representing the instructional steps teachers followed to teach students the strategies. Pre and post measures were used with each group as well. This included strategies tests were developed to measure student knowledge and use of the two strategies they were taught in their condition groups. Students who learned word mapping took the word mapping test and students who learned the vocabulary strategy took the vocabulary LINCS test. Each test had two forms and had students complete the word mapping or vocabulary LINCS tables on the sample words to assess their youth and knowledge of each strategy. Students were also provided a word knowledge test that measured student knowledge of the 20 vocabulary terms that were taught in both the word mapping and vocabulary LINCS conditions. For each word students were provided three prompts that had them provide any contextual information for the term, use the term in the sentence, and to define the term. To measure student ability to identify word parts with unknown words as well, a morphological analysis test was administered. For words that were not taught during the intervention, students were tasked with breaking words down into their morphological features and determining their meaning. A final assessment that was administered was a satisfaction questionnaire that were used to determine whether students in the word mapping and vocabulary LINCS condition were satisfied with the instruction they received. These questions had students rate responses on a seven point Likert scale. Students in the comparison condition only took the word knowledge and morphological analysis test.
Utilizing a pretest posttest comparison group design, data collected from these assessments were used to determine the effects of instruction on student strategy use and vocabulary knowledge. Across test and conditions, a repeated measures ANOVA was conducted to measure the strategy use student participants (i.e., students with/without disabilities). While no significant effect was found for the strategies test, there was a main effect for time found across student participants, with strategy use increasing from pretest post test. Similar findings were found for students in the vocabulary learning condition. Utilizing a two way ANCOVA, with pretest scores as covariates for word knowledge it was reported that posttest scores were present for all students when comparing pretest and posttest averages, and that SWD had similar scores on the posttest after having participated in the word mapping or vocabulary learning conditions. This includes significant differences between these groups and SWD and the comparison group having scored significantly lower. Similarly, student scores for all participants were significantly higher on the posttest and they were on the pretest. For the morphological test, results and post-hoc analysis from the ANCOVA also suggested that SWD who had completed word mapping instruction scored significantly higher than students in the vocabulary learning and comparison conditions. Results from the satisfaction surveys across the word mapping and vocabulary learning conditions were also similar. The results of the study suggests that for both students with and without disabilities these strategies can support the development of word knowledge and ability to independently break down words to find meaning.

**Vocabulary Instruction for Students Learning English**

Fillipini, Gerber, and Leafstedt (2012) conducted a study that examined the added value of a vocabulary intervention that was paired with a phonological awareness intervention when compared to a phonological awareness only intervention to measure the impact each intervention
had on the reading achievement of SLE at risk for reading difficulties. The purpose of this study was to see whether or not SLE who had reading interventions that provided substantial instructional time dedicated to vocabulary instruction and less to phonological awareness demonstrated greater gains in vocabulary and phonological decoding when compared to students who spent the entirety of their instructional time receiving instruction in phonological awareness and decoding time. Participants for this study included 60 students identified as a limited English proficient and 10 native English speaking students in first grade classrooms.

This study utilized a repeated measures pretest – posttest design. Students were split into three groups. These groups included instruction that focused on: (a) phonological awareness only, (b) vocabulary intensive instruction focused on semantic features of words and phonological awareness, and (c) vocabulary intensive instruction focused on morphological features of words and phonological awareness. In each group students were instructed by members of the research team. The methods used in the setting provided student explicit lessons in the identification, production, and manipulations of sounds in words supplemental to typical classroom instruction in reading and language arts. All instructional condition shared features related to frequency, duration, number of lessons, and group size. All conditions also included explicit instruction in and phonological awareness and decoding, though the amount of time dedicated to this instruction differed across conditions. Students in the phonological awareness condition were provided direct and explicit lessons that focused on the identification, production, and manipulation of the sounds in words. Phoneme sequences were taught in a systematic order, from simple words to more complex words (i.e., CVC to CCVCC). Each lesson began with a short phonological awareness warm-up activity and was followed by in-depth activities that focused on phonological awareness, decoding, and decoding words in the context of a sentence.
as well as practice with sentence level decoding. For the students in the vocabulary plus conditions, the same warm-ups for phonological awareness were used, following this more instructional time was spent on vocabulary terms that were selected from expository text that we’re read aloud to all groups. This is included high utility Tier II words, including nouns, verbs, adjectives, and adverbs. Vocabulary words were taught in the same manner in both vocabulary plus conditions, with visual representations provided along with direct instruction and word meanings through the use of since names, antonyms, examples and non-examples, and definitions provided. Multiple exposures of the word in a wide variety a context were also provided both within and across lessons. Differences in instruction for the two vocabulary plus conditions centered on either conditions focus on semantic or morphological features of the terms. Any semantic relation condition students instruction focused more on words relationships to each other and students were taught to group words based on their meanings and ultimately to categorize target words based on their relationship to other words. Any morphological awareness condition students were explicitly taught to identify their meaning, but specifically to focus on how morphemes contributed to the meaning of the word.

Following the implementation of these lessons students word ministered a variety of assessments to assess their breadth of vocabulary knowledge, target vocabulary knowledge, and phonological decoding skills. To measure students breath a vocabulary knowledge the Peabody Picture Vocabulary Test (PPVT) was administered to gain insight into students receptive vocabulary in English. To measure student knowledge of target vocabulary, researcher created tests were administered. True and false sentences were provided for each of the vocabulary terms taught through the interventions and students had to indicate which sentences used terms in the correct or incorrect fashion by circling a thumbs-up or thumbs-down for each sentence. Measure
students phonological decoding skills, the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) Nonsense Word Fluency subtest was implemented to measure students knowledge of the alphabetical principle, phonological awareness, and phonics skills. To report on the effectiveness of each intervention and the instructional condition effects, analyses were conducted through the use of ANOVAs.

The authors report that no between group differences were statistically significant and that within each Group there were high variations and large standard deviations. To shed some light on the findings that were found in the conditions, the authors also provided effect sizes for each intervention. Reporting with the in group effect sizes, the authors report that students who received morphological based vocabulary instruction outperformed students whose vocabulary instruction focused on semantic relationships and students who received phonological awareness instruction only. The findings of the study suggest that when used as a supplementary instructional activity, vocabulary instruction can't support early literacy development as well as vocabulary development. These findings should be considered along with the limitations of this study however. This includes that a small sample size that was included and that statistical significance was not found between the groups. Additionally, the authors suggest that when working with SLE populations, research should go beyond focusing on literacy and vocabulary skills and also focus on higher order language development skills as well.

Another study conducted by Jozwik and Douglas (2017) focused on how a multicomponent academic vocabulary intervention could support SLE with learning difficulties in general education settings. As part of study 6 fifth-grade students identified as limited English proficient were recruited for the study. The purpose of the study was to measure the effects of multicomponent academic vocabulary instruction on students oral reading fluency and their
ability to define academic vocabulary words. Additionally, it was the goal of this research to identify student retention of knowledge over a six-month period. This study utilized a multiple probe design across word sets and replicated across participants.

Vocabulary instruction in this study took place in three 5th grade classrooms during 25 minutes of a language arts instructional block. Instruction was provided to all students in each classroom though data or only recorded for the participants of the study. As part of this study, multiple instructional materials were implemented. This included academic vocabulary word list that included 72 advanced academic vocabulary terms for grade 5. Across each dyad, 24 terms were assigned and divided into equal sets of mathematics and language arts terms to be taught. Word cards were also developed in printed on card stock for use instruction student. Academic vocabulary graphic organizers were also created and provided space for the terms, content areas they fit into, student crafted definitions, and space for visual representations or examples to be included. The self-regulation sheet to contain space for goalsetting, self-recording, and self-evaluating performance were also used.

As part of their standard instruction students were first given a 500 word passage from their literacy curriculum. These passages included for highlighted words with meanings that could be inferred from in the context of the passage. Students then read the text allowed the partner and stopped at each highlighted word to make inferences about the potential meaning of that term. Students were then asked to record there in for definition in a notebook and to continue reading. Once all four words were read and discussed student stopped reading. Once this had occurred the teacher presented definitions of the words and students had to either confirm or just their definitions. The final component of this had students working pairs to complete exercises (e.g., word sorts, crosswords) with each target intern. During probe sessions, that immediately
followed the vocabulary instruction, the researchers would independently in a one-on-one setting have students complete oral word reading and expressive definitions tests. In the oral reading test students would be presented flashcards with each term on them and ask to read them out loud. For the expressive definitions test students would be presented the same words and asked to provide a definition for each term. To supplement this instruction, the multicomponent academic vocabulary instruction designed for this study was implemented after these procedures. Across five consecutive school days, each word set was taught during 25 minute sessions. These sessions would begin with the researcher introducing the vocabulary terms for that session to the student. The researcher then had students set goals for themselves for the lesson. Instruction during these lessons follow the explicit instructional and cooperative learning procedures. Typically, these procedures included teachers introducing students to the water, having students restate the word, modeling how to write the word, orienting students to the content areas the word fitting, transferring this information into a graphic organizer, hearing the word with an image and explanation, having students restate the meaning of their word to three different listeners, having students independently record a definition and construct a visual representation of the word. These procedures were repeated for the words targeted in each lesson. Following these intervention sessions, students completed the same procedures they had after receiving their traditional vocabulary they had after receiving their traditional vocabulary instruction.

As part of their single subject research design, data are presented on individual student graphs. Data collected prior to the implementation of the multicomponent vocabulary instruction show a flat trend for how students read the fine content specific vocabulary words, with low scores consistent across participants. Once intervention occurred all students demonstrated and immediacy of effect following interventions for each of the word lists. Across subsequent probe
conditions, all students maintained increasing levels of word reading and providing academic vocabulary definitions. Across all six participants there’s also 100% PND recorded, suggesting a strong intervention effect. Follow up probes at one month, three-month, and six month intervals suggested that while student word reading and retention of vocabulary term definitions decreased, all six participants demonstrated levels higher than they had during baseline. Social validity measures administered also suggested that students thought the multicomponent instruction was beneficial when compared to traditional instruction, and teachers felt that implementation of those procedures were feasible and helpful for students. The findings of the study suggest that brief sessions of direct explicit instruction in word meaning can support student acquisition of word knowledge and word reading ability.

An additional study that looked at how vocabulary instruction can support SLE in inclusive classrooms, Carlo et al (2004) investigated multiple influences and practices that support SLE development of vocabulary. This study focused on the results of a 15-week intervention that evaluated instructional strategies for teaching new words as well as word learning strategies. Specifically, this study looked to outline how to choose vocabulary terms to teach, how to introduce terms, when to teach terms, and what instructional strategies to use. Additionally, this study looked to identify methods that could support students in general education classrooms. Participants included 254 bilingual and mono-lingual students from nine 5th grade classrooms. One hundred forty-two students were identified as SLE and 112 were English speakers. Ninety-four SLE and 75 English speakers were assigned to the treatment condition and the remaining students to the control condition. Utilizing a quasi-experimental, classrooms were randomly assigned to these groups.
Across 15 weeks of instruction, 10-12 target words were introduced and taught per week. During five day instructional weeks, vocabulary instruction was delivered for 30-45 minute sessions for four days, with review conducted on the fifth day. Each instructional unit was built around the use of a single text. To supplement the instruction, Spanish speakers for given the text to preview in Spanish on Monday before the introduction in English on Tuesday. On Tuesdays whole group instruction involved presentation of the text in English, target words introduced, an activity that involved identifying target words in the text and inferring their meaning in context. Wednesday lessons included heterogeneous language groups of 4 to 6 where students completed two types of cloze activities with the target words, and Thursday instruction involving robust vocabulary instruction that included word association tasks, synonym and antonym tasks, and semantic feature analysis. Review sessions conducted on Fridays promoted analysis of root words and derivational affixes, as well as clarification of cognates when necessary. Teachers deliver these materials after they’re provided detailed and scripted lesson plans, as well as supplementary materials to project, and assignments that aligned to the text.

To measure the impact of these materials, multiple measures were utilized in this study. These included the PPVT, multiple choice cloze passages, multiple choice vocabulary assessments, word association tasks, and a morphology analysis task. Across these six dependent measures, a MANOVA that included language status and condition assigned as predictors was conducted. Initial analysis suggests there were significant within-subject gains made over the course of the intervention and significant interactions between gain over time and condition. Post-hoc analysis also suggests that for word mastery, word association, morphology analysis, and cloze activities students in the intervention group significantly outperformed students in the control conditions, though varying effects were noticed at the site-level for treatment conditions.
The findings of this study suggest that Tier I vocabulary interventions and word learning strategies that include evidenced-based practices and delivered in a systematic way can support the development of word knowledge for both SLE and English-speakers in general education classrooms.

**Combining Approaches to Vocabulary Instruction**

Evidence for both SWD and SLE suggest that vocabulary knowledge can be effectively delivered in general education classrooms and embedded as a part of traditional curricula. Additionally, many of the components of instruction for vocabulary are similar across these student groups with student friendly definitions, word feature analysis, and word connections common elements of effective vocabulary instruction for SWD and SLE. However, there are some differences in the instructional approaches that are present in the literature that could make it difficult to deliver Tier I interventions in an inclusive classroom to both groups. While mnemonic instruction has been shown to support word learning for SWD, students without a firm grasp of English could find the interaction of a keyword and an illustration confusing. The same could be said for language, translation supports, and cognate clarification provided for SLE and how those supports may confuse SWD during vocabulary instruction. With the ability to program or assign specific components of instruction, technology-based tools could be a potential solution for teachers. However, like instruction, developing effective methods for both student groups involves understanding common design features and digitally delivered instruction shown to support learning outcomes for SWD and SLE.

**Educational Technology to Support Learning in Classrooms**

Technology plays an increasingly large role in multiple aspects of daily life. From completing work tasks or engaging in recreational or social activities, personal and mobile
technologies are becoming more ubiquitous. As the tech industry continues to define the role technology plays in our work, recreation, and leisure activities, innovations are also made with assistive and instructional technology (Edyburn, 2013). However, with the pace modern technological advancements make, it is important for research to validate methods for the development and implementation of assistive and instructional technologies. This includes ensuring that all student groups are considered, and that as advancements in technology are made they build on previous research.

**Educational Technology for Students with Disabilities**

Technology has always played a crucial role in supporting access to the general education curriculum for SWD. Increasingly, digital tools and technology are being utilized in a variety of setting serving students with disabilities. However, due to the intensive learning needs of SWD, it is important that the tools schools and teachers invest in have empirical evidence that supports their use (Edyburn, 2013). The evidence that exists for the use of technology with SWD, suggest that well-designed and tested materials can create access to general education content and supporting independent learning. This includes technology-based tools that provide direct instruction, support students while they complete independent tasks, and create flexible learning tools that can be modified to meet the individual needs of students. While this evidence from the research has begun to illuminate how technology can be developed for and implemented in classrooms serving SWD, there are still gaps in the literature related to the role of technology in the classroom and how technology based tools support the increase student achievement.

In a study looking to explore the efficacy of using evidenced-based multimedia practices to improve the vocabulary learning of students with LD, Kennedy, Newman-Thomas, Meyer,
Alves, and Lloyd (2014) developed content acquisition podcasts (CAPs) to teach social studies vocabulary to students with LD in secondary world history classes. The researchers utilized an experimental pretest-posttest design, with embedded curriculum based measures, to conduct this study. The purpose of this study was to compare the vocabulary learning of students who had received instruction using CAPs to those who had not, and to discuss how these findings may provide empirically backed guidance for creating materials aligned to the tenets of UDL. As part of the research, 141 students were recruited to participate. This included 32 SWD and 109 students who were not identified with a disability or receiving special education services. These students were recruited from a single teachers course sections and randomly assigned by course period to receive CAPs or teacher led instruction for portions of two world history units.

The instructional materials utilized in this study included CAPs and traditional teacher-led instruction. The CAPs used in this research were developed using Mayer (2009) principles of cognitive theory of multimedia learning (CTML) and validated by two reviewers with experience creating CAPs to ensure they adhered to the evidenced based CTML principles. The CAPs were characterized by embedded text, audio, graphics, and videos that provided multiple effective forms of vocabulary instruction. In total, 81 CAPs were created and utilized in this study. During teacher-led instruction, the teacher would provide students with text-based definitions of terms and have them copy these definitions into notebooks.

Prior to the study, student participants were administered a pre-test. The pretest included a school district provided assessments. This included two assessments for the units covered in this study. Both assessments included short answer questions, multiple-choice questions, and essay questions. The short answer questions required students to write one to 3 sentences relating to basic and applied world history content, and essay questions required students write 5 to 10
sentences to describe and explain world history knowledge. In addition to these assessments, the researchers created eight CBM probes that had students match historical figures or terms to definitions.

Across eight weeks of instruction for the two units, students were assigned to receive CAPs based instruction for one unit and teacher led instruction for the other based on their course period. For students who received CAPs based instruction, their teacher was provided CAPs that were shown during an instructional day and just prior to taking the CBM with the corresponding terms. For students in the teacher-led conditions, teacher provided definitions were given on a day of instruction and reviewed prior to the administration of the corresponding CBM. This included SWD receiving two additional exposures to the CAPs and terms in their study skills class following instruction and prior to the administration of the CBM.

To be able to analyze student vocabulary learning, Kennedy et al (2014) collapsed the sections who had received alternating treatments across the two units of instruction into two groups, CAPs and business as usual (BAU) for the pretest and posttest. To compare performance and growth on the CBMs, a multilevel growth model what’s used. In the between groups analysis a series of one-way ANOVAs was conducted. These comparisons included the collapsed groups that fit into the CAPs or BAU conditions, and scores were compared on the CBM probes and posttests that were administered. Results from these analyses indicated that SWD in the CAPs condition significantly outscored students in the BAU conditions on multiple probes and the posttest for the first unit. Similar findings were noticed in the analysis of the second unit probes and posttests, with students in the CAPs conditions outscoring students in the BAU condition on multiple probes and the posttest. Additionally, analysis from the multilevel growth model that looked to account for the growth related to the form of intervention (i.e., CAP,
BAU) suggested that students in the CAP conditions made greater gains in vocabulary learning when CAPs were implemented. These results suggest that the use of CAPs is an effective way to supplement traditional instruction and support the vocabulary learning of SWD.

An additional study conducted by Kennedy, Deshler, and Lloyd (2015) investigated the effects of direct vocabulary instruction delivered through CAPs had on the acquisition of specific social studies vocabulary. As part of this study, Kennedy et al. (2015) utilized an experimental pretest-posttest design. The purpose of this study was to evaluate CAPs as an instructional tool used to support the vocabulary learning of students with LD in secondary content courses. To support this analysis a total of 278 students who attended an urban Midwestern school were recruited for the research. This included 30 students who are identified with an LD in reading and 248 students who are not identified with disabilities.

CAPs which were the technology-based tools evaluated in this research, developed through CTML principles and containing effective methods for teaching vocabulary to students with LD (i.e., explicit instruction, keyword mnemonic strategies). To find the most effective combination of theoretically valid instructional and design features, four types of multimedia based instruction were developed and evaluated. This included: CAPs containing only explicit instruction of vocabulary terms (EI), (b) CAPs only containing keyword mnemonic support for vocabulary terms (KMS), (c) CAPs containing both explicit instruction and keyword mnemonic strategies (EI+KMS), and (d) instructional videos with explicit instruction that did not adhere to the principles of CTML (NM). For the EI CAPs, students were provided vignettes that covered a rationale for why a given term is important, direct instruction of word meanings, awareness of closely related terms, guided practice in scaffolding, and word consciousness (i.e., morphological aspects of a word). In the KMS CAPs, students were provided a rationale for why learning the
term is important, direct instruction in word meaning, rationales for why the KMS are valid tools for remembering terms, and keywords paired and interacting with an image that supported recall of a term’s definition. In the EI+KMS conditions, the components of EI and KMS were combined and provided to students. In the final CAP group, NM, students were provided only narration that was provided in the EI CAPs that was presented as text only.

Multiple measures were developed and implemented to measure student and and vocabulary learning and satisfaction with the interventions. This included a multiple-choice (MC) instrument of the 30 terms covered in the interventions. This instrument had students identify correct definitions for the terms covered. This instrument provided scores ranging from 0 to 30. Participants were asked to match a sentence them to the appropriate definition provided in a multiple-choice format. And additional assessment used to measure students vocabulary knowledge wasn’t open ended (OE) instrument. The purpose of this instrument was to evaluate students depth of vocabulary knowledge to see if they could provide synonyms or antonyms to the terms as well as any contextual understanding of the term that was taught in a CAP condition. This instrument asked students to provide any additional information they cut on the 30 terms or concepts and was scored on a range from 0 to 60. If I don’t instrument used with the satisfaction survey that was given to all participating students at the end of the study. This survey included Likert type items with responses ranging from 1 to 10, with responses of 1 representing strongly disagree and responses of 10 representing strongly agree. The items on the survey were meant to reflect student perceptions related to the ease of function of the developed CAPs and the usefulness of CAPs for learning social studies vocabulary.

As part of the pretest – posttest design students first completed a pretest that included the MC and OE instruments. One week later, students were provided a CAP that they viewed on
individual laptops. This CAP introduced them to the format of instruction delivered through CAPs and introduced them to their features. Across three days of instruction students in each condition watched a total of 30 CAPs. This process included having students watch 10 total CAPs during one instructional period. Student viewing of CAPs was broken down into segments of five, where in one instructional period, students would watch five CAPs and proceed to take the OE and MC instruments, and upon completion watch five more CAPs and complete additional OE and MC assessments. This procedure was repeated for three instructional periods in each condition. Three weeks following the completion of the study’s implementation, a maintenance probe and student satisfaction surveys were administered.

To analyze the results of the assessments, Kennedy et al (2015) utilized multiple analyses to compare the effects of the CAP delivery methods and performance on the vocabulary measures of the participants over time. In the main analysis, a 4 x 2 split-plot, fixed-factor repeated measures ANOVA was conducted to compare the scores of students with LD who participated in the study over time (i.e., pretest, posttest) based on their group assignment (i.e., EI, KMS, EI+KMS, NM). No significant difference was noted between group assignment or time in this analysis, though an interaction between group and time was found. Post-hoc analysis highlighted that while no significant differences existed between student scores on the pre-test, significant differences existed between the scores of students in the EI+KMS and NM conditions significantly differed on the post-test. An additional 4x3 split-plot, fixed factor repeated measures ANOVA was run to compare student group assignment to test performance, this time including the maintenance probe. The results of this analysis indicate that there was a significant manifest for group and the interaction between group in time. There was however no significant affect for time. Post hoc tests were conducted and this analysis indicated that students with LD in
the EI+KMS group had significantly higher scores on the maintenance programs students with LD in the NM group. The final instrument provided to students was the satisfaction survey. Results from the survey indicate that: students did not have technical problems when utilizing the CAPs, students found the content of the CAPs engaging, and that the format and delivery method of CAPs what’s beneficial to their learning of new vocabulary terms. Post hock analysis conducted suggested that students in the EI+KMS condition felt that the CAPs were easier to use and more beneficial to their learning than students in the NM conditions. These results suggest that CAPs that provide both explicit instruction and supports using keyword mnemonic strategies can be useful in supporting students with LD learning content area vocabulary.

Combined, the results of these studies related to CAPs suggest that technology-based tools can be an effective way to teach academic vocabulary at the secondary level. Additionally, as Kennedy, et al (2014) described, well designed technology based tools can align themselves to the tenets of UDL and support the learning of SWD in general education classrooms. Future research should continue to align specific design components to the tenets of UDL and describe how these elements impacted student learning. This should include descriptions of how these items were developed and how they were ultimately used by students in a variety of content areas.

Similar to the studies investigating CAPs, Lowman and Dressler (2016) looked at how explicit vocabulary videos delivered through mobile technology (i.e., iPods) could supplement traditional instruction and support the word learning of students with specific language impairments (SLI) when paired with reading activities. An experimental pretest-posttest design. A total of 18 students in the fifth and sixth grades participated in the study and randomly assigned to conditions where they received alternating treatments traditional instruction guided
by a novel (traditional sequence) and traditional instruction supplemented by videos delivered by an iPod (video). Participants were recruited because they: (a) received speech language services, (b) scored below average in reading on state assessments, (c) were identified as being two grade levels below their current grade in reading, (d) were within the average range for IQ, and for whom consent was secured.

Prior to the implementation of the research, participants were screened to assess their prior vocabulary knowledge. This screening suggested that students did not exhibit significant differences in vocabulary knowledge prior to the study. Once this was established, students were then assigned to the traditional sequence/video conditions (n=10) and the video/traditional sequence (n=8) and provided instruction for two fiction novels. Across bowl novels, participants were exposed to 12 words per novel for a total of 24 words. In the traditional condition students were assigned a set of chapters to read which lead to the completion of each book in 4 weeks. Students would orally read a portion of the book with reading assistance provided by research assistant as necessary, but no explicit vocabulary instruction was provided. In the video condition students read the same assign chapters as in the traditional condition but we’re provided 15 minute videos to watch two times paired with their reading chapters. These videos explicitly top three words that appeared in each week’s reading assignment. Each video included five segments that included: (a) priming for learning, (b) phonemic instruction, (c) semantic instruction, (d) syntactic instruction, and (e) review. This instruction followed a sequencer where a narrator would introduce the three words to be taught and explain their importance to students. Phonological instruction was provided by demonstrating how words were spelled and pronounced, with explicit phonemic instruction also provided. Student friendly definitions were
also displayed on screen and read by the narrator with the word as it was seen in text presented to students. This instruction was then provided for all three words via an iPod.

Prior to and following the implementation of each condition students were administered five measures of word learning. This included having students generate their own definitions for terms, having students use the term in a sentence, having students use terms to fill in the blank of sentences, having students evaluate it terms reused correctly in a sentence, and having students complete multiple-choice assessments where they match definitions to the correct term. These items were scored by the researchers and research assistants. From these measures, change scores were calculated to measure the impact of each condition. It was reported that there were no significant carryover effects from the change of instructional materials. In utilizing linear mixed models that adjusted for timing of condition implementation, condition, and student’s assigned instructional sequence. The results and analysis of change scores indicated that there were significant differences in the change scores of students who had participated in the video conditions when compared to students in the traditional conditions, including when instructional order and time are controlled for. The results of this study suggest that instruction that is aligned to research-based vocabulary instruction practices can be delivered through mobile technology. This includes highlighting that these materials can be created by an individual the authors deem as a technology novice. However, limitations to this study include that the researchers cannot guarantee that students read all passages in the book in traditional sequences and that previous diagnoses and data related to student identification were used to qualify students for participation rather than a proximate measure of student language needs.

Future research in this area should continue to define the role of technology in supplementing traditional literacy instruction. This includes determining how teachers acquire or
develop tools they can use to supplement their own instruction, as well as how students will use these tools. Additionally, descriptions for how these tools can be delivered in a tiered system in inclusive classrooms, and their effects on various poor readers and individuals with diverse language needs are needed.

Another study looking at how technology can support SWD, King-Sears, Evmenova, and Johnson (2017) investigated the role technology could play in making chemistry homework accessible for students with and without disabilities. An action research model was used to conduct this study. In total, 19 students from a general education (n=15) and a self-contained (n=4) serving students with LD and other health impairments (OHI) were included in the study. One teacher who was licensed in both chemistry and special education was recruited for the study and taught both course sections. The purpose of this study was to gain insight into how students and teachers use and perceive using Pencasts in chemistry.

The main tool investigated in this study were Pencasts. King-Sears et al (2017) describe Pencasts as lessons recorded on smart pens that are equipped with a microphone for audio recording an infrared camera that simultaneously attracts content written or drawn on microdot paper and matching it to verbal content. In this investigation a Livescribe Smartpen was utilized. In lessons conducted a teacher would use the Smartpen to record himself writing and solving chemistry problems. Once this was completed these examples and recorded lessons were uploaded to a learning management system (LMS) accessible to both classes. Pencasts were developed to last 25 minutes and were created for approximately 90% of homework assignment to sign the students. At the beginning of school year students were trained on how to access and utilize pen cast and the class learning management system. This included how to access, view, and manipulate the content in each Pencast.
In order to report on how students perceived the use of Pencasts, student completed questionnaires and participated in interviews with the researchers. Questionnaires were designed to measure student satisfaction with the pen cast and consisted of three parts. First six statements were designed to determine student satisfaction and have students respond using a three-point scale related to their experience with Pencasts. Students responded to items scoring them as 1=Unhappy, 2= I did not notice any changes, and 3= Happy with the results. In the second portion students self Report of the frequency they used Pencasts on a five point scale, 1=none of the time, 2=Sometimes, but not much, 3=About half the time, 4=Most of the time, and 5= All of the time. The final portion consisted of for open ended questions that students can respond and report whether or not the intervention was effective and beneficial to them, and whether or not they would recommend it for other students. Additionally, focus group interviews were arranged with all of the suspense to elicit more in-depth information then can be measured by the student questionnaires. Students were asked a total of five questions about their use and satisfaction with Pencasts for homework. The participating teacher was also interviewed so that the perceptions they had on the impact of Pencasts on student homework completion and learning could be obtained.

Results related to student feedback questionnaires were reported for all 19 students. Across all students the meaning for each statement ranged from 2.84 to 3.0 which indicate that on average most students were happy with the results of having used Pencasts in chemistry. Though the sample is small, the participating SWD indicated scores of 3 on five of the six student perception questions provided. In reporting how often students used the pen cast and the options available within each Pencast, student responses suggest that students used Pencasts most of the time ($M=4.0$, $SD=1.03$) when completing homework assignments. While limited in
the number of participants, results suggest that SWD used the Pencasts more to determine how to solve problems, check their work, and really listen to teacher descriptions of how to complete problems. Finally, the researchers aggregated responses from the open-ended interviews conducted with each class. In summarizing the results the authors suggest that most students felt the Pencasts were helpful and that they would recommend them to other students and teachers in various contents. Students also reported that using these tools were beneficial to their graves, provided them the way to check their homework, and help them solve problems they did not know how to solve independently. Teacher feedback was also collected using an open-ended interview. Overall the teacher identified two main benefits of Pencasts, suggesting that they provide additional assistance and accountability for students. The preliminary findings of this research suggest that a variety of tools can be beneficial in supporting the independent work habits of SWD and can be feasibly implemented by their teachers with limited amount of training. This study did however contain multiple limitations. A small sample was included, and the responses for students were also self-reported. While it is beneficial to report on how students view the benefits technology-based tools have for them individually, it is important to have an academic outcome measure tied to the use of specific technology in specific content areas. Future research should include comparison groups that illuminate how technology can increase the amount of independent work or homework that students complete when using technology compared to students who do not, as well as finding ways to identify the value added of using Pencasts to increase the amount of independent practice students complete in content areas. Data related to students technology acceptance and use should continue to be collected, but this should also be held up against the benefit these tools have on student academic outcomes.
Another study conducted in science classrooms by Marino, et al (2014) looked at how videogames with comprehensive learning supports (e.g., text to speech, adaptable reading levels) could support the acquisition of science knowledge for SWD in science. As part of this research, 57 students with LD were recruited from four middle schools. The purpose of this study was to extend the literature on how curricular materials in science could be designed to adhere to the tenets of UDL and support the learning of students with LD. In particular, the study sought to determine if relationships existed between the use of video games, alternative text, and the level of engagement of students with LD in science, and whether or not there were differences in performance on paper and pencil posttest when students were provided video games with embedded learning supports (e.g., text to speech, glossaries) to learn science material, and whether or not student responsiveness to these interventions was based on prior reading ability.

Overall five teachers participated in the research which one teacher recruited from fifth grade and four from seventh grade. As part of the research a mixed methods design was employed, and participants in the study followed and ABAB model where a represented non-UDL units and B represented UDL aligned units. Teachers used the non-UDL and UDL-aligned Materials and supplements to their traditional curriculum during the study. Overall the researchers implemented materials to supplement 10 units of science instruction. This included paper and pencil pre- and posttests, science videogames, and commercially available science texts.

Prior to and following each unit the pre-and post tests were administered. Each test contained between 20 and 24 items that were chosen using a Delphi process that included teachers, a science professor, and a senior representative of the National Science Teachers Association. The video games used in this study came from a suite of four life science video
games developed by Filament Games. The games cover topics that included selling adamant functions, genes and inheritance, bacteria and viruses, and photosynthesis and plant lifecycles. The authors reported that a detailed discussion of how these games were developed to align to tenants UDL was outside the scope of their study, though examples are provided to describe how each game provides multiple means of representation, action, and expression to align to the UDL Guidelines (CAST, 2010). The text that students were provided for the non-UDL aligned units presented alternative representations of science vocabulary and concepts in a format that was written and illustrated specifically for struggling readers.

During implementation of the materials, students were provided unique access codes to each of the life science video games provided. This allowed the researchers to track analytic data for how students interacted with and used features of the videogames. These video games for use on the last day of unit construction during the UDL-aligned conditions and were meant to reinforce and supplement key science concepts and vocabulary from the unit taught by their teachers. In the non-UDL aligned units, students were provided the alternate level text to use in place of their traditional texts to supplement their teachers instruction.

To evaluate the effectiveness of each intervention implemented in this study, multiple questions and levels of analysis were conducted. To determine student level of engagement during UDL units, semi structured focus groups were conducted and results were transcribed coded and analyzed using qualitative methodologies. Results from these analyses students indicated that they preferred the alternative text to their traditional text, but did not enjoy reading to learn science. Additionally students reported a preference to video games overtaxed and that they enjoyed using video games to learn science. To examine and test performance for the students that participated, a 2x2 repeated measures ANOVA was performed. This analysis was
conducted to compare the types of instruction delivered to performance on pre- and post-measures. Results from this analysis indicates that significant differences were found between students who began the intervention with advanced reading levels when compared to students at all other levels. Students at the below basic reading level perform significantly worse than students at the proficient level across all conditions. Additionally, the interaction between condition and time variables was not found to be significant. This indicates that there were no different improvements from pre- to posttest units based on assignment to traditional teacher led conditions or UDL-aligned units. Finally, to ascertain the impact of that gameplay or use of features within the game had on student learning outcomes a multiple regression analysis was conducted. Results from this analysis indicate that well three test scores amount for a moderate amount of the variation post test scores gameplay and use of UDL supports within games did not account for significant changes in the posttest scores of students. Combined the qualitative and quantitative data captured by this study provide information about the use of UDL-aligned technology in the classroom. While it is suggested that students much prefer the videogames and tech-based tools for learning, the quantitative data suggest that these tools add little value to the learning outcomes experienced by students. The findings of this study could have been affected by a few limitations however. As part of the research, 800 minutes of instruction was provided, though only approximately 100 of those minutes were spent with UDL aligned materials. The authors also report that their may have been a mismatch between the study materials and assessment options. It is suggested that paper and pencil tests may have not matched student learning needs and contributed to their post-test scores adversely. Future research should continue to compare the effects of technology-based tools, and continue to describe how aspects of their design (e.g., UDL Guidelines) impact student learning outcomes. Additionally, when
investigating flexible technology based tools in classrooms, it can be beneficial to utilize these same methods in assessing students, providing them multiple means to express their knowledge.

**Educational Technology for Students Learning English**

Similar to SWD, technology has multiple applications to the instruction of SLE. With technology becoming more ubiquitous in modern classrooms, it is important that instructional technology be responsive to the needs of students in the multitude of courses they attend. This includes SLE who are a fast growing student population. This means that teachers need technology-based tools that help them meet the diverse academic, social, and language based needs of their SLE. As a variety of technology (e.g., personal devices, LMS) become available, it is important for research to guide their development and use with SLE.

One such study conducted by Prince (2017) examined the use of personal devices (i.e., iPads) and their instructional utility in supporting SLE. This study employed a case study design and was meant to examine the social and academic language development of SLE in fourth grade. Specifically, the study looked to describe how the use of personal devices could support the development of specific content knowledge and English language skills simultaneously. A total of eight students were recruited from an international school, where students spoke a variety of languages, but where English was the language used for instruction.

Working with the researcher, the teacher that was recruited for this study created unit goals with specific content knowledge goals, English language goals, and determine how technology and pedagogical choices could be made to support and enrich these goals through the implantation of technology. In general, these goals we’re develop to help guide the analysis in the case study and support the structured investigation into how iPads are used in the classroom. Following the case study design, data were collected. Following the case study design, data were
collected through multiple sources including interviews, artifacts, classroom observations, and journals. This included more than 30 student artifacts that were gathered to represent a variety of work samples that were generated from artifacts and as another way to understand how iPads can support the learning process. Classroom observations were also conducted during a social studies class to help triangulate the findings. Additionally, researcher journal was kept and member checking with participants was used to enhance the trustworthiness of the findings.

This analysis produced three main findings. This includes feedback and observations that suggests that I’ve had to have specific functionalities that can be used to support SLE, observations that suggest that student engagement increases with the use of iPads during content lessons; and that both teachers and students perceived language and cognitive growth in SLE when using the iPad for instruction. Specifically, When looking at the functionality and options are available through an iPad, Observations and interviews conducted with the participants suggested that the international settings (i.e., multiple language keyboards, translation applications, text-to-speech) were beneficial allowed students to work in their L1 and L2. Additionally, the visuals and print translation that were provided through multiple applications were useful in explaining and clarifying content area vocabulary and supplementing teacher lead instruction. Another key finding was that the iPad supported communication between students and their teacher as well as provided multiple ways for students to demonstrate their learning. This includes supporting the sharing of documents between students and teachers, utilizing translation services in the communication between students and teachers, and provided multiple ways students record or demonstrate their knowledge in a variety of ways (i.e, drawings, diagrams, video/audio recordings, typed responses). A second finding was related to the engagement students demonstrated when iPads were used during instruction. During lessons
when the iPads for utilized it was noted that there was a need for less redirection and that students were on task more often during instruction. Additionally, the use of iPads during instruction also supported increase student responses and participation in classroom activities that were differentiated through various applications or synchronous activities delivered through the iPad. Through interviews with the students Prince (2017) also suggested that students may have been more aware of their own learning and that along with engagement in lessons students were more independent using an iPad. It was noted however that the teacher participant expressed concern with engagement as the use of the iPads could support student off task behavior. The final area findings looked at how the use of an iPad supported students language development and content knowledge. While no quantitative measures of content knowledge or proficiency were used, teacher observations, testing reflections, and researcher observations were used to describe this area. Both teacher and student participants reported feeling that the use of an iPad in class supported both the acquisition of content knowledge and language development. The findings of this case study suggests that singular mobile devices such as iPads can serve as suites or delivery methods of a variety of instructional supports in content area courses for SLE. However, while the study highlights a limited samples experience using an iPad for instructional purposes, there are limitations to the findings that should be considered. These include the small sample size, lack of quantitative measures to report student outcomes, lack of detail as to exactly how iPads were used for instruction and language development purposes, and the lack of a comparison group to control for how no use of personal devices such as iPads could affect student perceptions of language development and content knowledge. Future research should continue to measure the perceptions of participants using technology in the classroom, but should highlight specific applications, specific design features within technology-based tools that
support student learning outcomes, in the role teachers play in utilizing technology-based tools as delivery methods and supplements to their instruction.

Andrei (2016) conducted a study that investigated how teachers specifically used technology to support SLE. This included taking stock of the different types of technology available to teachers in various classrooms and discussing how these were used to deliver instruction to students. Specifically this research look to describe how teachers use technology in the classroom, what factors influence their use of technology, and how specific changes will enable them to use technology more often and more effectively. Participants for the research included three middle school teachers who are responsible for providing English as a Second Language (ESL) instruction to SLE. These teachers worked at schools that had higher than average rates of SLE. Teachers were between the ages of 26 and 32, were certified in ESL and had four or five years of teaching experience.

In describing the technology available for use by teacher participants the terms old and new technology. New technology included items such as laptops, iPods, digital boards, personal devices with Internet connection, while old technology consisted of televisions, blackboards, white boards, or textbooks. The amount and type of technology varied across the three teachers classrooms though both new and old technology were available to all teachers. To collect data and report on how teachers utilize technology in the classroom, classroom observations were conducted. The observation occurred in the three teachers classrooms which were designated as self-contained ESL language arts classes, and only included SLE at the beginning stages of language proficiency. Classroom observations were conducted once a week for a total of 10 weeks and teacher interviews were conducted three times about teacher using technology. Data collection and analysis for reported to have occurred simultaneously and that an iterative process
was used. As data were collected reflections were conducted to look for themes and emerging ideas. At the end of data collection things were identified and supporting evidence for these themes were categorized and organized to support the findings.

Findings from the iterative qualitative design suggested that teachers were comfortable users available technology despite having a little training. The teachers experience frequent instances of technology malfunction, and that these factors translated into frequent but basic use of available technology. It is suggested that teachers were comfortable and frequent users of technology as they were all within the first few years of their teaching careers and familiar with new technology available. It was also reported that certain factors influence teacher use of technology. These factors included whether technology would make a process more expedient and more user-friendly for students, and if they help reach content area objectives and goals. Additionally, teachers reported that the amount of time it would take to learn or implement new technology influence their decision to use specific tools. It was also reported that would tools teachers were comfortable with, there was an easy implementation and transitions between use of interconnected technology in the classroom (i.e., transitioning from teacher computer to document camera and laptop). Teachers also use technology to vary the ways in which they delivered instruction and assess student knowledge. This included using personal devices such as iPods to allow students to record responses, using Internet searches to provide descriptions and visual representations of content, any use of digital boards to project and model tasks. A second area of findings were related to teacher concerns specifically focused on the impact technology malfunctions had on classroom instruction. All teachers expressed concerned that the use of new technology could cause classroom interruption or lack of productivity due to miss use of the technology or possible malfunctions. Teachers reported often needing a backup plan in the
instance that technology malfunctioned. This assertion was reinforced by classroom observations that demonstrated teachers often had to transition to separate activities when malfunctions occurred. Based on the findings of this research, it is suggested that potential benefit could arise from teachers receiving additional planning time and professional development for the use of existing technology in determining how to best fit that into their classrooms to support these diverse academic and linguistic needs of SLE.

Similar to previous studies, the findings of this research are illuminating and shed light as to how teachers use technology to support their practice and the needs of SLE. However similar limitations to these findings exist as well. While it is helpful to understand how technology is using the classroom, to be able to generalize this using technology and to support its use, Academic outcomes related to specific activities should be reported. Additionally, guidance for how students with specific language proficiencies respond to specific technology based interventions should also be reported, with guidance provided in how technology based tools can be used to differentiate Academic and linguistic materials for SLE.

In a study that provided insight into a specific intervention delivered through technology, Macaruso and Rodman (2011) evaluated the benefits of computer-assisted instruction (CAI) in supporting the reading acquisition of SLE. The purpose of this study were to extend the findings of previous studies conducted with CAI and reading for SLE. Specifically, the purpose of this study was to compare the effectiveness of a CAI reading program to that a traditional classroom instruction. As part of the research 66 students identified as SLE participated in the research. These participants were sampled from four kindergarten classrooms and assigned to CAI or BAU conditions. To compare the effectiveness and value added value of each intervention, the Group Reading Assessment and Diagnostic Evaluation (GRADE) was used as a pre- and post-
test. This assessment contained subtest for rhyming, print awareness in sound matching, letter recognition and listening comprehension, phoneme-graphing correspondence, and word reading. A series of independent samples t-test were run prior to implementation and study to ensure that participants did not contain significant differences on these measures. The results of this analysis indicated that students displayed comparable pre-literacy skills prior to the implementation of study.

Students in both conditions received traditional language arts instruction that included lessons guided by commercially available reading and phonics programs. These programs were characterized by guided reading activities that taught students strategies for reading comprehension and systematic instruction in phonemic awareness and phonics. To supplement and reinforce this instruction students in the CAI conditions were provided opportunities to utilize the CAI program, Lexia. This program was utilized with regular weekly use, with 2 to 3 sessions per week lasting 15 to 20 minutes per session. For students in the CAI conditions there were guidelines provided to teachers for use, ensuring that students have access to the program each week, and teachers were provided training as to how the program could supplement their traditional instruction. Students were placed in level one of the program and allowed to work through activities at their own pace working through discrete units designed to enhance phonological awareness and an initial blending. Across eight months of the school year, students completed lessons designed to enhance early literacy skills including: (a) phonological awareness, (b) recognition of initial and final sounds, (c) rhyming words, (d) segmenting words and syllables, (e) blending syllables, (f) identifying letter sound correspondence for consonants and vowels, and (g) consonant digraphs. These lessons were delivered through discrete units built into Lexia. Students in the control condition were provided the same amount of time to
work on a separate computer program the provided games that reinforced math and reading related skills. The students were provided the choice of what games, either math or reading based, they worked on during this time.

Following implementation of the study, the same sections of the GRADE were administered. A series of one sample $t$-tests were conducted to examine games for each domain measured by the GRADE. Through the series of $t$-tests, significant difference in gains between the CAI and control condition were reported in the domain of phonological awareness and word reading. In the areas of rhyming, print awareness and sound matching, letter recognition and listening comprehension, gains were reported for each group, with no significant differences noted between the groups through the use of $t$-tests or for when pretest scores in each domain were used as covariates to post-test scores. The results of this study suggest that CAI or other technology based tools can support the development and reinforcement of reading skills for SLE. This includes when these types of tools are used to supplement traditional teacher led-instruction. When considering these findings, it is important to consider the limitations to the study as well. These limitations include a small sample size, not accounting for differences in student language proficiency, and not controlling for the quality of the typical reading instruction students received during the extended intervention period. Future research in this area should continue to investigate the impact technology-based tools have on the literacy development of SLE who have a variety of language proficiencies and are enrolled in higher grades. Additionally, with the variety of instructional settings SLE are served in, the use of technology-based tools should be evaluated as part of curricula used in both sheltered and inclusive instructional settings.

An additional study conducted by Ryoo (2015) investigated how technology could differentiate the language complexity used in instruction. The goal of this study was to embed
every day social language into science through technology rather than the typically dense and
ccontent specific language used in science. Specifically, this study looked to examine the effect
teaching complex science concepts in everyday English prior to teaching complex science
concepts in technology enhanced instruction when compared to a textbook based approach.
Participants were sampled from nine classrooms and included 220 fifth graders in general
education classrooms, with 68 students identified as SLE. Student participants were randomly
assigned to everyday English or textbook based conditions.

Prior to the administration of the study, all students were individually administered paper
and pencil pretests. A week after the pre-test word ministered students began working on web-
based instruction on photosynthesis and respiration in their schools computer lab for three days.
each session lasted approximately 50 to 60 minutes. Students in the everyday English condition
completed everyday English versions of the web-based instruction that covered concepts in
student friendly terms prior to providing vocabulary instruction while students in the textbook
condition previewed the same concepts in everyday English but had scientific vocabulary
instruction simultaneously provided.

The web-based instruction was developed using an iterative process and consisted of
three main activities that taught the key concepts of photosynthesis and respiration. These items
were developed by the team of participating teachers and the researcher, covering material that
was gleaned from the textbooks used in the textbook based condition. The web-based
construction was used by both conditions and provided information through multiple
representations that included text, visuals, and animations. This included dynamic visualizations
that supported student investigation into the unseen and abstract processes of photosynthesis.
Each condition provided students three activities to complete. The first activity was developed to
describe the process of photosynthesis. This included for lessons using interactive and dynamic visualization to describe the process. In the everyday English version concepts were time in plain language without introducing any content specific vocabulary where is in the text book version the second activity was designed help students acquire vocabulary related to photosynthesis. The everyday English version league students new vocabulary words to everyday English terms where is the textbook only version focused on the technical definitions for each term. The final activity provided students multiple opportunities to use newly acquired terms and solve problems related to photosynthesis to virtual experiments. This activity focused exclusively on scientific vocabulary and no difference between the two conditions existed in this step. Students were allowed to self-pace themselves through these tools, and view the visualizations and explanations individually.

Following student use of these materials, two assessments were administered. These included a multiple-choice test and a short essay test. These were developed to measure students ability to make connections between their understanding of scientific concepts and terms. Multiple-choice test measured dunes understanding of photosynthesis and contained 18 items. The short essay test measured students ability to articulate their understanding of the concepts of photosynthesis and required students to use specific vocabulary terms in their answers. The multiple, choice test had a total of 18 points and the short essay test was scored using rubrics that totaled 24 points.

Data from these assessments were used to compare the effectiveness of each intervention. To compare student scores on the pre- and post-measures, separate repeated measures ANOVA was conducted to compare student scores on the multiple choice and short answer tests. Results for the multiple-choice analysis produced a significant interaction effect for time and condition
and a significant main effect for time. No significant effects were reported for condition. Similarly, for the short essay test, a significant interaction was present for time and condition, with a significant main effect also produced by time. No significant effects were seen by condition. These results suggest that both versions of instruction were effective at providing science instruction to SLE.

**Common Features of Technology Use for Diverse Student Populations**

For both SWD and SLE, technology is used by teachers to augment and supplement their traditional instruction. For both student groups these approaches are meant to support access to general education instruction and learning activities. To accomplish this task, these tools are used to provide multiple representations of topic covered and provide students multiple forms of comprehensible input that traditional methods might not be able to provide. Another common feature with the use of technology between both student groups is that technology can be used to alter the content delivered to students to support their independent use of the materials without teacher guidance. With the role vocabulary plays in science, technology can prove to be an effective method for delivering individualized vocabulary instruction that provides the appropriate supports for SWD and SLE. This includes providing students multiple representations of content through multimedia and instructional supports through digital tools (i.e., text to speech, instructional videos, hyperlinks).

**Summary**

Contemporary science education focuses on the development of science knowledge through hands-on activities that deepen students understanding of science phenomena and practices. However, for SWD and SLE, making the connections between the experiences in hands-on activities to bodies of science knowledge can be difficult without requisite background
knowledge or language skills. A common approach that supports content are learning of SWD and SLE is direct and explicit academic vocabulary instruction. This instruction builds background knowledge and primes students to participate in other activities that extend their knowledge of domain specific concepts. Additionally, the literature supports the notion that teachers that are provided the training and curricula can support positive learning outcomes in content area classes like science for SWD and SLE. However, while research exists that suggests Tier I vocabulary instruction can be implemented with SWD and SLE in general education classrooms, this research does not report interventions that have been used with SWD and SLE simultaneously. Because of this, there are some differences in the recommendations for how to effectively deliver Tier I vocabulary instruction for both groups in inclusive classrooms. While technology has also been shown as an effective instructional delivery tool, there is also limited research that discusses how these tools can be delivered as a Tier I intervention or in multi-tiered system of support (MTSS) for both SWD and SLE in inclusive classrooms. The purpose of this research is to provide preliminary findings for the efficacy of technology based tools and their use with SWD and SLE.
As employment becomes more competitive and jobs become more specialized, current educational reforms have focused on ensuring students are ready for the college and career demands of the 21st century. Guiding educational practice in science, the NGSS outline educational standards and practices meant to prepare students to be college and career ready (NRC, 2012). Shifting from previous models of science education that focused on direct instruction and memorization of science concepts, the NGSS outline expectations and standards for the exploration of science concepts and use of scientific practices (Krajcik & Merritt 2012). This focus on student application of science knowledge and practices is meant to prepare students for the problem-solving nature of STEM careers and the rigorous academic demands of entry level college science courses (Jung, 2016).

With SWD and SLE gaining increased access to general education science classrooms, their exposure to curricula focused on college and career readiness in science can help to bridge the employment gaps these populations experience in STEM fields when compared to their English-speaking peers without disabilities (Gottfried, et al 2016). However, inclusive science classrooms that previous research (King-Sears et al 2014) has characterized as being driven by Tier I interventions led by general educators who may be unprepared to meet the needs of diverse learners (Brigham, et al 2014; Lee, et al 2014) should include additional supports to meet the needs of SWD and SLE. Approaches that have been shown to support the needs of SWD and SLE in science are interventions that prime students with essential conceptual knowledge through academic vocabulary instruction. However, because SWD and SLE have unique
learning needs, flexible instructional approaches and tools should be used to provide evidenced based interventions for both groups. Instructional technology has been shown to deliver instruction that supports the needs of both student populations (Golonka, et al 2014; Nordness, et al 2011). This study looked to compare the effectiveness of Tier I vocabulary interventions delivered in inclusive science classrooms delivered through TLI or PMI. The purpose of this study was to investigate the effectiveness of TLI or PMI delivery methods, as well as the impact of timing of instructional delivery in relation to inquiry-based activities that allowed students to explore the concepts covered in the TLI and PMI, on depth of vocabulary knowledge.

**Research Questions**

This research study was designed to answer the following questions:

Research Question 1: Is there a statistically significant difference in the depth of word knowledge of students with disabilities participating in treatment conditions compared to students in the control condition?

It was predicted that students who receive vocabulary instruction via mobile devices prior to hands on activities will have significantly higher depths of vocabulary knowledge than students in the other treatment conditions.

Research Question 2: Is there a statistically significant difference in the depth of word knowledge of students learning English participating in treatment conditions compared to students in the control condition?

It was predicted that students who receive vocabulary instruction via mobile devices prior to hands on activities would have significantly higher depths of vocabulary knowledge than students in the other treatment conditions.
Research Question 3: Is there a statistically significant difference in the depth of vocabulary knowledge of SWD and SLE based on the timing of their vocabulary instruction?

It was predicted that participants (i.e., SWD, SLE) who received instruction prior to engaging in inquiry assignments would have significantly higher depths of vocabulary knowledge than students who received vocabulary instruction following an inquiry assignment.

Research Question 4: Are there differences in teacher perceptions of student learning based on the treatment group they participated in?

It was predicted that teachers would have higher views of student learning when a technology-based intervention was implemented in their classrooms.

Research Question 5: Are student perceptions of their own learning different based on the treatment group they participated in?

It was predicted that students will have higher perceptions of their own learning when a technology-based intervention was implemented in their classrooms.

Participants

Participants in this study included students in inclusive biology classrooms, including students receiving special education services, SLE, and their teachers. These students and teachers were sampled from inclusive high school biology classrooms from three school sites in an urban school district in the Southwest. Tables 1 and 2 provide demographic data for the participants of the study.
Table 1.  
**Student Demographic Data**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Personal Mobile Instruction-Prior</th>
<th>Personal Mobile Instruction-Following</th>
<th>Teacher Led Instruction-Prior</th>
<th>Teacher Led Instruction-Following</th>
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<td>4</td>
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<td>0</td>
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<tr>
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<td>4</td>
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<td></td>
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<tr>
<td>Student Learning English</td>
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<td>4</td>
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<td>4</td>
<td>8</td>
<td>4</td>
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<td>4</td>
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<tr>
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<td>0</td>
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<tr>
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</table>

Table 2.  
**Teacher Demographic Data**

<table>
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<th>Condition Assigned</th>
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<th>Gender</th>
<th>Ethnicity</th>
<th>License</th>
<th>Years Teaching</th>
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<td>Personal Mobile Instruction-Following</td>
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<td>General Education Science</td>
<td>6</td>
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<td>Personal Mobile Instruction-Following</td>
<td>36</td>
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<tr>
<td>Teacher Led Instruction-Prior</td>
<td>37</td>
<td>Female</td>
<td>Caucasian</td>
<td>General Education Science</td>
<td>4</td>
</tr>
</tbody>
</table>
Students with Disabilities

Students who participated in the study were enrolled in an inclusive biology class and identified by a multidisciplinary team as having a disability receiving special education services via an individualized education plan (IEP). Participating SWD were eligible for services under the categories of LD, autism, and other health impairment (OHI). This information was provided by the participating teachers on a student enrollment form (See Appendix A) after parents and students provided consent for this information to be obtained.

English Language Learners

Students learning English were also recruited for this study. Once consent was obtained from students, teachers provided this information from the student enrollment form. This information was used only to identify students’ classification as an English learner, not their specific language proficiency.

Student Selection Procedures

Students included in this study met the following criteria: (a) they received science instruction in an inclusive biology classroom, and (b) received special education services under an IEP, or (c) had a current or previous identification as a SLE. These students were sampled through a convenience sample and were randomly assigned to treatment groups at the site level. Prior to participation in the study, parents (See Appendix B) and teachers (See Appendix C) were asked to provide informed consent; students were asked to provide student assent (See Appendix C).
D). These forms explained the study, its purpose, risks and benefits of participating, and contact information for the investigators.

**Teacher Selection Procedures**

General and special education teachers providing instruction in the recruited science classes were invited to participate in the study as well. To be included, teachers had to be assigned as a co-teacher in an inclusive biology classroom. This included fully or provisionally licensed teachers or substitutes.

Prior to the study, meetings with school principals at the participating sites were held to identify potential general and special education teacher participants. The student investigator then met with the identified general and special educators to inform them of the study, its purpose, specific research questions, and to discuss the teachers’ role in the study. One special education teacher served dual roles in this study, working in both the TLI and PMI classrooms at one site. Prior to the study, this teacher met with the student researcher and agreed not to use any materials from either treatment group in classes they were not assigned to during the study. Treatment fidelity was measured during each lesson to ensure this did not occur. Additionally, drop-in observations of the classrooms during traditional instruction occurred to be sure implementation of study materials was not occurring. Following the meeting teachers were provided an informed consent form to indicate their desire to participate in the study.

**Setting**

This study took place in inclusive Biology classrooms in a large urban school district in the Southwest. All classrooms served high school aged students, including SWD and SLE. Each
classroom was taught by a science and special education teacher who both agreed to participate in the study. Additionally, as a requirement for participation, all classrooms sampled were required to have access to Wi-Fi and enough site based mobile devices for each individual student to use in the sampled classrooms, in the event that the classroom was assigned to a PMI condition.

**Instrumentation**

This study utilized multiple instruments to collect data. These instruments included: (a) pre- and post-test measures of student recall and application of specific science vocabulary targeted in the study, (b) classroom observation checklists, (c) teacher fidelity checklists, (d) student perception surveys, and (e) teacher perception surveys.

**Pretest and Posttest**

This study utilized a paper and pencil pre-and posttest to determine differences in students’ ability to recall and apply definitions of specific science vocabulary terms after receiving vocabulary instruction. However, traditional tests of student vocabulary knowledge have been criticized for being shallow measures of student word knowledge by focusing solely on their ability to recall or match definitions rather than a student’s depth of word knowledge (Graves, August, Mancilla-Martinez, 2013; Stahl & Bravo, 2010). To address the multiple dimensions of student word knowledge, the pre- and posttest contained open- and closed-ended questions that mirror previous measurements used in content area vocabulary research (i.e., Harris, et al, 2011; Kennedy, et al, 2015; Terrill, et al, 2004) that have students not only recall the definitions for terms, but also provide contextual information for these terms as well. To accomplish this, the pre- and posttest contained two sections. The first section was an open-ended response section where students provided contextual information related to a term. As
Stahl and Nagy (2006) suggested, deep learning of content and domain specific (i.e., tier 3) words requires students to orient those words in a system of ideas or contexts within a discipline.

To measure student contextual understanding of specific science terms, a 4-point scale rubric (See Appendix E) was used to score student responses. On the second section of these tests, students matched sentence stems containing content specific vocabulary to the correct definition in a multiple-choice format. These sections were administered separately across multiple school days, to avoid any influence of provided answers as choices on students’ open-ended responses. Scores from both instruments were then combined to provide a measure of students’ depth of vocabulary knowledge.

**Classroom Observation Forms**

This study took place in a condensed amount of time, with approximately 300 minutes of classroom time controlled for in each treatment group. While this amount of instructional time falls short of the recommendations made by Gersten and Edyburn (2007) for research investigating technology-based interventions, the instructional time frame is similar to many technology-based interventions previously conducted (e.g., Kennedy, et al., 2015; Marino, et al., 2014; Slavin, et al., 2014). Additionally, this study was conducted across sites with multiple teachers. To address potential extraneous variables (e.g., incidental teaching of vocabulary) a classroom observation form (See Appendix F) was used to compare instructional styles across sites and teachers. Observations were conducted several times in each participating teacher's classroom prior to the implementation of study materials to establish a comparable baseline for how the recruited co-teachers followed their established lesson plans that embedded vocabulary instruction in their lessons. This approach followed the methods of previous research (Israel, et al 2016; Marino, et al 2014; Swanson, Orosco, Kudo, 2017; Wexler, Mitchell, Clancy, &
Silverman, 2017) to help control for extraneous variables (i.e., difference in teacher approaches, incidental vocabulary teaching) that may have affected the results of the study. The observation form was used to measure co-teachers’: (a) adherence to their lesson plans, (b) use of vocabulary instructional techniques during lessons not designed as vocabulary lessons, (c) teacher rapport with students, (d) behavior management in the classroom, and (e) use of co-teaching strategies. The form produced teacher scores related to the frequency and quality of vocabulary instruction, quality of teacher rapport with their students, and behavior management strategies used in their classrooms. Scores in each of these areas were compared to ensure that differences were not present that could influence the findings of the study when scripted lessons or activities were not provided. Two additional drop-in observations were conducted with each treatment group during days the study was not being conducted to continue monitoring for differences in instruction and content provided to students.

**Student Perception Surveys**

Following the study, students took a survey regarding their perceptions of their science knowledge. This survey (See Appendix G) related to how well they felt they understood the concepts taught after having received science-related vocabulary instruction. Students responded to Likert items on a 5-point scale where 1 was strongly disagree and 5 was strongly agree; surveys also included open-ended questions for students to provide feedback.

**Teacher Perception Surveys**

Following the study, teachers completed a survey (See Appendix H) measuring their perceptions of students’ science knowledge. This survey related to how well they felt students understood the concepts taught after having received vocabulary instruction in science.
Participating teachers responded to Likert items on a 5-point scale where 1 was strongly disagree and 5 was strongly agree; teachers were also provided an area to provide open-ended feedback.

**Teacher Fidelity Checklist**

During the study, participating teachers were observed to measure their fidelity to the implementation of the scripted lesson plans for TLI, or protocols for PMI and hands-on activities. A checklist was used to measure teacher fidelity of implementation (See Appendix I). A goal of 100% procedural fidelity was set for all lessons. If teachers fell below this level during a lesson, procedures were in place for the student investigator to meet with the participating teachers to discuss components of the lesson that needed to be covered for that class section, and to schedule time with the teacher to deliver this instruction to students.

**Materials**

This study required the use of several materials. For the TLI conditions, the following materials were used: (a) scripted lesson plans, (b) projection hardware, (c) presentation software, (d) student science notebooks, and (e) protocols for implementing hands-on science inquiry activities. For the PMI conditions, the following materials were used: (a) implementation protocols, (b) mobile devices, (c) online presentation software, (d) student science notebooks, and (e) protocols for implementing hands-on science inquiry activities. The science notebooks and inquiry activities were the same across conditions.

**Scripted Lesson Plans for Teacher-Led Instruction**

For the conditions where teachers delivered vocabulary instruction, teachers were provided scripted lesson plans to follow (See Appendix J). These instructional sequences
included: (a) orienting students to the contexts in which words were to be used, (b) developing definitional knowledge, (c) providing examples and non-examples, (d) developing relationships between words through semantic and morphological features, and (e) supporting student use of the terms. These lessons were accompanied by paper and pencil science notebooks that students completed during instruction. The scripted lessons and science notebooks were developed by the student researcher and were aligned to the academic content standards covered during the study. The targeted standards are provided in Table 3. For each standard, seven aligned vocabulary terms (See Table 4) were taught for three 50-minute vocabulary lessons. Each scripted lesson plan was designed to ensure that teachers were able to deliver all components of instruction for all seven terms within a 50-minute period of time. Group assignment determined if these lessons occurred prior to or following a related hands-on science inquiry activity.

Table 3.  
**Nevada Academic Content Standards Covered**

<table>
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<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS.LS.3.1</td>
<td>Ask questions to clarify relationships about the role DNA and chromosomes in coding the instructions for characteristic traits passed from parent to offspring.</td>
</tr>
<tr>
<td>HS.LS.3.4</td>
<td>Use a model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms.</td>
</tr>
<tr>
<td>HS.LS.3.2</td>
<td>Make and defend claims based on evidence that inheritable genetic variation may result from: (a) new genetic combinations, (b) viable errors occurring during replication, or (c) from mutations caused by environmental factors.</td>
</tr>
</tbody>
</table>

Table 4.  
**Vocabulary Terms**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Aligned Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS.LS.1.5</td>
<td>Genetics, DNA, Chromosomes, Heredity, Traits, Genotype, Phenotype</td>
</tr>
<tr>
<td>HS.LS.1.6</td>
<td>Cell Division, Parent Cell, Mitosis, Meiosis, Probability, Dominant, Recessive</td>
</tr>
<tr>
<td>HS.LS.1.7</td>
<td>Genetic Variation, Mutations, Mutagens, Carcinogens, Epigenetics, Cell Specialization, Levels of Organization</td>
</tr>
</tbody>
</table>
Table 5 displays the instructional sequences for each condition. These activities were aligned to the same content standards as the vocabulary lessons and were designed to be completed individually by participating students.

<table>
<thead>
<tr>
<th>Week</th>
<th>Personal Mobile Instruction-Prior</th>
<th>Personal Mobile Instruction-Following</th>
<th>Teacher Led Instruction-Prior</th>
<th>Teacher Led Instruction-Following</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Day 1: Vocabulary Instruction on Mobile Devices</td>
<td>Day 1: Inquiry Assignment</td>
<td>Day 1: Teacher led Vocabulary Instruction</td>
<td>Day 1: Inquiry Assignment</td>
</tr>
<tr>
<td></td>
<td>Days 3-5: Typical Instruction</td>
<td>Days 3-5: Typical Instruction</td>
<td>Days 3-5: Typical Instruction</td>
<td>Days 3-5: Typical Instruction</td>
</tr>
</tbody>
</table>

**Interactive Lessons for Personalized Mobile Instruction**

The same components of robust vocabulary instruction included in the teacher led lessons were embedded into the PMI lessons students used. The presentations were accessed through an online presentation platform. The same standards listed in Table 3 and terms listed in Table 4 were used for the PMI conditions. Students had 50-minutes to complete the mobile presentations and accompanying science notebook activity at their own pace. Whether these activities took place prior to or following a related hands-on inquiry activity was determined by group assignment.

**Online presentation platform.** To deliver the instructional content to students, the online presentation platform *eMaze* (Visual Software Systems Ltd., 2015) was used. *eMaze* was chosen for use in the study due to the creating, editing, and presentation tools that are built into
the platform. Most importantly, *eMaze* allows for clear connections to be made between the design components and instructional tools within the platform as checkpoints of integration of the UDL Guidelines (CAST, 2011). A multimedia planning framework (See Appendix K) was used to develop the instructional components of each word in the modules and was used to maintain the relationship between the design options and instructional tools used in *eMaze* to specific tenets of UDL and evidenced-based multimedia practices (i.e., CTML principles). This framework is similar to one developed by Kennedy et al. (2014) to align tenets of UDL and CTML, and includes guidelines for the interactive features of the PMI modules. A final consideration made in utilizing *eMaze* was its portability. Samples of these products are provided in Appendix L. As an online platform, it was able to deliver presentations via the internet to a wide variety of devices. This eliminated any difficulties that could have arisen with differences in device availability across sites.

**Science Notebooks**

For each vocabulary lesson and accompanying hands-on inquiry assignment, students also completed a science notebook (See Appendix M). Previous research has suggested the efficacy of using science notebooks to help guide student learning and inquiry within science content areas (Rappolt-Schlichtman, Daley, Lim, Lapinski, Robinson, & Johnson, 2013). These notebooks guided student participation in their hands-on science activities. These notebooks served as a guide for students to word map, record definitions, and make any other notes during vocabulary instruction. During inquiry activities, the notebooks provided space for students to record data and their observations as they completed hands-on activities. For both activities, the science notebooks were meant to support student inquiry while highlighting the key information and tasks to focus on. These materials were stored in individual folders for each student and were
checked after each day of instruction by their teacher to measure the work students completed. These materials were developed by the student researcher.

**Inquiry Assignment Protocols**

Inquiry assignments were used in this study to orient students to science phenomena by allowing them to witness concepts through hands-on activities. These activities were completed by students independently. Participating teachers served in a support role during these activities. 

To guide teachers during these activities, lab protocols and scripted introductions to the lesson were developed by the student researcher. Teachers were provided scripted lesson plans that introduced the activities, as well as completed protocols to help them answer student questions.

**Design and Procedures**

This study took place in two phases. During phase one, consent from participants was obtained, necessary teacher and student training was provided, intervention groups were assigned, and pre-tests were administered. In the second phase, the intervention took place across four weeks for six days of instruction, posttests were administered, perception surveys were implemented, and data were collected and recorded.

**Phase One**

During Phase One, support for the study was obtained. Administrators were contacted via e-mail, inviting their school site to participate in the intervention. Once administrators agreed, email fliers were sent to teachers in inclusive science classrooms to recruit teacher interest. Once teachers were chosen, a one-hour training was provided to teachers at their school site in order to prepare them to implement the intervention for their assigned treatment group. Observations of
teachers’ classrooms were conducted to establish a baseline of typical instructional practices. Consent was also obtained from parents and assent from students. For students assigned to the PMI conditions, a tutorial presentation that oriented students to the use of the presentation software was also provided. Finally, the pre-test was administered prior to delivery of any interventions.

**Consent.** Informed consent was obtained from participating teachers and students' parents, as well as assent from students. The student researcher provided teacher consent forms at teacher meetings and discussed requirements for participation in the study. For students' parents, consent forms detailing the study were sent home with students. For students' parents who provided consent, assent forms were obtained from students. The student researcher presented the details of the study to students prior to obtaining assent. These forms were also collected prior to beginning any study related interventions.

**Teacher training.** To implement either the TLI or PMI conditions, participating teachers, both general and special educators, received training related to their assigned conditions. For teachers in the PMI conditions, training consisted of how to: (a) introduce each day’s lesson, (b) log into the presentation platform, (c) navigate each presentation, (d) troubleshoot any problems that may arise while students were utilizing the presentation software, and (e) implement the accompanying science notebooks students were to complete during this instruction. Teachers in the TLI conditions went over lesson materials (i.e., presentation slides, science notebooks, scripted lesson plans) with the student researcher. All participating teachers received the same training on how to implement the inquiry assignments. These trainings took place at each participating teachers’ school and took approximately one hour.
**Student training.** Students assigned to the PMI groups received training for how to navigate the online presentation platform. This training included students being provided a tutorial presentation. The purpose of this presentation was to familiarize students with the functions and structure of the online presentation platform. No vocabulary instruction was delivered in this tutorial. Rather, instruction for how to navigate the resources and tools embedded within *eMaze* was provided. This included how to (a) log into the program, (b) utilize hyperlinks within each presentation, (c) access instructional videos, and (d) utilize translation tools within the program.

**Pretest.** Prior to beginning the intervention students completed the pretest (See Appendix N). Data were only analyzed from students who had both parental permission and who provided assent, but all students enrolled in the classroom participated in the pretest process as this intervention replaced typical instruction in the classroom environment. The pretest included multiple measures of vocabulary acquisition that were contextualized and decontextualized. Assessments were aligned to the terms selected for the intervention and designed to measure students’ depth of vocabulary knowledge. Students were administered each section of the assessment separately. For the contextualized assessment, students were provided sentence stems for all 21 terms (e.g., DNA is) and tasked with matching the stem to the appropriate definition in a multiple-choice format. For the decontextualized section, students were provided each term and space to provide their own definitions for the term and any other contextual information they could provide. Students in all treatment conditions took the pretest.

**Phase Two**

During Phase Two, the interventions for each condition were implemented. Three 50-minute vocabulary lessons were provided for students in the treatment groups. Three 50-minute
inquiry assignments were also completed by students in the treatment groups. These inquiry assignments took place either prior to or following inquiry, based on student assignment to one of the four treatment groups. Once students completed these activities, they completed the posttest and perception surveys. Throughout the study, fidelity of implementation was collected for teachers in each treatment condition regarding their implementation of lesson plans and protocols. Following the study, teachers also completed perception surveys.

**Lesson implementation.** Interventions within each treatment were implemented within units of instruction aligned to the same set of standards assigned by the school district this study took place in. These lessons took place following instruction covering energy transfer within ecosystems and covered topics related to how complex organisms form from single cells. All teachers who participated in the research were at different points in their curriculum when the research began. To ensure that the lessons for this research were implemented in the appropriate sequence, the student researcher met with the participating teachers to schedule the appropriate time to implement the vocabulary lessons and inquiry assignments. These groups implemented the interventions across multiple weeks, with six total days of instruction dedicated to the study.

The first set of lessons covered HS.LS3.1 and was designed to provide students instruction for key vocabulary terms that helped describe the processes for how traits and genes are passed on from generation to generation. This included vocabulary instruction for seven terms and a hands-on activity that was designed to get students considering how parent and offspring share and pass on traits. The second set of lessons covered HS.LS3.4 and was designed to provide students instruction for key vocabulary terms that helped describe the processes for cell division and describe how complex organisms form to be different. This included instruction for seven vocabulary terms and a hands-on activity where students
completed coin flips to simulate the passing on of traits between generations. The final set of lessons covered HS.LS3.2 and was designed to provide students instruction for key vocabulary terms that helped describe how environmental factors can influence how genes and traits are expressed. This included instruction for seven vocabulary terms and a hands-on activity where students simulated the impact a mutation could have on the survival of a species.

**Posttest.** At the completion of the study, the posttest was administered. The posttest was the same test that was administered as the pretest. The posttest was implemented and scored in the same fashion as the pre-test. Data from the post-test were collected, scored, and entered into SPSS for data analysis.

**Perception surveys.** Following the study, the student and teacher perception surveys were administered. The surveys were designed to measure student and teacher perception of students’ science knowledge after receiving vocabulary instruction in science, as well as what teachers thought of the instructional approaches they implemented. The surveys included a Likert rating scale from 1 (strongly disagree) to 5 (strongly agree). Responses on the perception surveys were entered into Microsoft Excel, and averages of student responses were calculated across treatment groups for analysis.

**Treatment of the Data**

Research Question 1: Is there a statistically significant difference in the depth of word knowledge of students with disabilities participating in treatment conditions compared to students in the control condition?

Analysis: In order to determine if there was a significant difference between the depth of word knowledge between students with disabilities in the treatment conditions, a 2x2 repeated
measures ANOVA was conducted to determine if there was a difference in group scores over time. An Alpha Level of .01 was established.

Research Question 2: Is there a statistically significant difference in the depth of word knowledge of students learning English participating in treatment conditions compared to students in the control condition?

Analysis: In order to determine if there was a significant difference between the depth of word knowledge between students learning English in the treatment conditions, an independent samples t-test was conducted to determine if there was a difference in group scores over time. An Alpha Level of .01 was established.

Research Question 3: Is there a statistically significant difference in the depth of vocabulary knowledge of SWD and SLE based on the timing of their vocabulary instruction?

Analysis: In order to determine if there was a significant difference between the depth of word knowledge between students based on the timing of instruction, a 2x2 repeated measures ANOVA was conducted to determine if there was a difference in group scores over time. An Alpha Level of .01 was set.

Research Question 4: Are there differences in teacher perceptions of student learning based on the treatment group they participated in?

Analysis: Descriptive statistics (i.e., mean, median, standard deviation) were reported to describe and compare teacher perceptions.

Research Question 5: Are student perceptions of their own learning different based on the treatment group they participated in?

Analysis: Descriptive statistics (i.e., mean, median, standard deviation) were reported to describe and compare student perceptions.
Across all statistical analyses, effect sizes were calculated using Cohen’s $d$, where the difference between group means ($M_1 - M_2$) was divided by the pooled standard deviations of the groups. The guidelines established by Cohen (1988), were used to describe effect sizes.

CHAPTER FOUR

RESULTS

In a world driven by technology and innovation, future employment opportunities are predicted to be plentiful in STEM fields (Carnevale & Smith, 2011). However, individuals with disabilities and persons from culturally and linguistically diverse (CLD) backgrounds continue to be underrepresented in STEM fields (National Science Foundation, 2017). As classrooms continue to represent increasingly diverse student populations, instructional methods and tools that meet the diverse cognitive and linguistic needs of students with disabilities and students from CLD backgrounds are needed. While contemporary reforms in science education have sought to increase the achievement of all students in science (NRC, 2012), the shift to inquiry-focused models of science education could widen the achievement gaps experienced by SWD and SLE (Brigham, et al 2014; Lee, 2014). One way to address these issues is by proactively planning to meet the diverse needs of all students in science by applying the tenets of UDL to instructional methods and tools in science (Marino, 2010). The use of technology to deliver
universally designed curricula, especially in science, has the potential to increase the science achievement of all students (Basham & Marino, 2013; King-Sears, et al. 2014).

While the UDL Guidelines (CAST, 2011) provide a starting point for the planning and development of accessible educational materials, little research exists between individual guidelines and student learning outcomes (Rao, et al 2014). This dearth of empirical evidence extends to technology-based tools designed based on the UDL guidelines that are essential to the implementation of learning tools that are responsive to the needs of diverse students (Edyburn, 2010). As schools continue to invest in technology, it is important that research highlight strategies that are useful to teachers in meeting the needs of diverse student populations, particularly in science.

The purpose of this study was to determine the utility of technology-based tools in delivering a Tier 1 academic vocabulary intervention in inclusive science classrooms to meet the needs of students with disabilities and students learning English. This included comparing the efficacy of technology-based tools to teacher-led instruction, as well as the effect that timing of vocabulary instruction in inquiry-based science models had on depth of student word knowledge. Lesson materials for each condition were based on research related to vocabulary instruction. Additionally, research in multimedia learning guided how the multiple means of representation were provided in the technology-based tools, to address the goal of highlighting specific connections between technology-based tools anchored in the UDL Guidelines (2011) and specific student outcomes (i.e., acquisition of academic vocabulary).

Overall, 31 students participated in this study (See Table 2). All student participants were selected from inclusive science classrooms, with comparisons made between conditions based on students’ status as a SWD \( (n = 22) \) or SLE \( (n = 9) \). Seven teachers from general \( (n = 4) \) and
special \((n = 3)\) education also participated. These students and teachers were assigned to one of four treatment groups: (a) personal mobile instruction prior to inquiry assignments, (b) personal mobile instruction following inquiry assignments, (c) teacher led instruction prior to inquiry assignments, and (d) personal mobile instruction following inquiry assignments. Each group received three 50-minute vocabulary lessons, each covering seven specific biology terms. These vocabulary lessons were paired with three 50-minute inquiry assignments. Prior to the implementation of the study, students took a pre-test to determine their current knowledge of the terms covered in the study.

A total of 8 sections of biology participated in the study, with two sections assigned to each treatment group. To ensure that teachers in each condition implemented the interventions as they were designed, observations of each lesson in both teacher led and technology-based interventions, as well as during inquiry-based assignments, were conducted. At the end of the study, students completed a post-test of the vocabulary terms covered.

**Teacher Fidelity to Interventions**

Teacher fidelity checklists were developed to measure teacher adherence to the scripted lesson plans during the teacher-led instruction and during the inquiry assignments. The student investigator conducted observations for every lesson and inquiry assignment, with inter-rater data collected for 50% of the lessons. Fidelity was calculated using the following formula:

\[
\frac{\text{number of steps implemented correctly}}{\text{total number of steps in the lesson}} \times 100 = \text{percent fidelity for each lesson}
\]

For both teacher-led conditions and for all inquiry-based assignments, fidelity is reported in Table 6. After each session, the student researcher met with teachers to share the fidelity of implementation of that lesson and to answer any questions the teachers had.
Overall, teachers in both conditions implemented all components of the intervention accurately and reached an overall fidelity score of 100%.

Table 6
Teacher Fidelity to Intervention Scores by Session

<table>
<thead>
<tr>
<th>Session</th>
<th>Teacher Led Instruction-Prior Percent of Fidelity</th>
<th>Teacher Led Instruction-Following Percent of Fidelity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Analysis of Vocabulary Knowledge of Students with Disabilities

As part of the study, students were asked to demonstrate their knowledge of specific biology terms. Students were asked to express their knowledge of terms tied to the following Nevada Academic Content Standards (NVACS) in science: HS.LS.3.1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parent to offspring, HS.LS.3.4 Use a model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms, and HS.LS.3.2 Make and defend claims based on evidence that inheritable genetic variation may result from: (a) new genetic combinations, (b) viable errors occurring during replication, or (c) from mutations caused by environmental factors. The NVACS used in this study are based on NGSS standards that have been adopted by the Nevada Department of Education.

Data from the pretests and posttests were used to answer the following question:
Research Question 1: Is there a statistically significant difference in the depth of word knowledge of students with disabilities participating in treatment conditions compared to students in the control condition?

It was predicted that students with disabilities who participated in the mobile instructional conditions would have significantly greater depth of word knowledge than students with disabilities who participated in teacher-led instruction. Descriptive statistics (See Table 7) related to the depth of word knowledge of students with disabilities who participated in the study are provided.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Personal Mobile Instruction Conditions</td>
<td>10.4</td>
<td>6.5</td>
<td>10</td>
</tr>
<tr>
<td>Teacher Led Instruction Conditions</td>
<td>17.16</td>
<td>8.17</td>
<td>12</td>
</tr>
<tr>
<td>Posttest Personal Mobile Instruction Conditions</td>
<td>21.4</td>
<td>8.9</td>
<td>10</td>
</tr>
<tr>
<td>Teacher Led Instruction Conditions</td>
<td>30.4</td>
<td>13.71</td>
<td>12</td>
</tr>
</tbody>
</table>

To address the hypothesis, scores from the pre-tests and post-tests were analyzed to compare the differences in depth of vocabulary knowledge between the groups who received mobile instruction and teacher-led instruction. A 2x2 repeated measures ANOVA was conducted to describe the differences in achievement between the groups. Initial analysis of these data
suggested that student scores were not normally distributed. Greenhouse-Geisser values were used to adjust for this violation of sphericity and used to evaluate the effects of the interventions.

The two-way ANOVA was conducted to compare the mean scores of students with disabilities across instructional method (i.e., PMI, TLI) and tests (i.e., pre-tests, post-tests). The results suggest that there was not a significant difference between the groups following the intervention, $F(1, 20)=2.697, p = 0.116$. Table 8 provides the results of the tests of between-subjects effects. Table 9 also provides the post-hoc pairwise comparisons made between the groups. These results suggest that while there were differences in the average scores between the groups, these differences were not statistically significant.

Table 8
*Tests of Between-Subjects Effects for Method of Vocabulary Instruction for SWD*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>505.673</td>
<td>1</td>
<td>505.673</td>
<td>86.743</td>
<td>.116</td>
</tr>
<tr>
<td>Error</td>
<td>3749.258</td>
<td>20</td>
<td>187.463</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p.<.01
Within-subjects analysis comparing student scores on the assessment across time (e.g., pretest, posttest) suggest that both intervention method groups made significant growth in depth of vocabulary knowledge over the course of the intervention.

Table 9
*Test of Within-Subjects Effects for Method of Vocabulary Instruction for SWD*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>1581.837</td>
<td>1</td>
<td>1581.837</td>
<td>67.104</td>
<td>.000</td>
</tr>
<tr>
<td>Error(Test)</td>
<td>571.328</td>
<td>21</td>
<td>19.281</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p.<.01

**Analysis of Vocabulary Knowledge of Students Learning English**

Data were also collected from pre- and post-tests to answer the following question:

Research Question 2: Is there a statistically significant difference in the depth of word knowledge of students learning English participating in treatment conditions compared to students in the control condition?
It was predicted that students learning English who participated in the mobile instruction conditions would demonstrate greater depth of word knowledge than students learning English who participated in teacher-led conditions. Descriptive statistics (See Table 10) and inferential statistics (See Table 11) related to the depth of word knowledge of SLE who participated in the study are provided.

Table 10.

<table>
<thead>
<tr>
<th>Summary of Means and Standard Deviations for Assessment Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
</tr>
<tr>
<td>Pretest</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Posttest</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

To address the hypothesis, scores from the pre-tests and post-tests were analyzed to compare the differences in depth of vocabulary knowledge between the groups who received technology-based and teacher-led instruction. An independent samples t-test was conducted to compare student performance on the post-test. Results from the analysis suggest that there were no significant differences \( t(7) = .278, p = .789 \) between the depth of word knowledge for students who participated in mobile and teacher led instructional groups.

Table 11.

| Independent Samples Test of Students Learning English Depth of Vocabulary Knowledge |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| \( t \) | df | Sig (2-Tailed) | Mean Difference | Std. Error Difference |
| .278 | 7 | .789 | 1.7 | 6.1157 |

**Impact of Timing on Depth of Vocabulary Knowledge**
Additional analyses were conducted on data from the pretests and posttests to answer the following question:

Research Question 3: Is there a statistically significant difference in the depth of vocabulary knowledge of SWD and SLE based on the timing of their vocabulary instruction?

It was predicted that students who received their vocabulary prior to hands-on inquiry assignments would demonstrate higher depths of vocabulary knowledge. To answer this question, student data from treatment groups were collapsed into two cells, based on just the timing of their instruction, either prior to inquiry (PTI) or following inquiry (FI). With this data, a 2x2 repeated measures ANOVA was conducted to describe the differences in achievement. The two-way ANOVA was conducted to compare the mean scores of all students based on their instructional timing. Descriptive and inferential statistics are provided in Tables 12. Tables 13 and 14 provide within- and between-subject analysis results for the effect timing had on students’ depth of vocabulary knowledge.

Table 12.
Summary of Means and Standard Deviations for Assessments

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to Inquiry</td>
<td>14.93</td>
<td>7.37</td>
<td>14</td>
</tr>
<tr>
<td>Following Inquiry</td>
<td>10.06</td>
<td>6.95</td>
<td>17</td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to Inquiry</td>
<td>27.79</td>
<td>11.27</td>
<td>14</td>
</tr>
<tr>
<td>Following Inquiry</td>
<td>20.12</td>
<td>12.05</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 13.
Tests of Between-Subjects Effects for Timing of Vocabulary Instruction

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>603.433</td>
<td>1</td>
<td>603.433</td>
<td>3.636</td>
<td>.066</td>
</tr>
<tr>
<td>Error</td>
<td>4812.664</td>
<td>29</td>
<td>165.954</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 14.

Tests of Within-Subjects Effects for Timing of Vocabulary Instruction

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>2015.866</td>
<td>1</td>
<td>2015.866</td>
<td>102.323</td>
<td>.000*</td>
</tr>
<tr>
<td>Error</td>
<td>571.328</td>
<td>29</td>
<td>19.701</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. p<.05*

These analyses suggest that the impact timing (p = .066) had on student performance approached significance. Post-hoc analysis suggests that students who received instruction prior to inquiry assignments approached statistically significant gains on post-test measures when compared to students who received instruction following inquiry-based assignments.

**Analysis of Teacher and Student Perceptions of Vocabulary Knowledge**

At the end of the study, teachers and students were asked to take surveys to rate their perceptions of student depth of word knowledge. Both teacher and student surveys contained 10 items designed to measure student and teacher perceptions of the usefulness, ease of use, and impact on science performance related to the vocabulary instruction they received as part of the study. Teachers and students responded to 5-point Likert style questions, with response options ranging from 5 strongly agree to 1 strongly disagree. Data from these surveys were used to answer the following questions:

Research Question 4: Are there differences in teacher perceptions of student learning based on the treatment group they participated in?

Research Question 5: Are student perceptions of their own learning different based on the treatment group they participated in?

It was predicted that both students and teachers would rate their perceptions of student learning higher when technology-based interventions were implemented. To address this
hypothesis, descriptive statistics are provided to compare the mean, median, and standard deviations of student and teacher responses. Data related to student responses is provided in Tables 15 and Table 16.

Table 15.

**Student Survey Responses**

<table>
<thead>
<tr>
<th>Question Category</th>
<th>Groups</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpfulness of Activities</td>
<td>Personal Mobile Instruction</td>
<td>3.64</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Teacher Led Instruction</td>
<td>3.83</td>
<td>0.70</td>
</tr>
<tr>
<td>Personalization of Instruction</td>
<td>Personal Mobile Instruction</td>
<td>3.60</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>Teacher Led Instruction</td>
<td>3.31</td>
<td>0.87</td>
</tr>
<tr>
<td>Preference of Instruction</td>
<td>Personal Mobile Instruction</td>
<td>3.52</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Teacher Led Instruction</td>
<td>3.70</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Table 16.

**Teacher Survey Responses**

<table>
<thead>
<tr>
<th>Question Category</th>
<th>Groups</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
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<td>Teacher Led Instruction</td>
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Across groups for student and teacher perceptions, there does not seem to be a difference based on the condition individuals were assigned. Between student groups, minimal differences existed in the perceptions of how helpful or personalized PMI or TLI materials were. While students felt that vocabulary instruction was helpful in science, there does not appear to be a difference in their preference of delivery method, or their perceived learning gains from either PMI or TLI materials. Similar findings exist in the teacher responses, with differences in perceptions and perceived impact on students not apparent between groups. What is noticeable in these data are that teacher and student perceptions had an apparent difference in their perceptions of the interventions. While students somewhat agreed that the interventions were helpful, met their learning needs, and impacted their learning, teachers more strongly agreed that the interventions were helpful and had an impact on student learning.

CHAPTER FIVE
DISCUSSION

Academic vocabulary is a critical component of content area learning for the provision of access to the general education curriculum for both SWD and SLE (August, et al. 2005; Bandes & McMaster, 2017; Kuder, 2017). This is particularly true in science where academic vocabulary is crucial to accessing other areas of science instruction that explain and reinforce scientific phenomena (Kaldenberg, et al 2015). While recommendations for contemporary science education models suggest that academic vocabulary be embedded in hands-on activities, there is consensus that both SWD and SLE benefit from direct and explicit academic vocabulary in
content areas like science (Hall, et al. 2017; Jitendra, et al. 2003). However, there are differing recommendations in the literature related to the instructional methods used to address the academic vocabulary needs of these student populations. These conflicting recommendations pose challenges for teachers working in inclusive science classrooms. One way to provide flexible learning materials that address the needs of students in inclusive science classrooms is by utilizing technology-based tools designed to provide multiple instructional and support options for diverse learners (Marino, 2010). With instructional technology becoming more of a staple in modern classrooms, it is important to define the roles and benefits technology can have for students in inclusive classrooms.

While there is support for the use of instructional technology for teaching academic vocabulary to SWD and SLE, there is also support for the use of teacher-led instruction to teach academic vocabulary for SWD and SLE. However, little research exists comparing the efficacy of these methods. Additionally, there is also a paucity of research on the outcomes of implementation of these materials with both SWD and SLE. To support the needs of teachers and the diverse student populations they serve, empirical evidence is needed that describes the differential effects of technology-based tools and teacher led interventions (Gersten & Edyburn, 2007). These investigations will support future research and define the role technology plays in certain educational contexts. While technology provides multiple and flexible delivery methods, it is important for research to identify when and how technology-based tools support, supplement, or take the place of traditional teacher-led instruction.

The purpose of this study was to determine the effects technology-based tools had on the acquisition of academic vocabulary in science when compared to traditional teacher led instruction. Additionally, how academic vocabulary could be reinforced by the timing of
vocabulary instruction was investigated. It was predicted that the depth of vocabulary knowledge would be higher for students who had participated in the technology-based conditions prior to inquiry.

Teacher and student ratings regarding their respective perceptions of student learning were also collected at the conclusion of the study. Surveys were provided to both teachers and students to ascertain how helpful each group felt the instructional procedures (i.e., technology-based, teacher-led) supported the learning needs of students. On these surveys, students and teachers responded to Likert-style questions with possible ratings from 1 (strongly disagree) to 5 (strongly agree). The data were collected and analyzed to determine if students and teachers felt there were differences in the benefits of the intervention materials implemented.

Across three school sites, a total of 22 SWD and 9 SLE participated in the study. Four teachers in general and three in special education from these sites also participated in the research. Prior to administering the study materials, all participants were assessed on a student-researcher created vocabulary assessment. Following the administration of the pretests, classrooms were assigned to PMI and TLI conditions. Students in each condition received three vocabulary lessons for a total of 21 terms and three hands-on inquiry activities meant to reinforce or introduce students to the topics covered in the vocabulary instruction. Following the implementation of the study materials, students completed post-tests that measured their depth of vocabulary knowledge. Teachers and students also completed perception surveys to describe their experiences and perceptions of using the study materials.

**Student Depth of Vocabulary Knowledge**

Prior to implementing the treatment conditions, students were administered a pretest that measured their depth of academic vocabulary knowledge related to the terms used in this study.
The pretest measured students’ ability to match sentence stems to appropriate definitions and to provide their own definitions and contextual information for the terms covered in the study. After the implementation of the study materials, students were administered an academic vocabulary posttest that measured the same knowledge.

Analysis from these assessments suggested that for both SWD and SLE there were no significant differences realized in the depth of academic vocabulary knowledge based on the treatment conditions. However, in both conditions, both SWD and SLE demonstrated significant growth in their depth of vocabulary knowledge on the posttest when compared to their pretest scores. This suggests that both PMI and TLI materials contributed to significant growth in participants’ depth of vocabulary knowledge. When the comparisons of instructional timing were considered, the impact of vocabulary instruction that occurred prior to inquiry produced higher gains in students’ depth of vocabulary knowledge, and approached significance (p = 0.66).

Potential contributing sources to the lack of statistical significance could be the brief length of the intervention, small sample sizes, and the fact that two interventions (i.e., PMI, TLI) that were aligned to evidenced-based practice were implemented simultaneously with high fidelity. While little research exists examining the implementation of flexible and tiered systems of support through technology in inclusive science classrooms, this study was designed to (a) compare the efficacy of technology-based and teacher-led academic vocabulary instruction, and (b) determine teacher and student perceptions of the helpfulness of technology-based and teacher-led academic vocabulary instruction. With the limited number of participants and the brief intervention period, more time could have provided students the ability to become familiar with the intervention procedures, technology-based tools, or inquiry-based assignments that may have had an impact on the depth of students’ academic vocabulary knowledge.
Like previous technology-based interventions (Kennedy et al 2015; Li, 2010; Lowman & Dressler, 2016; Ma & Kelly, 2006), this study utilized a brief intervention period and compared the effectiveness of technology-based and teacher-led instructional methods as supplements to traditional curricula. Similarly, the findings in this study also mirror those of previous research. Through evidenced-based instructional practices, teachers can deliver effective vocabulary instruction that increases student depth of vocabulary knowledge. However, well-designed personalized learning tools can as well. The findings of this study support this claim, and mirror previous research that has provided teachers with professional development, training, or materials to implement effective instruction and compared these methods to technology-based methods (Kennedy, et al 2014; Lee, et al 2016; Macaruso & Rodamn, 2011; Marino, et al 2014).

However, this study provided students with different instructional tools and methods than they may have been used to. Observations of classrooms conducted prior to and during the study indicated that while academic vocabulary instruction and inquiry-based activities were in place in each classroom, their implementation was fully teacher driven and conducted for different time frames than they were in the study. Each co-teaching pair that participated in this study followed a guided inquiry approach that was heavily teacher driven. This included heavy teacher modeling and prompting for how to (a) keep track of vocabulary in science notebooks, (b) respond to questions and tasks during hands-on activities, and (c) while completing independent assignments or assessments. The materials utilized in the study were meant to follow guided inquiry procedures but were designed to help students make their own connections between science vocabulary and concepts. The intervention utilized in this study involved students independently following along with teacher lectures, organizing notes in a science notebook, and completing inquiry assignments in groups without teacher guidance. Despite these differences,
students in PMI and TLI conditions demonstrated increased depth of vocabulary knowledge following the implementation of the study materials.

**Teacher and Student Perceptions of Treatment Usefulness**

After the study, teachers and students completed a survey regarding their perceptions of the helpfulness of the treatment materials. The survey asked teachers and students to rank their perceptions of the helpfulness of treatment materials in meeting the learning needs of students.

**Student Perceptions of Treatment Usefulness**

In general, student participants rated the treatment materials in each condition as helpful. In both conditions, students reported that the intervention materials were helpful and tailored to their individual needs. There was also consensus among student responses that they preferred teacher-led activities and that they did not prefer independent activities (i.e., text-based activities, use of dictionaries) to learn vocabulary. Additionally, students in both conditions reported that vocabulary instruction was important and beneficial in science and that their treatment materials met their unique learning needs.

**Teacher Perceptions of Treatment Usefulness**

Teachers also completed perception surveys related to the treatments they implemented as part of the study. In each condition, teachers rated vocabulary knowledge as important to student achievement in science. Teacher responses in each condition also rated the instruction delivered as helpful and tailored to the needs of SWD and SLE. Teachers in each condition also rated the helpfulness and impact on student learning similarly. Finally, teachers in each condition also rated the role of technology as important in explaining science content. Teacher responses were similar to those of students, and also align with the depth of vocabulary outcomes seen in each condition.
Considering that there were no significant differences in student performance on post-test measures, it could be surmised that there truly were no differences in how materials in either condition met the needs of participants. With the growth that students demonstrated in either condition, the findings of this study and previous research (Kennedy, et al, 2014; King-Sears, et al, 2017; Macaruso & Rodman, 2011; Prince, 2017) support the idea that teachers can utilize technology in inclusive classrooms as they see fit to implement tiered systems of support and implement various instructional groupings as they see fit to supplement their traditional instruction. In science where multiple activities (e.g., instruction, inquiry) can occur at once and require the application of a variety of skills and background knowledge, it can be beneficial to allow students to use personalized learning tools and allow teachers to implement multiple tiers of interventions in their classrooms.

**Conclusions**

From the various sources of quantitative data and anecdotal records collected and analyzed in this study, there are several conclusions that can be drawn. It should be noted that the limitations to this study should be considered when evaluating the conclusions and the generalizability of these conclusions.

1. Although the posttest scores for students in TLI and PMI conditions were not significantly different, SWD and SLE participants demonstrated growth from pre- to post-test measures. This suggests that either technology-based or teacher-led instruction can support the depth of academic vocabulary knowledge of both student groups.

2. When provided brief training, teachers can implement vocabulary instruction that embeds evidenced-based practices for academic vocabulary instruction for SWD and SLE.
3. While not statistically significant, there is some indication that vocabulary instruction that occurs prior to hands-on activity implementation may be more effective at developing deep word meaning for SWD and SLE.

4. Technology-based tools developed using the UDL guidelines and adhering to CTML principles can be used to deliver vocabulary instruction with embedded evidence-based supports for SWD and SLE.

5. The data from perception surveys suggest that students find teacher-led and technology-based instruction similarly helpful at supporting SWD and SLE in science.

6. The data from perception surveys suggest that teachers find teacher-led and technology-based instruction similarly helpful at supporting SWD and SLE in science.

**Recommendations for Future Research**

Classrooms are becoming increasingly diverse in the United States. Teachers in inclusive science classrooms are tasked with not only addressing science content, but also making this content accessible by meeting students’ cognitive, cultural, and linguistic needs. One method that can support teachers in meeting students’ diverse learning needs is by using well-designed instructional technology. However, there is still a need for more research in the area of instructional technology’s role in inclusive classrooms. Suggested areas for future research include:

1. This study should be replicated with a larger sample size and in a variety of school sites to allow for more definitive and generalizable findings.

2. The intervention period for this research should be extended. This would provide time for students to become acclimated to the different methods and materials utilized in this
study while also providing a measure of student maintenance of material covered through instruction.

3. The amount of instruction controlled in future studies should be increased to allow for direct observations of how vocabulary can be reinforced and developed in comprehensive units of inquiry-based science. This includes controlling for additional inquiry-based activities and other activities that explain and expand on students understanding of science topics.

4. Increased levels of randomization could have school sites and teachers engaging in multiple treatment conditions to allow for greater insight when comparing teacher perceptions of treatment usefulness.

5. Online modules that train students to use the PMI tools should be more robust and provide students opportunities to become familiar with and explore the tools in a sandbox environment and build on the tutorial module and teacher explanations that were provided in this study.

6. Increased attention should be payed to the timing aspect of vocabulary instruction as well, with inquiry assignments situated within a larger number of lessons than they were in this study.

7. Increased analytics that measure student behaviors while using PMI tools should also be utilized to help measure the impact different types of online tools (e.g., text-to-speech, explanatory videos, digital agents guiding learning) have on student outcomes.

8. Future research should include a control condition that allows for greater comparisons and analysis to be conducted.
9. Future research should also provide technology-based tools students can use to differentiate their responses on assessments rather than traditional paper and pencil tests.

10. Future research should also embed digital agents and personalized guidance through lessons where students are formatively assessed throughout lessons and guided to instruction and tools that support their learning.

11. Future research should also compare the different models of integrating technology into science classrooms. This includes evaluating fully online instruction with digital labs to blended and fully teacher led instruction in science.

Summary

As classrooms continue to grow in diversity, teachers and students need tools that are responsive to the different cognitive, cultural, and linguistic backgrounds students represent. One promising avenue is the continued development of instructional technology’s capabilities in providing flexible and individualized learning environments. Realizing the impact that instructional technology can have on student performance in school, ESSA (2015) and the most recent NETP (2017) highlight the importance of increasing student access to instructional technology. As personal, assistive, mobile, and instructional technology become staples in daily life, it is important to build on previous research that has described the positive impacts well-designed tools can have in supplementing traditional instruction for SWD and SLE.

The preliminary findings of this study extend the findings of previous research into how technology can support the needs of SWD and SLE in content areas. As technology becomes a part of the modern classroom, it is important to identify the methods that support the diverse needs of all students. This study utilized evidenced-based practices in academic vocabulary instruction for SWD and SLE and built them into technology-based and teacher-led instruction to
deliver vocabulary instruction in inclusive biology classrooms. While no significant differences were found between the teacher-led and technology-based conditions, valuable information was garnered related to the ability to deliver tier one interventions in science that support the needs of SWD and SLE, as well as valuable information related to developing technology-based tools that support the needs of SWD and SLE in content area classes.

The present study establishes an initial step into a fruitful line of inquiry that investigates how SWD and SLE interact with digital tools and content, how vocabulary instruction can be embedded in inquiry-focused science classrooms, and how teachers can deliver tier one and differentiated lesson content to diverse student populations. As classroom technology becomes more ubiquitous, there is great potential for individualizing instruction for the increasingly diverse student populations in inclusive content area classrooms. However, the promise of these tools does not accomplish the task of meeting student needs alone. Careful consideration, planning, and research are needed to guide the development and use of technology-based tools with SWD and SLE. This includes identifying when and how to use technology during instruction, the role of technology in the explanation and exploration of scientific concepts and phenomena, and the role of both technology and teachers in guiding the development of science knowledge and its application in inquiry-based activities.

As technology continues to become more of a constant in classrooms, it is important that these tools be used for their designed purposes and that teachers and students are familiar with how to use these tools. It is also important that research support the development of instructional tools. As the use of technology grows in the classroom, so too should a literature base that describes how technology can be used to support the needs of SWD and SLE in a variety of content area courses and in a variety of instructional arrangements. This should include feedback.
and input from educators in the field and the diverse student populations seen in modern classrooms. This can then create a relationship between research and practice that ultimately guides and influences the use of technology in the classroom and creates flexible and accessible learning environments for all students.
APPENDIX A

STUDENT ENROLLMENT FORM
Student Enrollment Form

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</table>
Purpose of the Study
Your child is invited to participate in a research study. The purpose of this study is to compare the effectiveness of when and how vocabulary instruction is delivered. We are looking to compare the effects teacher-based lessons have when compared to instruction that students receive from an online instructional tool. We are also interested in evaluating whether using either of these methods is effective before or after students complete science labs is more effective.

Participants
Your child is being asked to participate in the study because they are in a high school biology class where their teachers have agreed to participate in this research and deliver the instruction related to the research. All students in participating biology teacher’s classrooms are invited to participate in this study. As part of participating, we are asking that participants parents provide consent for the researchers to collect enrollment data from the Clark County School District that contains your child’s age, gender, grade level, and whether or not they are identified as limited English proficient or have been identified with a disability. We are asking for this information so that we can compare and describe the effects the different types of vocabulary instruction delivered in this study have on the different student groups in inclusive science classrooms. The requested demographic information will allow for analysis and description of the effects the study materials have on students related to participants age, gender, grade level, and whether they are identified as limited English proficient or have been identified with a disability.

Procedures
Your child is being invited to participate in a study. This invitation is being extended as part of your child’s school administration and teachers having agreed to participate in this study. The next step in this process is to gain parental consent for students to participate. What consent is being requested for is the collection of student enrollment data that would provide your child’s age, gender, grade level, and whether your child is identified as limited English proficient or has
been identified with a disability. This information will be requested from the Clark School District collected from district enrollment data. Additionally, consent is being requested to allow your child to participate in one of the treatment groups or the control group that will be implemented in this study and to allow the researchers to collect data from the pre- and post-tests developed for this study. These items are described below.

There are multiple treatment groups and a control group that are being implemented in this study. These groups will be assigned randomly to the teachers who have agreed to participate in the study. For the treatment groups, a total of 8 days, across 5 weeks, will be used to conduct the study materials. This includes two days to administer the pre- and post-tests and six days to deliver the instructional materials related to the study. It should be noted that during the duration of the study, each of the treatment conditions is meant to provide instruction for the same 21 vocabulary terms across the three weeks of the study (seven per week) as well as the same three labs. Your child’s biology teachers have agreed to participate in this study and will be randomly assigned to implement the pre- and post-tests and treatment or control groups. If your consent is provided, you are acknowledging that it is ok for your child to be assigned to one of the groups and that it is permissible for them to participate in the pre- and post-measures the researchers will analyze to evaluate each group.

If you do not provide consent, your child will not participate in this research. Instead, they will receive their typical instruction from one of their science teachers while the study materials are being implemented. Additionally, if you do provide consent, you can withdraw it at any time by contacting the researchers. This will result in your child’s information being deleted electronically from all databases kept for this research, and any physical data sources in being shredded. It should also be noted that if your child’s teacher chooses to withdraw from the study, their classrooms and students will be removed from the study as well and all their records deleted or shredded.

**Benefits of Participation**
There may not be direct benefits to your child as a participant in this study. However, we hope to learn about effective methods for teaching all students vocabulary in science classrooms.

**Risks of Participation**
All research has some level of risk associated with it. This study however, has very little risks to your child. We are asking that they participate in instruction that may be different than their teacher typically provides. This instruction may not be as effective as what their teacher typically delivers, but we have attempted to limit this risk by developing our tools and lessons based on research and evidenced based practices. Additionally, because we are collecting some personal information, there is a chance this information could be accessed by other people not associated with this research. To prevent this from happening, for those who choose to participate in this study, we will store all information of participants on a password protected computer and assign numbers to de-identify your info. This process will involve using Microsoft Excel to assign a random 3 digit number to replace your child’s name. These numbers will take the place of student names on all communications and use of data related to the research. One master copy of student names and their assigned 3 digit number will be stored on a password protected computer in the investigator’s office.
**Cost /Compensation**
There will/will not be financial cost to you to participate in this study. The study will take approximately 8 hours of your child’s time. This time includes participating in 6 classroom lessons and the time it takes to complete the tests and surveys related to the research. Your child will not be financially compensated for their time.

**Contact Information**
If you or your child have any questions or concerns about the study, you may contact Dr. Joseph Morgan at 702-895-3329. For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.

**Voluntary Participation**
Your child’s participation in this study is voluntary. Your child may refuse to participate in this study or in any part of this study. Your child may withdraw at any time without prejudice to your relations with the university. You or your child is encouraged to ask questions about this study at the beginning or any time during the research study.

**Confidentiality**
All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link your child to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be electronically deleted and all physical records will be shredded.

**Participant Consent:**
I have read the above information and agree to allow my child to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

Signature of Parent ___________________________ Child’s Name (Please print)

Parent Name (Please Print) ___________________________ Date

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APPENDIX C

TEACHER CONSENT FORM
Title of Study: Promoting Depth of Vocabulary Knowledge in Inclusive Science Classrooms: Comparison of Instructional Methods

Investigator(s): Dr. Joseph Morgan and Matthew Love

Contact Phone Number: 702-895-3329

Purpose of the Study
You are being invited to participate in a research study. The purpose of this study is to compare the effectiveness of when and how vocabulary instruction is delivered. We are looking to compare the effects teacher-based lessons have when compared to instruction that students receive from an online instructional tool. Teacher led instruction for the purposes of this study is defined as teacher lectures on key vocabulary related to the biology concepts they will be covering. These lessons are designed to be 50 minutes long and cover seven essential vocabulary terms related to an academic standard covered in class. Online instructional tools are materials where students will be provided access to an online platform that delivers vocabulary instruction to students through an interactive presentation. Students will be required to independently use web links built into the presentation to view instructional videos, read text, view examples in media galleries, and access explanatory audio files for the seven assigned vocabulary terms. We are also interested in evaluating whether using either of these methods is effective before or after students complete science labs is more effective. The types of instruction that will be delivered as part of this research are described in the procedures section below.

Participants
You are being asked to participate in the study because you are a teacher in a co-taught biology classroom. To be included in this study, you must be assigned either as a special educator or general educator in a co-taught biology classroom. This can include licensed personnel and assigned substitutes with long-term status (i.e., 11 days in the position prior to the study). Substitute teachers without long-term status and school support staff (i.e., instructional assistants) will not be included in the research.

Procedures
If you volunteer to participate in this study, you will be asked to do the following (a) have your classroom observed so the researchers may establish a baseline of your current vocabulary instruction, (b) allowing the researchers to observe your classroom for fidelity of implementation
of the lessons related to the research, and (c) take a survey at the end of the study to provide your perceptions related to participating in the research. Each of these activities is described below.

Classroom Observations: Prior to the study, the researchers would like to observe your classroom to get a baseline for current vocabulary instruction practices you use in your classroom. This is meant to support the description of what classroom instruction looks like when study materials are not being implemented. What this observation includes is one of the researchers sitting in during one of your lectures prior to the study for 50 minutes to take field notes and complete a classroom observation protocol that the researchers will cover with you before and after the observation of your classroom. These observations will not be recorded.

Fidelity of implementation observations: During the research the researchers will observe your classroom to ensure that you are following the steps outlined in the lesson plans related to the research. This includes all six lessons that are part of the research. These observations will not be recorded.

End of study survey: At the end of the study, teachers will be asked to take a brief survey that asks them to describe their experience from participating in the study. The survey will consist of open ended questions where you will be able to describe your experience, as well as questions where a rating scale will be used to describe your experience. The nature of these questions is to ascertain your thoughts on the helpfulness of the study materials and how they supported student learning needs.

If you do provide consent to participate and wish to withdraw later, you can do so at any time by contacting the researchers. This will also cause the students in your class who have agreed to participate to be withdrawn from the research as well.

**Benefits of Participation**
There may not be direct benefits to you as a participant in this study. However, we hope to learn we hope to learn about effective methods for teaching all students vocabulary in science classrooms.

**Risks of Participation**
There are risks involved in all research studies. This study however, has very little risks to you as a participant. We are collecting some personal information, there is a chance this information could be accessed by other people not associated with this research. To prevent this from happening, for those who choose to participate in this study, we will store all information of participants on a password protected computer and assign numbers to de-identify your info. This process will involve using Microsoft Excel to assign a random 3 digit number to replace your name.

**Cost /Compensation**
There will not be financial cost to you to participate in this study. The study will take approximately 1-2 hours of your time. Your will not be compensated for their time.

**Contact Information**
If you or your child have any questions or concerns about the study, you may contact Dr. Joseph Morgan at 702-895-3329. For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.

**Voluntary Participation**
Your child’s participation in this study is voluntary. Your child may refuse to participate in this study or in any part of this study. Your child may withdraw at any time without prejudice to your relations with the university. You or your child is encouraged to ask questions about this study at the beginning or any time during the research study.

**Confidentiality**
All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link your child to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be electronically deleted and all physical records will be shredded.

**Participant Consent:**
I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

________________________________________
Signature

________________________________________
Name (Please Print)                      Date
APPENDIX D

STUDENT ASSENT
1. Our names are Dr. Joseph Morgan and Matthew Love.

2. We are asking you to take part in a research study because we are trying to learn more about how different methods of vocabulary instruction support your learning in science. Specifically, we want to compare the effectiveness of teacher-led vocabulary instruction to vocabulary instruction you receive from an online module, and whether these methods are more effective at helping you recall and apply vocabulary terms if you receive them before or after a lab in science.

3. If you agree to be in this study we are asking that you participate in the instruction that your teacher has agreed to implement as part of this research. Agreeing to participate also means that you will be assigned to either a treatment or control group. The treatment groups include: (a) technology-based instruction paired with science labs and (b) teacher lectures paired with science labs. There is also the chance for you to be assigned to a control group, where you will receive the typical instruction your teacher delivers. For all participants, we are also asking that you take assessments related to the research and allow us to analyze these tests. At the end of the research, we will also ask you to take a survey where you describe your thoughts and experiences related to participating in the research. We are also requesting data from school records that will provide your status, in terms of your age (e.g., 14), gender (e.g., male, female), grade level (i.e., 9-12), and whether you are identified as limited English proficient (i.e., status listed as limited English proficient in enrollment data) or have been identified with a disability (e.g., yes, with disability label such as learning disability, autism, etc. listed).

4. All research has some level of risk associated with it. This study however, has very little risks to you. We are asking that you participate in instruction that is different than your teacher typically provides. This instruction may not be as effective as your teacher typically delivers, but we have attempted to limit this risk by developing our tools and lessons based on research and evidenced based practices. Additionally, because we are collecting some of your personal information, there is a chance this information could be accessed by other people not associated with this research. To prevent this from happening, if you choose to participate in this study, we will store all your information on a password protected computer and assign numbers to you to de-identify your work. It is also important to note that because this study is being conducted in your classroom, it is possible that students in class may be aware if who is and is not participating in the research. To help minimize this risk, all materials used in the
study mirror typical classroom materials so that participation does not cause you to stand out from students who may not be participating.

5. By participating in this study, we hope that methods that help you learn vocabulary in your courses are developed.

6. Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say “yes” you can still decide not to do this.

7. If you don’t want to be in this study, you don’t have to participate. Remember, being in this study is up to you and no one will be upset if you don’t want to participate or even if you change your mind later and want to stop. If you do make the decision to not participate, you will still receive instruction from one of your science teachers in your classroom. The instruction you receive will be up to your teachers in this case. It is important that you also know that if you do not agree to participate in the study, the researchers will not collect any materials or data from you.

8. You can ask any questions that you have about the study. If you have a question later that you didn’t think of now, you can call me at 702-895-3329 or ask me next time. You may call me at any time to ask questions. If I have not answered your questions or you do not feel comfortable talking to me about your question, you or your parent can call the UNLV Office of Research Integrity – Human Subjects at 702-895-2794 or toll free at 877-895-2794.

9. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

_________________________________  ______________
Print your name                                      Date

_________________________________
Sign your name
### Genetics
**Key Elements:** Study of biological process; looks at how traits and genes are passed on

<table>
<thead>
<tr>
<th>4 points</th>
<th>3 points</th>
<th>2 points</th>
<th>1 point</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>The <strong>study of how genes and traits</strong> are passed from generation to generation.</td>
<td>Missing one key element</td>
<td>Missing two key elements</td>
<td>Any mention of passing on genetic material Ex: Stuff passed on from parents to their kids</td>
<td>Missing all key elements</td>
</tr>
</tbody>
</table>

#### Additional Info (1 point per topic if not mentioned in the definition)
- Mentions that it is a study of a biological process
- Mentions that it is related to the passing of traits from generation to generation
- Mentions that it is related to the passing of genes from generation to generation

<table>
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<th>Score:</th>
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### DNA
**Key Elements:** Double helix shaped structure; made of proteins, ATCG (proteins), building blocks/foundation of life

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<thead>
<tr>
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<th>3 points</th>
<th>2 points</th>
<th>1 point</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>The foundational unit of biology that is made of ATCG proteins and shaped as a double helix.</td>
<td>Missing one key element</td>
<td>Missing two key elements</td>
<td>Missing three key elements</td>
<td>Missing all key elements</td>
</tr>
</tbody>
</table>

#### Additional Info (1 point per topic if not mentioned in the definition)
- Double Helix
- Foundational unit of life/biology
- Made of proteins
- Proteins are ATCG
- Mentions that DNA is “what makes individuals unique/what makes you, you”

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<th>Score:</th>
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### Heredity
**Key Elements:** biological Process; focuses on traits passed on from generation to generation, observable between generations

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<th>3 points</th>
<th>2 points</th>
<th>1 point</th>
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<tbody>
<tr>
<td>A biological process that looks at how traits are passed on from generation to generation.</td>
<td>Missing one key element</td>
<td>Missing two key elements</td>
<td>Mentions that traits are passed on from generation to generation.</td>
<td>Missing all key elements</td>
</tr>
</tbody>
</table>

#### Additional Info (1 point per topic if not mentioned in the definition)
- Biological Process
- Traits passed on from generation to generation
- Observable between generations
- Provides a specific example of traits that may be passed on from parents to offspring

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<th>Score:</th>
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APPENDIX F

CLASSROOM OBSERVATION FORM
Introduction to Lessons
Are learning objectives posted and covered with students? …………………………..(Y/N)
Are objectives written and covered in student friendly language?…………………………(Y/N)

Instruction
1. Teacher provides warm-up/review activities for students that activate/review student knowledge of academic vocabulary. (Y/N)
2. Teacher makes connections between previously learned concepts to new concepts (Y/N)
3. Teacher provides definitions of terms and concepts that are introduced in the lesson (Y/N)
4. Teacher provides examples and non-examples of new concepts to be covered (Y/N)
5. Teacher takes time to explain new content and vocabulary to students (Y/N)

New Concept and Skill Development
6. Teacher uses language scaffolds, vocabulary supports, and student friendly language when explaining new concepts (Y/N)
7. Teacher uses analogies and metaphors to explain concepts (Y/N)
8. Teacher conducts frequent checks for understanding (Y/N)
9. Teacher supports student generation of notes/summaries of lecture (Y/N)
10. Teacher provides opportunities for students to process information and ask questions (Y/N)

Guided and Independent Work
11. Teacher differentiate work for students based on academic and language needs
12. Teacher provides students opportunities to engage in discourse with their peers (Y/N)
13. Students are given adequate time for reflection, inquiry, discovery, discussion, problem-solving, and analysis (Y/N)

Closure and Review
14. Teacher generates evidence of student learning/assessment (Y/N)
15. Teacher provides differentiated ways for students to demonstrate what they learn (Y/N)

Considerations for ELLs
16. Teacher provides wait time after providing students directions (Y/N)
17. Teacher uses visuals and other aids during instruction (Y/N)
18. Teacher makes language adaptations to material to make it accessible (Y/N)
19. Teacher provides opportunities for students to interact with each other (Y/N)

Considerations for Students with Disabilities
20. Co-teaching models are utilized in the classroom (Y/N)
21. Materials are differentiated based on student needs (Y/N)
22. Accommodations are in place in the classroom (Y/N)

Classroom Environment
23. Routines and procedures are evident (Y/N)
24. Classroom arrangement is conducive to student learning (Y/N)
25. Technology is used in the classroom for instructional purposes (Y/N)

Classroom Management and Student Rapport
26. Teacher exhibits positive rapport with all students (Y/N)
27. Teacher affirms positive student behavior (Y/N)
28. Progressive discipline is evident in the classroom (Y/N)
29. Behavior is addressed consistently between all students (Y/N)
30. Student to student interactions during instruction are respectful and productive (Y/N)
1. Vocabulary Instruction is helpful for learning biology/science.
   
   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

2. The way my teacher taught the key terms for biology was helpful.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

3. The order (i.e., before or after and a lab activity) I received my lessons was helpful.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

4. I prefer to learn vocabulary on my own through activities (dictionary, web search, textbooks, assignments, labs).

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

5. I prefer to receive vocabulary instruction from my teacher.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

6. I feel the way key terms were taught was easy for me to understand and useful.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

7. I think that the way key terms were taught fit my own individual learning needs.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

8. 21 terms were the right amount to learn in 3 weeks.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

9. The strategies (definition, word maps, memory aids) provided helpful information.

   1 - Strongly Agree  
   2 - Agree  
   3 - Neutral  
   4 - Disagree  
   5 - Strongly Disagree

10. The activities completed with the vocabulary instruction helped reinforce my knowledge.

    1 - Strongly Agree  
    2 - Agree  
    3 - Neutral  
    4 - Disagree  
    5 - Strongly Disagree

On the back, please provide any additional information about your experience related to how vocab was taught in this study.
APPENDIX H

TEACHER SURVEY
Teacher Satisfaction Survey

From the following responses, please select the response you feel is most appropriate for the prompt.

1. The methods used in this study were beneficial to my students.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

2. Vocabulary instruction is the best way to provide students with background information in biology.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

3. Students should master foundational concepts before being exposed to complex activities like inquiry in science.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

4. The activities conducted in this study (lecture and labs) were beneficial to my students.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

5. The order the activities took place in class best supported students understanding of concepts.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

6. The materials used in this study were easy to implement.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

7. I can implement these materials and similar lessons once the study has ended.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

8. The activities used in this intervention helped my students learn science concepts.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

9. The activities used in this study helped make science accessible for all of my students.
   1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree

10. Vocabulary instruction can be used to support students access to scientific inquiry.
    1- Strongly Agree  2- Agree  3- Neutral  4- Disagree  5- Strongly Disagree
APPENDIX I

FIDELITY CHECKLIST
<table>
<thead>
<tr>
<th>Lesson Component</th>
<th>Teacher Actions</th>
<th>Completed (Check if Yes)</th>
</tr>
</thead>
</table>
| **Introduction** | • Teacher introduces Lesson Topic  
• Introduces Terms to Be Covered  
• Guides students in putting folders together  
• Demonstrates how to use folders  
• Introduces Semantic Map | ○ Teacher introduces Lesson Topic  
○ Introduces Terms to Be Covered  
○ Guides students in putting folders together  
○ Demonstrates how to use folders  
○ Introduces Semantic Map |
| **Instruction for Term 1:** | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples  
○ Recall Supports |
| **Time Started:** | | |
| **Time Ended:** | | |
| **Instruction for Term 2:** | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples  
○ Recall Supports |
| **Time Started:** | | |
| **Time Ended:** | | |
| **Instruction for Term 3:** | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples  
○ Recall Supports |
| **Time Started:** | | |
| **Time Ended:** | | |
| **Instruction for Term 4:** | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information |
| Time Ended: | • Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Examples and Non-Examples  
○ Recall Supports |
|---|---|---|
| Instruction for Term 5: | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples |
| Time Started: | | |
| Time Ended: | | |
| Instruction for Term 6: | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples  
○ Recall Supports |
| Time Started: | | |
| Time Ended: | | |
| Instruction for Term 7: | Teacher provides instruction through the following:  
• Present Word and Definition  
• Organize word on Semantic Map  
• Key Contextual Information  
• Examples and Non-Examples  
• Recall Supports | ○ Present Word and Definition  
○ Organize word on Semantic Map  
○ Key Contextual Information  
○ Examples and Non-Examples  
○ Recall Supports |
| Time Started: | | |
| Time Ended: | | |
| Review/Closure | • Teacher reviews semantic map, the terms covered, and how they relate to each other.  
• Provides time for students to complete essential questions. | ○ Teacher reviews semantic map, the terms covered, and how they relate to each other.  
○ Provides Time for students to complete essential questions. |
Lesson 3: Mutations

Lesson Plan 1: Genetic Variation and Mutations (50 Minutes)

Standards: HS-LS3-2: Make and defend claims based on evidence that inheritable genetic variation may result from: (a) new genetic combinations, (b) viable errors occurring during replication, or (c) from mutations caused by environmental factors.

Essential Questions: Is DNA your destiny? Are all mutations bad?

Vocabulary:
1. Genetic Variation
2. Mutations
3. Mutagens
4. Levels of Organization
5. Cell Specialization
6. Epigenetics
7. Carcinogens

<table>
<thead>
<tr>
<th>Lesson Component</th>
<th>Teacher Script</th>
</tr>
</thead>
</table>
| Introduction of Lesson | **Introduce Lesson Topic:** We have been talking about genetics, heredity, cellular division, and looking at how organisms are formed and inherit traits. As part of that, we have seen that most organisms, especially humans, share large amounts of DNA. Despite the large amounts of DNA shared between most organisms, we have seen that organisms are unique due to how traits are inherited and how genes are expressed. To continue building on this information, we will look at other factors that lead to the diversity of organisms gene pools and other factors outside of traditional genetics that lead to how genes are expressed differently.  

**Build Rationale for Lesson:** We have seen that people are all unique thanks to their genetic makeup. From what we have covered, we know that most of what makes an organism what they are is through what they inherit from their parents. But does that explain how organisms end up the unique beings they are? Can individuals and the choices they make end up supporting the unique people they become?

**Essential Questions:** The main things we are going to look at today relate to the following two questions:
1. Is DNA your destiny?
2. Are all mutations bad? |
| Introduce Topics and Semantic Map | The concepts we are covering are a continuation of topics that we have covered previously. Our main idea continues to be gene expression, but we are digging in a little deeper and looking at other factors that may lead to the different and unique ways that genes express themselves. Specifically, we will look at how an organisms environment can influence gene expression and how cells are organized and specialize to form complex organisms like humans. Ultimately, everything we cover today looks at how |
complex organisms are organized and how processes in this organization can lead to differences in how genes are expressed and how this leads to increased diversity among a species.

| Term 1: Genetic Variation | Present Word and Definition: To get us started, we will look at genetic variation.  
| Definition: Genetic variation describes the genetic differences among organisms of the same species that cause them to express different traits and characteristics.  
| Orient students to terms place in overall context (Refer Students back to Semantic Map): If you look at our semantic map, you will see that our main idea is still gene expression. Looking at one of our main points of discussion today, it is important to realize that there are different ways genes can express themselves, and that it is these differences that lead to the differences in complex organisms like people and animals. This is how genetic variation ultimately ties back to gene expression.  
| Key Contextual Information:  
| • Individuals of a species have similar characteristics but they are rarely identical, the difference between them is called variation.  
| • Genetic variation is a result of subtle differences in our DNA.  
| • This variation support the survival of a population in the face of changing environmental circumstances.  
| • Genetic variation results in different forms of genes.  
| • For example, eye color, skin tone, and face shape are all determined by our genes, so any variation that occurs will be due to the genes inherited from our parents.  
| • Genetic variation in a population is derived from a wide assortment of genes. The survival of populations over time through changing environments depends on their capacity to adapt to shifting external conditions.  
| • Sometimes the addition of a new allele to a population makes it more able to survive; sometimes the addition of a new allele to a population makes it less able. Still other times, the addition of a new allele to a population has no effect at all, yet the new allele will persist over generations because its contribution to survival is neutral.  
| Examples and Non-Examples:  
| Example: When you look at people you can see that they are different. This is seen through the different physical characteristics (phenotypes) people show even though they share large amounts of DNA (genotypes).  
| Non-Example: It is very rare that people are identical. That being said, the exception to this rule are identical twins. Identical twins share a genetic makeup, meaning that their genotypes and phenotypes are the same. This actually makes them very important for certain studies that look to examine the effects of prescription drugs, treatments, and environmental factors on health and behavioral outcomes.  
| Recall Supports (Word Association): To help you recall what genetic... |
variation means, the easy way to do it is to understand what the term variation means. Variation means different. Remembering that will help you remember that genetic variation refers to the differences amongst genes in a species.

| Term 2: Mutations | Present Word and Definition: Now that we have looked at what differences in gene pools are called, it is time to take a look at the factors that lead to genetic variation. The first one we are going to look at are mutations. **Definition:** A mutation is a permanent change in the DNA sequence that makes up a gene. **Orient students to terms place in overall context (Refer Students back to Semantic Map):** Going back to our semantic map and our main idea of gene expression, it is these permanent changes to DNA structures through mutations that cause these genes to express themselves (phenotype) differently. **Key Contextual Information:**
- To function correctly, each cell depends on thousands of proteins to do their jobs in the right places at the right times.
- Sometimes, gene mutations prevent one or more of these proteins from working properly.
- Only a small percentage of mutations cause health problems, and most have no impact on health or development.
- A very small percentage of all mutations actually have a positive effect. These mutations lead to new versions of proteins that help an individual better adapt to changes in his or her environment.
**Examples:**
One way mutations can occur is through an organism being exposed to radiation. One form of radiation that we are exposed to everyday is UV radiation from the sun. This UV radiation can also damage DNA in your skin cells, causing genetic mutations that can lead to skin cancer.
**Recall Supports (Word Analysis):** Looking at the word mutation, pay particular attention to the suffix –ation which means an action or a process. Remembering this will help you remember that a mutation is the process of DNA changing the sequence of a gene. |
| --- | --- |
| Term 3: Mutagens | Present Word and Definition: The next thing we will look at are the factors that cause mutations. These are mutagens. **Definition:** A mutagen is a physical or chemical agent that causes a mutation. **Orient students to terms place in overall context (Refer Students back to Semantic Map):** Having just discussed what mutations are, the next step is seeing that it is mutagens that cause mutations, which ultimately influence gene expression. **Key Contextual Information:**
- Mutagens can be anything capable of altering the genetic constitution of DNA.
- Ultimately, mutagens cause errors in DNA sequence. |
- Mutagens can originate from inside someone’s body or from outside their body, in their environment.
- Many forms of electromagnetic radiation (e.g., cosmic rays, X rays, ultraviolet light) are mutagenic, as are a variety of chemical compounds that can cause changes in DNA structure.

**Examples:**
Mutagens can come in the form of radiation, chemicals, or infectious agents/diseases. Specific examples include X-Rays, processed foods, STDs, or illnesses contracted from contaminated food.

**Recall Supports (Word Analysis):** The suffix of the word mutagen comes from the word agent. Remembering this can help you recall that mutagens are agents that ultimately cause a mutation.

<table>
<thead>
<tr>
<th>Term 4: Carcinogens</th>
</tr>
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</table>
| **Present Word and Definition:** Building off what mutagens are, our next term is something that is important for you to know for your own health purposes moving forward, and is probably a term you may hear a lot already. That is, the term carcinogen.

**Definition:** A carcinogen is an agent that causes cancer.

**Orient students to terms place in overall context (Refer Students back to Semantic Map):** This term is probably something that you hear a lot either on the news, radio, or when you’re reading or hearing about things that cause cancer. A carcinogen is a type of mutagen that can alter the form or production of DNA, and ultimately lead to genetic changes.

**Key Contextual Information:**
- Many people worry that substances or exposures in their environment may cause cancer.
- Cancer is caused by changes in a cell’s DNA – its genetic “blueprint.”
- Some of these changes may be inherited from our parents. Others may be caused by outside exposures to carcinogens.
- Carcinogens do not cause cancer in every case, all the time. Substances labeled as carcinogens may have different levels of cancer-causing potential. Some may cause cancer only after prolonged, high levels of exposure.

**Examples:**
Carcinogens are typically found in an individual’s environment and can include a wide range of exposures, such as:
- Lifestyle factors (nutrition, tobacco use, physical activity, etc.)
- Naturally occurring exposures (ultraviolet light, radon gas, infectious agents, etc.)
- Medical treatments (radiation and medicines including chemotherapy, hormone drugs, drugs that suppress the immune system, etc.)
- Workplace exposures
- Household exposures
- Pollution
<table>
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<tr>
<th><strong>Recall Supports (Pegword Mnemonic):</strong> People often refer to cancer as the big C. If you can picture the word carcinogen like this, it may help you to remember they are the agents that cause the big C, cancer.</th>
</tr>
</thead>
</table>
| **Term 5: Epigenetics** | **Present Word and Definition:** Continuing our theme of looking at other factors that influence how genes are expressed, our next term is epigenetics. **Definition:** Epigenetics is the study of changes in gene expression that have nothing to do with an organism's DNA sequence. (It is a change in phenotype without a change in genotype). **Orient students to terms place in overall context (Refer Students back to Semantic Map):** Looking to where epigenetics fits in to what we are looking at today, you can see that it branches off into a different section related to our main topic of gene expression. While it still has something to do with how genes express themselves, our focus on epigenetics will branch out a little from this and tie it into how genes are expressed, but also how it is tied into how complex organisms are formed and organized. **Key Contextual Information:**  
- Epigenetics is the study of heritable changes in gene expression  
- Epigenetic change is a regular and natural occurrence but can also be influenced by several factors including age, the environment/lifestyle, and disease.  
- Epigenetic change can have more damaging effects that can result in diseases like cancer.  
- The field of epigenetics is quickly growing and with it the understanding that both the environment and individual lifestyle can also directly interact with the genome to influence epigenetic change.  
- These changes may be reflected at various stages throughout a person’s life and even in later generations. **Examples:**  
- The environment is being investigated as a powerful influence on epigenetic change and disease susceptibility. Pollution has become a significant focus in this research area as scientists are finding that air pollution could alter methyl tags on DNA and increase one’s risk for neurodegenerative disease.  
- Diet has also been shown to modify epigenetic tags in significant ways. An additional field of epigenetics explores how food and epigenetics work together to influence health and wellbeing. **Recall Supports:** |
| **Term 6: Cell Specialization** | **Present Word and Definition:** Shifting gears here, we are going to look at how organisms are formed, how they are organized, and ultimately how the processes that help form and organize individuals relates to gene expression and how each organism in a species is unique. To help us start looking at these processes, our next term is cell specialization. **Definition:** Cell specialization is the process by which generic cells change into specific cells meant to do certain tasks within the body. **Orient students to terms place in overall context (Refer Students back to Semantic Map):** |
When you look at our semantic map to see how all of these terms are related, you will see that cell specialization is off by itself, away from our main idea of gene expression.

Key Contextual Information:

- Cell specialization is the process by which cells become specialized in order to perform different functions.
- DNA controls the way cells function. It also determines what type of specialized cells will be made.
- Stem cells are cells that have the ability to become any type of specialized cell in the body. After an egg cell and sperm cell unite to begin forming a new organism, all of the DNA in each cell of that organism will be virtually identical.
- All complex organisms require specialized cells to function properly. Because all cells start out the same, it is through cell specialization that they change and turn into specialized cells to help organisms function.

Examples:

Some cells must be able to move (like sperm cells), while other cells need to contract (like muscle cells). Three of the many specialized cell types in animals include red blood cells, muscle cells, and skin cells.

Recall Supports (Word Association): The best way to remember what cell specialization means is to focus on the meaning of the word special or specialize. If you can remember that specialize means to do something specific. Remembering that will help you recall that cell specialization is the process cells go through to be able to do specific jobs.

| Term 7: Levels of Organization | Present Word and Definition: Once cells go through the process of specialization and are ready to perform their essential function in an organism, there has to be a way for these cells to be organized within the organism. The way this organization is classified is by looking at that organisms levels of organization. Our focus here will be on the levels of organization seen in humans. Definition: Levels of organization refer to how living things are arranged and they build from the most simple to complex parts of an organism. For people the levels of organization are: cells, tissue, organs, and organ systems. Orient students to terms place in overall context (Refer Students back to Semantic Map): As we have seen, once cells go through the process of specializing they need to find some level of organization. That is the easy connection to how this term relates back to cell specialization. Key Contextual Information: The scientific study of the different levels of organization of living beings, helps us gain an insight into the their structure and functioning. Every organism on Earth, from the smallest to the largest one, follows some form of organizing themselves. Cell: Basic unit of structure and function of all living things. Tissue: Group of cells of the same kind. |
Organ: Structure composed of one or more types of tissues. The tissues of an organ work together to perform a specific function. Human organs include the brain, stomach, kidney, and liver. Plant organs include roots, stems, and leaves.

Organ system: Group of organs that work together to perform a certain function. Examples of organ systems in a human include the skeletal, nervous, and reproductive systems.

While these are the basic levels of organization for humans, it is important to know that there are other systematic structures and functioning of various components that form more complex systems of the organization of life forms (e.g., communities, populations).

The biological, or precisely the living entities of our planet constitute a very complex and sophisticated system.

Examples:
Structure of human on slide
Recall Supports (Infographic):
Refer students to the infographic on the slide (Pyramid of the levels of organization).

Review and Closure

So to look back at what we have covered today, remember that our overall themes have been to understand different aspects of gene expression and how organisms are ultimately formed. We covered things that occur outside of traditional genetic processes that effect gene expression and how these concepts lead to greater diversity and genetic variation in species. These items include mutations, mutagens, carcinogens, and epigenetics. From that we also looked at how organisms are ultimately formed through cell specialization and levels of organization. As we move forward, our next lessons will focus on how all of these things tie together to create differences within species and how this can support or hinder the survival of those species.
APPENDIX K

MULTIMEDIA PLANNING FORM
<table>
<thead>
<tr>
<th>UDL Guidelines</th>
<th>CTML Principles Applied</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Offer alternatives for auditory information</td>
<td>• Multimedia Principle</td>
<td>Students had access to visual aids, graphs, charts, and instructional videos with the option for closed captioning if necessary within each slide. Students had access to text to speech options and audio descriptions of each slide. By clicking on the option, students would be taken to a page that provided relevant images, but eliminated text to limit distractions.</td>
</tr>
<tr>
<td>1.3 Offer alternatives for visual information</td>
<td>• Coherence Principle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Redundancy Principle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Multimedia Principle</td>
<td></td>
</tr>
<tr>
<td>2.1 Clarify vocabulary and symbols</td>
<td>• Signaling Principle</td>
<td>Each component of the modules are designed to teach foundational science vocabulary. This includes providing definitions, contextual information, word analysis, and semantic feature analysis. These items were included on separate pages or layers of the modules to focus student attention to each component of vocabulary instruction.</td>
</tr>
<tr>
<td></td>
<td>• Redundancy Principle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Temporal Contiguity Principle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Multimedia Principle</td>
<td></td>
</tr>
<tr>
<td>2.4 Promote understanding across languages</td>
<td>• Voice Principle</td>
<td>Each module component included translation options for text and multiple options for perception presented through multiple media. Students could access these options by clicking an option embedded in the module and would be transferred via hyperlink to a translated version (Spanish) of the module. The original recordings and translations also included audio that was recorded in a natural voice.</td>
</tr>
<tr>
<td></td>
<td>• Voice Principle</td>
<td></td>
</tr>
</tbody>
</table>
| 2.5 Illustrate through multiple media | • Multimedia Principle  
• Temporal Contiguity Principle  
• Spatial Contiguity Principle  
• Modality Principle | Audio, visual, and textual information are provided in each module component. 
Textual information and graphics were aligned to each other where relevant, and audio narrations were only provided with relevant visuals to eliminate possible distractors. |
|---|---|---|
| 3.2. Highlight patterns, critical features, big ideas, and relationships | • Redundancy Principle  
• Spatial Contiguity Principle  
• Multimedia Principle  
• Signaling Principle | Each module component provided word and semantic analysis features, while also providing orienting contextual information for how each term is aligned within a scientific concept. 
These were delivered through instructional videos that included audio descriptions synced with visuals that demonstrated word transformations, word component analysis, and semantic connections between words. |
Key Info

- It is important to know the difference between Mitosis and Meiosis.

**Mitosis**
- Cell divides in 5 stages.
- Daughter cells have 46 chromosomes.
- Creates 2 daughter cells.

**Meiosis**
- Division of reproductive cells.
- Cells divide in 3 phases.
- Daughter cells have 23 chromosomes.

3 Things You Need:

1. Headphones
2. Computer
3. Folder

Word Analysis

**CELL DIVISION**

**CELL DI- VI-**

https://www.youtube.com/watch?v=Zxe_7eedaE
APPENDIX M

SCIENCE NOTEBOOK EXAMPLE
Mutations Activity

Introduction: This activity is going to get you thinking about the effects mutations have on species survival. More specifically, you will be asked to consider why and how species adapt.

Background

You will simulate an animal with a mutation that can only digest blocks as its food source. The goals of your group are to:
1. Gather the food (3 SETS OF BLOCKS per group member).
2. Store the food for later use (place the group’s blocks in your letter-designated container).
3. Retrieve the food at a later time (remove the blocks from the container and return with them to the home location).
4. Process and stack the food (remove the and simulate consuming them).

<table>
<thead>
<tr>
<th>Letter Drawn</th>
<th>Characteristic Produced by Mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Long Fingernails (Chopstick Gloves)</td>
</tr>
<tr>
<td>B</td>
<td>Different Hands (Cup and Spatula)</td>
</tr>
<tr>
<td>C</td>
<td>Hands Fused Together (Oven Mitts)</td>
</tr>
<tr>
<td>D</td>
<td>Legs Fused Together (Sweat Pants)</td>
</tr>
<tr>
<td>E</td>
<td>No Arms (Don’t use Arms)</td>
</tr>
<tr>
<td>F</td>
<td>Blind (Goggles)</td>
</tr>
</tbody>
</table>

Directions: In your groups, you will gather your materials (See Chart 1) and the items used to simulate your species food (Blocks). Take the “food” to the area in your class designated by your teacher. Once you do this, position your group at your home base area. In your home base, take turns drawing from the envelope provided by your teacher to determine what your mutation is. Once you have determined your mutation, it is time to begin simulating the experiment. Using your stop watch, you will time each member of your group to determine how many units of food they bring back in 1 minute. Record your results below.

<table>
<thead>
<tr>
<th>Mutation</th>
<th>Units Returned in 3 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>UNITS RETURNED</td>
</tr>
<tr>
<td>B</td>
<td>UNITS RETURNED</td>
</tr>
<tr>
<td>C</td>
<td>UNITS RETURNED</td>
</tr>
<tr>
<td>D</td>
<td>UNITS RETURNED</td>
</tr>
<tr>
<td>E</td>
<td>UNITS RETURNED</td>
</tr>
<tr>
<td>F</td>
<td>UNITS RETURNED</td>
</tr>
</tbody>
</table>

Additional Information: Your species requires that you eat at least an average of 100 blocks per day. Additionally, your species is only able to scavenge for food for 30 minutes a day to avoid being hunted by predators. Using this information, answer the following questions.

1. What mutation seemed to have the most detrimental effect on the species and how would this affect their survival? ____________________________________________________________
2. What mutation seemed to have the least detrimental effect on the species and how would this affect their survival? 

3. If your species also had to prepare to store its food for the winter, which mutation would be most beneficial? 

4. Think about what you observed with each mutation. Think about how these mutations might impact the survival of this species. With this information, what might members of this species look like in future generations?
APPENDIX N

PRE- AND POST-ASSESSMENTS
**Directions:** Provide a definition for the term provided. Also provide any other information that you can for this term. This can include anything about the term and how it fits into biology.

**Term 1: Genetics**

**Definition:**

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

**Other Information**

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

**Term 2: DNA**

**Definition:**

____________________________________________________________________________
____________________________________________________________________________

**Other Information**

____________________________________________________________________________
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____________________________________________________________________________
____________________________________________________________________________

**Term 3: Chromosomes**

**Definition:**

____________________________________________________________________________
____________________________________________________________________________

**Other Information**

____________________________________________________________________________
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Term 4: Heredity
Definition: ____________________________________________________________
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____________________________________________________________________
Other Information
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Term 5: Traits
Definition: ____________________________________________________________
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____________________________________________________________________
Other Information
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Term 6: Genotype
Definition: ____________________________________________________________
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Other Information
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Term 7: Phenotype
Definition:____________________________________________________
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Other Information
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Term 8: Cell Division
Definition:______________________________________________________
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Other Information
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Term 9: Parent Cell
Definition:______________________________________________________
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Other Information
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Term 10: Meiosis
Definition:__________________________________________________________
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Other Information
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Term 11: Mitosis
Definition:__________________________________________________________
____________________________________________________________________
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Other Information
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Term 12: Probability
Definition:__________________________________________________________
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Other Information
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Term 13: Dominant
Definition:  

______________________________________________________________________________

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Other Information
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Term 14: Recessive
Definition:  

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Other Information
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Term 15: Mutations
Definition:  

______________________________________________________________________________

______________________________________________________________________________

Other Information
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Term 16: Mutagens
Definition:____________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Other Information
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Term 17: Carcinogens
Definition:____________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Other Information
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Term 18: Epigenetics
Definition:____________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Other Information
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Term 19: Genetic Variation
Definition:  

Other Information:  

Term 20: Levels of Organization
Definition:  

Other Information:  

Term 21: Cell Specialization
Definition:  

Other Information:  

1. DNA is:
   a. An enzyme that catalyzes the formation of genetic material.
   b. The foundational unit of genetics that determines inherited traits.
   c. The outer surface layer of cells in humans and animals.
   d. The process of copying genetic material

2. Genetics is:
   a. The random change in the frequency of inherited genes in a population.
   b. The study of how traits are passed on from generation to generation.
   c. The study of physical barriers impacting natural selection in species.
   d. The study of how natural selection develops variation and diversity in species.

3. Heredity is:
   a. The process of how characteristics are passed from generation to generation.
   b. The process of enzymes separating DNA.
   c. The process of how parts of a gene are expressed as traits.
   d. The process of how the environment leads to genetic variation.

4. Chromosomes are:
   a. The part of a cell that expresses itself as a trait.
   b. DNA containing structures found in the nucleus.
   c. The outer membranes that surround embryos.
   d. The part of a cell that regulates the metabolism of protein.

5. Traits are:
   a. Genetically determined characteristics.
   b. Cells that develop from the fusion of gametes.
   c. Molecules that transfer amino acids.
   d. A collection of specialized cells.

6. Genotypes are:
   a. The set of genes in DNA responsible for traits.
   b. The physical expression of genes.
   c. Disorders that are linked to XY chromosomes.
   d. The category of species that contains families.

7. Phenotypes are:
   a. The genetic makeup of an organism.
   b. The physical expression of genes.
   c. Disorders that are linked to XY chromosomes.
   d. The category of species that contains families.

8. Cell Division is:
   a. The process cells use to replicate.
   b. The process of cellular decay.
   c. The process of parents passing on genes to offspring.
   d. The process of cells obtaining energy from carbohydrates.

9. Parent Cells are:
   a. Cells parents carry and pass on to offspring.
   b. The cells responsible for making sperm and egg cells.
   c. Cells that carry all of the information needed to create new cells.
   d. Proteins that carry material through cell walls.

10. Meiosis is:
    a. A term for organisms that have two alleles for traits.
    b. The process of cells making four daughter cells.
    c. The process of cells making two daughter cells.
    d. The synthesis of organic compounds from carbon dioxide.
11. Mitosis is:
   a. A term for organisms that have two alleles for traits.
   b. The process of cells making four daughter cells.
   c. The process of cells making two daughter cells.
   d. The synthesis of organic compounds from carbon dioxide.

12. Probability is:
   a. The chances of an event happening.
   b. The problems related to mutating genes.
   c. The certainty of something happening.
   d. The number of individuals that live in a defined area.

13. Dominant genes are:
   a. Genes that determine the phenotype of an organism.
   b. Genes that are expressed when they are inherited from both parents.
   c. Genetic markers that are masked and only recognizable as a genotype.
   d. Characteristics determined by many genes.

14. Recessive genes are:
   a. Genes that determine the phenotype of an organism.
   b. Genes that are expressed when they are inherited from both parents.
   c. Genetic markers that are masked and only recognizable as a genotype.
   d. Characteristics determined by many genes.

15. Genetic Variation is:
   a. The amount of genetic diversity in a population.
   b. The effects of mutations that lead to extinction.
   c. The process genes undergo during evolution.
   d. The random change in the traits of a species.

16. Mutations are:
   a. Environmental factors that activate genes.
   b. Changes in the structure of genes that alter traits.
   c. Consistent gene expressions seen between generations.
   d. Developments of humans made in utero.

17. Mutagens are:
   a. XY chromosome linked disorders.
   b. Factors that cause changes to the structure of DNA.
   c. Environmental factors that activate genes.
   d. Organisms complete set of proteins.

18. Cell Specialization is:
   a. The process of altering genes scientifically.
   b. The study of stem cells.
   c. The process cells go through to complete specific jobs.

19. Levels of Organization are:
   a. The organization of species in an ecosystem.
   b. How energy is transferred in an ecosystem.
   c. Long chains of several amino acids.
   d. The layers of specialized cells in organisms.

20. Epigenetics are:
   a. The study of how traits are passed on from parents to offspring.
   b. The study of environmental factors that influence gene expression.
   c. The study of chromosomal disorders.
   d. The study of species interaction within an ecosystem.

21. Carcinogens are:
   a. Substances that cause cancer.
   b. Extracellular substances that connect tissues.
   c. The factors that activate gene expression.
   d. The process of altering genes scientifically.
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EDUCATION AND PROFESSIONAL CREDENTIALS

Degrees
PhD. Special Education, 2018 (Anticipated)
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Dissertation: The impact of a universally designed academic vocabulary intervention in inclusive science classrooms for students with disabilities and English language learners.

M.Ed. Special Education, 2013
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Special Education, 2012
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B.S.

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*Published and Accepted Articles*


PRESENTATIONS


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**RESEARCH EXPERIENCE**

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Committee: Joseph Morgan, Kyle Higgins, Joshua Baker, Tracy Spies, and Jeff Shih

*The impact of a universally designed academic vocabulary intervention in inclusive science classrooms for students with disabilities and English language learners.*

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**Research Intern**
Center for Applied Special Technology (CAST)
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University of Nevada, Las Vegas
Project FOCUS (Forming Occupational and Career Understanding for Success)

**2015**

**Data Collector**
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Project LEAP (Learning English for Academic Purposes)
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**Fall 2017**
TESL 471 Language Acquisition, Development, and Learning

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ESP 708 Advanced Educational Strategies for Students with Disabilities

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TESL 752 TESL Methods and Materials
Summer 2016  ESP 724 Math Methods in Special Education
Fall 2015   ESP 733 Management and Modification of Students with Special Needs
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Fall 2014   ESP 733 Management and Modification of Students with Special Needs

UNIVERSITY TEACHING SUPERVISION
Spring 2017 ESP 737i Advanced Practicum with Exceptional Children
• Supervised 4 graduate alternative route to licensure candidates
EDSP 481 Practicum in a Resource Room
• Supervised 5 undergraduate students in a resource room practicum

Spring 2016 ESP 737i Advanced Practicum with Exceptional Children
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2012-2015 Clark County School District
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UNLV F.O.C.U.S. (Forming Occupational and Community Understanding for Success)
• Coordinated fundraising activities, social events, and summer transition camps in addition to research responsibilities.

Guest Reviewer Intervention in School and Clinic (March 2014; May 2015; July, 2015; September, 2015; November 2015; December, 2015)

Council for Learning Disabilities Local Arrangement Committee (October 2015)

Guest Reviewer LD Forum (Spring 2015)

UNLV Department of Educational and Clinical Studies Doctoral Recruitment (Spring 2015, Fall 2015, Spring 2016)

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   Teacher Education Division
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   Division of Research