Using Assistive Technology to Increase Vocabulary Acquisition and Engagement for Students with Learning Disabilities in the High School Science Classroom

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A dissertation submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

University of Washington

2014

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Program Authorized of Offer Degree:

College of Education

University of Washington

Abstract

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There is a growing recognition of the importance and effectiveness of instruction in the STEM subjects, including science. The movement towards increased requirements and expectations in science presents a challenge to both students and teachers as many students with Learning Disabilities (LD) often particularly struggle in their science classes. The purpose of this study was to investigate the use of an assistive technology (AT) intervention targeting the acquisition of science vocabulary for adolescents with LD in a general education secondary biology classroom. Participants for this study included 3 secondary students with LD who were enrolled in a biology class. An alternating treatment design was used to compare the effects of a keyword mnemonic vocabulary intervention via index cards or iPod touch on student, vocabulary acquisition, academic engagement and disruptive behavior. All students' acquired the content vocabulary equally well during both conditions. When using the AT, students' engagement increased compared to baseline conditions. It was clear that the students had a strong interest in using AT to increase their grades and engagement, however the teachers had little access and training on using AT to support their students with disabilities.

Acknowledgments

I would like to thank the mentors, family, and friends who have encouraged and inspired me to reach my goals.

My sincerest thanks goes to my advisor, Dr. Doug Cheney. Words alone cannot represent the gratitude I have for your exceptional mentorship. Over the past few years, you have not only advised me on how to become a research scholar in the field, but you have also shown me how to become a leader, professional, and future professor as well. I have always dreamed of earning a Ph.D. and becoming a professor; you have both given me the opportunity and the guidance on how to fulfill that dream. I am forever grateful for your time, wisdom, and friendship.

Dr. Beth West, I feel incredibly privileged and honored to have worked with you over the past few years. You have taught me so much around writing, research, and collaboration. I am grateful for our many conversations. Specifically, thank you for your support through each milestone of my doctoral studies.

Dr. Clay Cook, thank you for all of your time, assistance, and guidance throughout my doctoral studies. Throughout the doctoral program, you have encouraged deeper thinking, provided constructive feedback, and helped develop my research skills. Thank you for your support during my time at the University of Washington.

I am grateful for my fellow doctoral students. We have studied (sometimes until the early morning), supported, and laughed together. I look forward to being your friend and colleague for many years to come.

Thank you to my parents, Marshall and Sonia. Your support and inspiration mean the world to me. Thank you to Noa, Mark, Iggy, and Etta. Your encouragement and Skype

conversations always provided the best excuse for a break. Also, thank you to Kathy, Harvey, and Scott for supporting me from start to finish. I am grateful to have joined such a wonderful family.

Finally, I would like to share my love and upmost thanks to my wife, Shannon. Your love, encouragement, and support is the reason I am here today. We have taken this adventure together and throughout this journey you have hugged me when down, brought me food when hungry, and picked me up from school in the middle of the night. But most of all, you have believed in me. Thank you for your patience when I was writing, editing, and writing some more. Without you, I would have never reached my dream. My Beautiful, I share this Ph.D. with you.

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Chapter 1: Introduction and Statement of Problem

Since the passage of the Education for All Handicapped Children Act in 1975, now the Individual with Disabilities Education Act (IDEIA) (Office of Special Education and Rehabilitation Services [OSERS, 2004]), students with disabilities are ensured the right for a free and appropriate education (FAPE) in the least restrictive environment. As such, millions of children have been provided services under the classification of Learning Disabilities (LD). Students with disabilities generally earn lower grades than their peers in general education (Newman et al., 2011) and perform significantly below their peers without disabilities in science, reading, mathematic, spelling, and written expression (Scruggs & Mastropieri, 1993; Reid, Gonzalez, Nordness, Trout, & Epstein, 2004). Compared to researchers in other academic areas, researchers and educators in special education have only recently become interested in the issue of academic interventions for students with disabilities in the STEM (Science, Technology, Engineering, and Math) subjects. As a result, the educational needs of students with LD in the sciences have been almost completely neglected in research. The challenges for students with LD are specifically prevalent in STEM coursework, given the hefty demands of vocabulary terms and concepts (Therrien, Taylor, Hosp, Kaldenberg, & Gorsh, 2011) as students with LD tend to struggle with vocabulary and language-based learning activities (Jitendra, Edwards, & Sacks, 2004). This is a particular concern in that vocabulary knowledge directly contributes to comprehension of the curriculum (Snow, 2002).

Background and Context

Inclusive education. Although inclusion has been contested in the field of special education, (Litvack, Ritchie, & Shore, 2011; Kauffman, 1995; Rea, McLaughlin, & Walther-Thomas, 2002) IDEIA mandates that all students learn in the least restrictive environment. Thus,

students with LD are typically receiving most of their education in regular classrooms where they should have access to the same curriculum as their general education peers (McGuire, Scott, & Shaw, 2006). Additionally, they may receive special education services in resource rooms away from their general education peers. These circumstances pose specific challenges for both teachers and students. For example, Rea et al. (2002) found that students served in inclusive classrooms earned higher grades, achieved higher or comparable scores on standardized tests, committed no more behavioral infractions, and attended more days of school when compared to students served in pullout programs.

A difference in why some students are more successful in some inclusive classrooms may be because some teachers may not have training on how best to accommodate students with various disabilities, implement IEP goals, or lack information on appropriate academic interventions. Turner (2003) reported that most general education teaching programs only offer a single introductory-level special education course and the single course was not likely to provide practices on the appropriate academic and behavior accommodations necessary for students with disabilities in an inclusive setting. Overall, research on teacher preparation for general education teachers has indicated a lack of training on how to best support special education students in the inclusive setting (Jordan et al, 2009; Hardman, 2009).

Science Education and Special Education

The challenge of teaching science to students with disabilities has long been established. Just the same, the challenge for students with disabilities to access science curricula is well documented. Scruggs and Mastropieri (1994) identified a lack of research in science instruction for students with special needs. Cawley et al. (2002), described a school-based project designed to close the gap between research and practice in the design and implementation of science for

students with Emotional Behavioral Disabilities (EBD) at a junior high school setting. Lynch et al. (2007) researched implementing a previously successful small scale study to a larger middle school science curriculum for students with disabilities in general education classrooms. Accordingly, since the 1980's, students with disabilities are more likely to be taking science courses (Wagner et al., 2004). However, Wagner et al.'s findings did not provide details on how well the students are doing in those classes. Even with the challenge acknowledged, little research has been conducted on how to teach students with LD a science curriculum in a secondary inclusive classroom, let alone how to keep them engaged within science curricula.

Science proficiency encompasses a range of comprehension including a recall of critical information while relating that knowledge to the world today. Establishing academic interventions for science curricula is complex as various factors such as reading and writing (Parmar, Deluca & Janzak, 1994; Shepard & Adjogah, 1994; Steel, 2004), difficulties in math (Olson & Platt, 2004), limited prior content knowledge and experience, the ability to relate prior knowledge to new material, poor academic motivation (Scruggs & Mastropieri, 2000), and attention problems (Steele, 2007) all impact a student's success in the science classroom. Further, students with LD can have deficits in the basic skills of reading, writing, and mathematics (Mercer & Mercer, 2005) in additional to poor organizational skills, which increases the challenge for learning science. For example, if a teacher assigns a research project at the beginning of a unit with readings, outlines, research and references requirements, visuals, graphs, data analysis, and report and presentation instructions, students may have trouble following through on any or all aspects of the project because different challenges arise from different parts of the assignment. Specifically troubling for students with disabilities, science is often associated with the memorization of vocabulary that fits within complex theories and

processes. Fortunately, increasing interventions to support students with LD around reading, writing, and mathematic skills are being researched and academic interventions in these areas can be transferred to science classrooms. Nonetheless, it is difficult for science teachers to have the skills, experience, and time to individualize instruction for each student's behavioral and academic need.

High stakes assessments and standards. The national movement for high-stakes testing compounds concern with poor academic performance for students with LD. Furthermore, high school science has become a fixture in the national spotlight as both states and the federal government work to make science part of a high school graduation requirement. Nationally, the agenda to improve science comprehension and scores has led to a national focus on the subject (e.g. Race To The Top) (U.S. Department of Education, 2010). Even though the use of mandated large-scale testing has been used in the United States for more than 30 years (Heubert & Hauser, 1999; Horn, 2003), over the past decade this movement has accelerated. The No Child Left Behind (NCLB) Act in 2001 increased the emphasis on assessments to evaluate students' progress and accountability for State, local educational agencies (LEA), and schools in the core subjects (science, math, and reading) (U.S. Department of Education, 2002; U.S. Department of Education, 2010).

Concurrent with the national directive, students in Washington State will be required to take and pass the Biology End Of Course (Biology EOC) exam as part of a graduation requirement that begins with the class of 2015. According to Washington's Office of the Superintendent of Public Instruction (OSPI), the goal of the High School Proficiency Exams (HSPE) and the EOC's are for federal and state accountability (OSPI, 2012). According to OSPI, the assessment system was implemented in response to the state's Education Reform Law

of 1993 (Engrossed Substitute House Bill 1209), which required that the assessment system: (a) test all public school students across the state, including students with disabilities and students with limited English proficiency; (b) be administered annually in selected grades; (c) measure performance based on the Essential Academic Learning Requirements (EALRs), the state's learning standards; (d) report on the performance of individual students, schools and districts; and (e) serve as one basis of accountability for students, schools and districts. Similarly, the state's high-stake tests also fulfill the requirements of the federal Elementary and Secondary Education Act, passed in 1965, which stipulates that students must be tested annually in science in an elementary school grade, a middle school grade and a high school grade. Testing students in science in grades 5, 8 and high school, fulfills this requirement in Washington State (OSPI, 2012).

Special education. The movement towards increased requirements and expectations in science presents a challenge to both students with disabilities and teachers; and the requirement to pass a state subject exam is a formidable challenge as many students often particularly struggle in their science classes (Millar, 1991; Myers & Fouts, 1992; Mallow et al., 2010). A larger concern is that this challenge, difficult enough for most students, may become an impasse for students in special education.

There is clear evidence that students with disabilities struggle in science. The National Center for Educational Statistics (NCES) reported that the average scores and achievement-level results for students with disabilities in 4^{th}, 8^{th}, and 12^{th} grades in public schools were drastically lower than for students without disabilities (Aud et al., 2011). Over 50% of 4^{th} grade students with disabilities averaged a score below basic, compared to 26% for students without disabilities. For eighth graders, 67% of students with disabilities were below basic, compared to 34% for

students without disabilities. For 12th graders, the average score was 117 for students with disabilities and 152 for students without disabilities (percentage of students reaching at or above basic was not available) (Aud et al., 2011; Planty et al., 2009). No improvement by 12th graders for students with disabilities in science has taken place in the past decade. Data from 1996 show that the average score for 12th grade students with disabilities was 112, compared to 151 for students without disabilities. Data from 2000 show that the average score for students with disabilities was 108, compared to 147 for students without disabilities. Data from 2005 show that the average score for students with disabilities was 112, compared to 148 without disabilities (US Department of Education, 1996, 2000, 2005). Additionally, students with LD were found to score almost one standard deviation lower than students without disabilities on science achievement tests.

NGSS standards. A new set of ambitious learning goals for K-12 science education is being constructed as part of the national initiative known as the Next Generation Science Standards (NGSS). These new learning goals are planned to guide K-12 STEM education for the next decade. Developed by the National Research Council's Framework for K–12 Science Education, these new learning goals are designed for students to learn disciplinary core ideas in the context of science and engineering practices (NGSS, 2013). While the new NGSS report that the practices of the new standards offer rich opportunities and demands for advancing science learning for all students, including students with disabilities, methodologies or further explanations are not provided in the standards.

Theoretical frameworks. A specific challenge around science curriculum is that scientific learning has long been recommended and centered around the major learning theory of constructivism and inquiry based learning (Mastropieri et al., 2001; Driver, Asoko, Leach,

Mortimer, & Scott, 1994; Martin, 1997; Mintzes, Wandersee, & Novak, 1997; Rutherford & Ahlgren, 1990; Herr, 2008). This theory reflects a belief that existing knowledge is used to build new knowledge (Piaget, 1950). A predicament, however, is that while the constructivist theory has long been established in general education science practice, its use in special education, has not been shown to be effective. Historically, special educators have developed teaching practices based on principles of behaviorism (Steele, 2005). Another approach, however, can be constructed upon Vygotsky's Theory of Zone of Proximal Development (ZPD) thorough systematic scaffolding, guidance and support (Vygotsky, 1978). This approach may better suit students not only in special education, but also in both science education and through the use of assistive technology (AT) to support science learning.

Piaget's constructivist theory. Scruggs et al., (2010) is one of the few studies using Piaget's theory and they reported that when rules were presented systematically throughout a number of specific examples and reviewed, frequently higher achievement gains were found than those realized by students taught by more constructivist principles. Therefore, it is believed that students with disabilities may make significantly more progress when guided through explicit instruction than when left to discover important concepts for themselves (Graham & Harris, 1994; Mastropieri & Scruggs, 2002).

An additional challenge for teachers when delivering content by constructivist principles in the classroom is that some learners struggle with unstructured tasks; without structure and direction, some learners may experience failure and frustration in the classroom (Graham & Harris, 1994; Westwood, 2007), which may lead to additional behavioral problems. If not all students respond equally well to constructivist methodologies, this could be a specific hypothesis and plausible reason for why some students with disabilities struggle in science classes.

To learn science through a constructivist approach, students with disabilities need increased scaffolding and systematic review (Bulgren & Scanlon, 1997; Knight et al., 2013). A concern is how students with disabilities, in a general education setting, can be provided sufficient and appropriate opportunities and supports for science learning to take place. General education teachers lack the time, resources, and knowledge to provide the specific accommodations that students with disabilities need in their science classes.

Vygotsky's theory of Zone of Proximal Development. While science education generally is taught via Piaget's constructivist theory, the development of science concepts within a Vygotskian framework has been established. Vygotsky's concept of the ZPD is founded on the concept that development is socially embedded and established by both what a child can do independently and by what the child can do when assisted by an adult or more competent peer (Vygotsky, 1978; Hedegaard, 2006; Wertsch, 1991) (versus Piaget's theory that development is based on building knowledge from the individual's environment). For example, Hodson and Hodson (1998) explained that constructivism's limitation is that learning science is not simply a matter of 'making sense of the world,' in that learning must not lag behind development but instead that good learning should advance development.

The theoretical framework for research in both science and special education should not be whether to follow a constructivist and inquiry-base-learning model or not, since constructivism will likely continue in the general education science classroom. Thus, special education research should focus on how effective academic interventions can fit within the constructivist model. While a general education learner may effectively gain new knowledge via Piaget's theory of constructivism, an effective teacher must also incorporate appropriate learning theories, such as Vygotsky's ZPD, to support students with disabilities. By using effective

practices and scaffolds, teachers will be able to supplement missing knowledge and skills within the constructivist model to support students with LD reach the same level of success as their general education peers. Table 1 summarizes the differences between the two educational theories associated with science education as well as the use of technology to teach students.

Table 1
Theories Associated with Learning Science and the Use of Technology

Characteristics	**Piaget's Theory of Constructivism**	**Vygotsky's Theory of Zone of Proximal Development**
Major Components	Founded on the belief that existing knowledge is used to build new knowledge.	Founded on the belief that systematic scaffolding, guidance and support is used to build new knowledge.
Use in Science Learning	Create opportunities for students to make sense of the world by exploring their ideas and testing their predictions. Students function only at actual development.	Appropriate assistance, and scaffolding (Wood, Bruner and Ross, 1976), creates opportunities for students to use and take control of ideas. Students function at the level of potential development.
Use of Technology	Activities can provide a forum for students to form ideas and questions around how the world works.	Activities can be used as a form of scaffolding and systematic review tailored to the skill level of the student.

The promise of technology. While AT has been found to be highly valued and supported for students with disabilities (Christ, 2008), little research has been conducted on how AT can support the academics and engagement of students with LD in a science classroom. Subsequently, very little research exists on teaching science to students with disabilities or how AT might be used as a tool to enhance engagement or the acquisition of science knowledge to

students with LD. Of the literature that has been written around AT and students with disabilities, attention has focused on behavioral interventions (Cumming, 2010) as well as in types of media (i.e., hypermedia, simulation programs, online learning environments, multi-user virtual environments, multi-user virtual environments, and games) (Marino, 2010). As such, a significant gap in research exists in establishing AT as an intervention to promote access to general education curriculum for students with disabilities in a science classroom.

Learning. Even though little research has been conducted to determine if the use of AT increases the academic success (learning) of students with disabilities in a science classroom, data from other disciplines are promising and this practice should be investigated further. For example, Arthanat and Curtin (2013) found that for students with developmental disabilities (DD), academic scores improved during the course of iPad use (compared to standard computer use). Similarly, McClanahan et al. (2012) found that the use of an iPad facilitated both attention and learning. So much so that the student gained one year's growth in reading within a six weeks time period. Even more promising, Marino (2010) suggests that technology-enhanced science curricula may improve the accessibility of science content for students who struggle with reading.

Engagement. Recent studies demonstrate that technology shows promise as AT can be used as a tool to support the learning of students with disabilities; it potentially levels the playing field for students with disabilities in their academic tasks (Derer, Polsgrove, & Rieth, 1996; McClanahan et al., 2012). Just as importantly, technologies may have the capability to foster increased attention on tasks for students with disabilities (Schneps et al. 2010) and has the potential to increase both behavioral and cognitive engagement (Fredricks, Blumenfeld, & Paris, 2004; Bloom, 1956).

Moving forward. With the continued trend of students with LD struggling in their science classes, it is essential to discover methods, resources, and tools to increase science learning that general education teachers can readily use. With teachers already stretched thin on time, it is important that these do not take significant amounts of time and can be expanded to the whole classroom setting. Because of the requirement for all students, including those with disabilities, to take and pass both science courses and high stakes exams as part of a general education curriculum, it is important that district and school administrators, and classroom teachers, implement science content area instruction that addresses curriculum delivery, effective academic scaffolding, and content vocabulary learning.

Potential barriers and challenges in this area. The major challenge in this area of study is that learning theories and practices are geared towards the majority of students, those without disabilities. Therefore, to support students with disabilities in science, a general education teacher consistently needs to incorporate different academic and behavior accommodations for various disabilities within their own teaching practice and philosophies. To reach this goal, general and special education researchers and practitioners must increase their use and knowledge around effective academic interventions.

Statement of the Problem

While learning science may be unproblematic for some students, it can be overwhelming for others, especially those with disabilities. The consequences of not learning science or STEM in general has long-lasting disadvantages and reduces long term success in one's life (Matthews, 2007). For example, the National Research Council (Singer et al., 2005), reported, "most people in this country lack the basic understanding of science that they need to make informed decisions about the many scientific issues affecting their lives" (p. 1). Science teaches students how the

natural world works and provides the learning of inquiry based skills including problem solving, establishing hypotheses, and career training.

Although data and research are available to explain why students with LD struggle in science, little research has identified how to develop appropriate curriculum and methods to effectively teach students with LD science, to close the proficiency gap between students with and without disabilities.

Purpose of the Study

Based on a lack of research within the field of special education, it appears that further research is needed on how students with LD are able to acquire science concepts; and to evaluate what academic interventions are effective to enhance their science-learning skills. This group of students has been shown to struggle in science and require interventions that can increase relevant vocabulary, engagement, and scientific understanding. Additionally, it is imperative that these interventions are learned and practiced by the general education teacher in a cost effective manner. The goal of this study was to increase the vocabulary and access to the general education science curriculum for the students. Specifically, the purpose of this study was to investigate the use of an assistive technology intervention targeting the acquisition of science vocabulary for adolescents with LD in a general education secondary biology classroom. Concurrently, by gaining access to the general curriculum, students would approach the grade level standards and material that is found on the Washington State End Of Course (EOC) biology exam.

Research Questions:

The questions for the proposed research study include:

Research Question 1*: Is there a difference in the acquisition of science content vocabulary words presented through a traditional instruction medium compared to the acquisition of vocabulary presented through an assistive technology (AT) device?*

Research Question 2*: When compared to traditional teaching tools, does assistive technology increase engagement and decrease disruptive behaviors for students with LD?*

Research Question 3*: Is there a difference in how students with LD and their teachers perceive the social validity of the traditional or AT instructional mediums to learn general education core content words and definitions?*

Chapter 2: Literature Review

To develop effective science curriculum and instruction for students with high incidence disabilities, one must consider both the characteristics of students within each disability as well as the appropriate interventions within the subject itself. This chapter begins with the definitions and characteristics of students with LD and describes the commonalities and differences of students with LD and other high incidence disabilities. Next, a review of the literature, including methods and outcomes, in special education and science is presented following an overview of literature of studies in AT and science in special education.

Definition and Characteristics of Students with Learning Disabilities

Under IDEA, a specific learning disability (LD) means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The law specifies that a specific learning disability does not include learning problems that are primarily the result of visual, hearing, or motor disabilities, of mental retardation (now termed Intellectual Disability, ID), of emotional disturbance, or of environmental, cultural, or economic disadvantage (IDEA 300 /A/300.8/c). About 8% of all children, which accounts to about half of the students that receive special education services, are thought to have a learning disability (Pastor & Reuben, 2008). Students with LD tend to struggle across many content areas and in the special education science literature, this category of special education has benefited with the largest area of conducted research (compared to the other disability categories). An overall theme is that in addition to instructional modifications, to assist with memory and academic deficits, students

with LD benefit from short but frequent review and explicit instruction (Steel, 2007; Pullen et al., 2011).

Comparing Characteristics of Students with LD to Other High Incidence Disabilities.

Recent laws and policy initiatives have increased the pressure for schools and educators to best support students with high incidence disabilities within the inclusive classroom (IDEIA, 2004). To understand how best to support those students, research has sought to understand the academic and behavioral similarities and differences among disabilities, specifically around students with LD and EBD. For example, Lane et al., (2006), compared 49 high school students with LD and 45 students with EBD, from the same district, on the measures of academic, social, and behavioral functioning using a Social Skills Rating System (SSRS – Teacher Version), the Walker-McConnell Scale of Social Competence and School Adjustment, and the Woodcock-Johnson III Tests of Achievement. Results indicated that adolescents with EBD did not differ significantly from students with LD on standardized academic achievement performance. However, the authors reported significant differences in the characteristics of social behaviors. The authors reported that in general, adolescent students with LD exhibited higher levels of social competence and lower levels of behavioral problems when compared to adolescent students with EBD.

When comparing students with LD to students with ID in the secondary setting, academically, students with ID struggle in areas both similar and different to students with LD and other high incidence disabilities. Similar to students with LD, these students often struggle with memory – however, short-term memory is a common deficit area while long-term memory is usually similar to students whom are not disabled. Different, however, to other disabilities, is that these students often have additional difficulty around metacognition (Polloway et al., 2010).

When comparing characteristics of students across disabilities, research within the field of special education show that there are commonalities and differences in how well they perform academically as well as how they perceive school. Through a series of phone interviews, Wagner et al. (2007) contacted 2919 students with disabilities to study the perceptions and expectations of youth with disabilities in regards to their lives, skills, competencies, school experiences, and expectations for their future. In their NLTS2 report, the authors indentified that youth with disabilities are more likely than youth in the general population to report having daily trouble paying attention, completing their homework, and getting along with teachers and students. While across disabilities, most students did not differ on how hard they perceive school, 10 percent of youth with LD reported having no academic problems at school, whereas almost three times as many youth with EBD (27 percent) reported finding school to be without academic difficulty. The NLTS2 report also shares that 96.9% of students with LD surveyed expected to graduate from high school, compared to a similar 94% of students with EBD. Interestingly, when analyzing data from the National Educational Longitudinal Study (NELS), Reshly and Christenson (2006) reported that 26% of students with LD drop out of school and 49.9% of students with EBD drop out before graduating high school – a stark contrast to how surveyed students responded in the NLTS2 report.

Even with considerable progress around special education policies and services, students with disabilities are not receiving the full range of academic accommodations that they should. However, finding the most appropriate interventions is a complex predicament. While a significant amount of research has studied the comparisons of characteristics between students with EBD and students with LD (Anderson, Kutash, & Duchnowski, 2001; Glassberg, Hooper, & Mattison, 1999; Margalit, 1989), unfortunately, in this line of research, definitive results on

which academic interventions show progress across disability categories are few. For example, Vaughn et al. (2002), synthesized previous observation studies, via a systematic search of articles from 1975 to 2000, that conducted research on reading instruction for students with LD and students with EBD, and found that students with disabilities were not receiving reading instruction that was individualized to meet their special needs or reflective of the most effective practice.

In a study comparing the academic progress of students with EBD and students with LD, Anderson, Kutash, and Duchnowski (2001), gathered records of attendance, behavior offenses, type of special education setting, school mobility, and early retention data from a database of 8,000 students in a district in the southeastern United States. Data from a cohort of 42 students with EBD and 61 students with LD were specifically collected, compared, and analyzed through a comprehensive longitudinal information study. The study compared the academic progress of the students over five years measuring standardized reading scores at two points in time: kindergarten or 1st grade and 5th or 6th grade. After analyzing the data, the authors found that students with LD made significant progress using a reading intervention, however, students with EBD did not. Sabornie, Evans, and Cullinan (2006) completed a descriptive review by examining 34 studies that compared characteristics of high-incidence disability groups. The authors searched various electronic databases to find relevant studies (from 1977 to 2005) in which students in the categories of high-incidence disabilities were the participants or foci of the study. The authors organized the studies into the categories of IQ, academic, social, behavior, functional skills, and other (where the *other* category encompassed four subtypes of investigations: student characteristics not associated with the other five domains, parent perceptions, teacher attitudes and decisions, and ethnicity and socioeconomic status). By

comparing the studies within categories, their results found that students with EBD, LD, and ID do not significantly differ in their social adjustment, but do considerably differ in their cognitive and behavioral profiles. Therefore, they concluded that individualized, appropriate instruction, regardless of the disability category is the best practice for students with high-incidence disabilities in special and general education classrooms.

In sum, while students with LD may share the characteristics of students with other disabilities, they often differ in how they respond to various interventions. Specifically, literature consistently shows the broad difficulties a student with LD might face, academically or behaviorally, however what is clear is when compared to other disabilities, students with LD generally respond well to individualized interventions that support closing the gap between a student's potential and school performance. A review of the literature is also clear that students with LD often do not receive the appropriate individualized instruction to support them in the inclusive setting. In science, where content is primarily focused around vocabulary and memorization, this is particularly troubling. Literature, however, also shows promise that when appropriate individualized interventions are provided in vocabulary, reading, engagement, and inquiry based instruction, interventions can support students with LD in the classroom.

Science in Special Education Literature Review

Although limited in scope, there is some research that describes academic interventions that support students with disabilities in the science classroom. In order to locate articles around the topic of special education and science, criteria were established for the studies that would be considered for this literature review. The criteria for inclusion of these articles included: (a) published in peer reviewed journals in 1990 or later (b) focused on academic interventions to specifically improve science learning, (c) designed as an experimental or quasi-experimental

study, and (d) included secondary (Grades 6-12) school-aged participants with LD, EBD, Attention Deficit Hyperactivity Disorder (ADHD), or ID as subjects. To locate the studies, articles were collected through a comprehensive hand and electronic literature search to identify those that met my criteria for inclusion. Additionally, articles from previous literature reviews were included (Therrien et. al, 2011, Mastropieri & Scruggs, 1992, Scruggs, Mastropieri, & Boon, 1998). Electronically, peer-reviewed articles were found using the EBDSCO host (ERIC) using a combination of the keywords *special education, disabilities, science, and science education*. Additional hand sources searched included *Journal of Intellectual Disabilities*, *Journal of Special Education Technology*, *Journal of Emotional and Behavioral Disorders*, *Journal of Learning Disabilities*, *Focus on Autism and Other Developmental Disabilities*, *Journal of Special Education*, *Learning Disabilities Quarterly*, and *Remedial and Special Education*. A final sample consisted of 14 articles. Of the articles published, 10 reported on interventions that support students with LD, three reported on students with Autism Spectrum Disorder (ASD), four reported on students with EBD, four reported on students with ID, and one reported on students with ADHD. Some studies researched more than one disability category. Overall, while there are some data around science and special education, compared to other areas of research, especially when comparing science to the other academic areas, research is scant around interventions to support students with disabilities in a science classroom. Even more so, one article around supporting students with disabilities using Assistive Technology (AT) in the secondary science classroom has been published. A full description of the research is summarized in Table 6.

Of the articles that met criteria, Scruggs and Mastropieri have written the majority of literature on the topic. A meta-analysis, conducted by Scruggs and Mastropieri et al. (2010) that

review academic interventions across secondary content areas also was also found. The authors specifically located intervention studies that included data on secondary aged students with disabilities for which standardized mean difference effect sizes could be computed. The manuscript inclusion procedures included educational and psychological databases to identify studies using a combination of keywords including *content area learning*, *special education*, *students with disabilities*, *disabled*, *science*, *social studies*, and specific content areas such as *biology*, *chemistry*, *history*, and *geography*. A review of references was also completed on all obtained articles. Relevant articles were identified that represented the topic since 1984. By reviewing seventy studies, using more than 2,400 students with LD, EBD, and/or mild mental disabilities, the authors determined the effectiveness of various classroom-learning strategies, such as spatial and graphic organizers, mnemonic strategies, hands-on activities, classroom peers, and computer-assisted instruction. The overall effect size was 1.00, indicating an overall large effect across studies. For each type of academic intervention reviewed below, the effect size is reported.

Direct teaching interventions (explicit instruction) *(M = 1.68)*. Explicit, direct teaching interventions were associated with the highest overall mean effect sizes in a meta-analysis conducted by Scruggs et al. (2010).

Direct instruction, also referred to as explicit direct instruction, is a teacher-led instructional approach that is one of the most effective methods to teach students core academic skills (Kroesbergen & Van Luit, 2003). Explicit teaching, by way of increased scaffolding, gives structure to inquiry-based learning as some children struggle with unstructured tasks; without structure and direction, some students may experience failure and frustration in the classroom (Graham & Harris, 1994; Westwood, 2007), which may lead to additional behavioral problems.

Possibly, this intervention can be used to replace unknown knowledge within a constructivist or inquiry based method of teaching.

McCleery and Tindal (1999) conducted a study around the teaching of the scientific method to 14 students with LD through the concept of explicit instruction. In their study, 10 students with LD were assigned randomly to one of two experimental conditions – a pull-away group and period A & B groups where group A received hands-on constructivist instruction with explicit rule basis, the control group, which included four students with LD, did not receive instruction emphasizing concepts or explicit rules, and B received hands-on constructivist activities without explicit rules. Specifically, compared to students in group A, students in group B were taught concepts for an activity with few teacher-student interactions or questioning and answering. Using an immediate post-test, scoring the students' outcome of correctness of the explanation of the activity (yes or no) and qualitatively of the richness of their answer (coded on a scale from 1 to 3), the researchers found, by a Kruskal-Wallis nonparametric analysis and descriptive statistics, significant difference for students taught with the explicit instruction enhanced approach over just hands-on construction.

Likewise, for students with disabilities, explicit instruction has been researched in math education. Kroesbergen and Van Luit, (2003) conducted a meta-analysis of 58 studies addressing mathematic interventions and several finding are highlighted. Upon analyzing the effect size for the found interventions, the authors, reported that studies consistently show that even though typically developing students score better on post-intervention tests, from the general education mathematics program through a constructivist style of instruction, students who are at risk for serious mathematics deficits, fail to profit from those programs in a way that produces understanding of the structure, meaning, and operational requirements of mathematics.

However, the authors revealed that students with math disabilities earned higher post-test scores from explicit instruction than from discovery-oriented methods. The implications of this research is important as math is an integral part in a science curriculum as well as in data analysis from science experiments and reports. Additionally, with the challenge around constructivist thinking for many students with disabilities, this intervention may hold the most promise in being an effective strategy for increasing access to general education science curricula for students with high-incidence disabilities within a constructivist model of learning.

Vocabulary & mnemonic instruction *(M =1.47*). A very high mean effect size has been found for the use of mnemonic instructional techniques, including the keyword method (Scruggs & Mastropieri, 2000; Scruggs et al., 2010).

A growing concern for teachers in the STEM subjects is around textbook use and vocabulary instruction. Over the past two decades, Scruggs and Mastropieri have researched and reported many findings around mnemonic instruction for students in special education, especially for students with LD (Mastropieri, Scruggs, & Levin, 1985; Mastropieri, Scruggs, McLoone, & Levin, 1985; Mastropieri at al., 1987; Scruggs & Mastropieri, 2000; Mastropieri, Scruggs, & Graetz, 2005), making mnemonic instruction the most researched intervention found to support students with disabilities in science instruction. Table 2 summarizes studies in which mnemonic instruction was the focus for students with LD in the science classroom.

Table 2
Mnemonics Instruction For Students With Disabilities In Secondary Science

Author	Participants	Intervention	Analysis	Outcomes
King-Sears, Mercer, & Sindelar (1992)	n=30, LD, n=7, EBD	Keyword mnemonics used to teach definitions of unfamiliar science terms	ANCOVA	Results for imposed and induced keyword methods were reported that students scored higher on

				matching quizzes after the intervention was implemented.
Mastropieri, Scruggs, & Graetz (2005)	n=10, LD	Students participated in class-wide peer tutoring of important content including mnemonic and other verbal cues	ANOVA	Students in the experimental condition outperformed students in the traditional condition on post-tests that consisted of factual items and comprehension items and gains of students. LD exceeded typically-achieving students on factual and comprehension post-tests.

Note. EBD – Emotional/Behavioral Disability; LD – Learning Disability

Mnemonic instruction is a method that has been demonstrated as effective in vocabulary learning. Types of mnemonic strategies include loci, keyword, pegword, acronyms, reconstructive elaborations, phonic mnemonics, spelling mnemonics, number-sound mnemonics, and Japanese "Yodai" mnemonic methods (Scruggs & Mastropieri, 1990) with the goal being to improve a link between known and unknown information. For example, to help students remember that the scientific classification ranidae (which refers to the family of common frogs), students could be given a "keyword" for ranidae, such as "rain" or "rainy day" that sounds like ranidae, while simultaneously shown a picture of a frog sitting in the rain (Scruggs et al., 2010). Table 3 summarizes the types of mnemonic strategies along with examples. Similarly, a specific advantage to teaching science vocabulary is that in science, terms often combine Greek and Latin

roots that may be familiar to students from another context in their life. For example, *hydroplane* has a similar root of hydrant from *fire hydrant* and students can relate the vocabulary word to water. Due to the importance of students connecting the known and unknown of the natural world within a constructivist model of learning, this intervention may provide an effective support for students with disabilities that struggle with cognition and the use of language.

Table 3
Mnemonic Instruction Examples (Scruggs & Mastropieri, 2000)

Mnemonic Strategy	**Description**	**Example**
Loci	A memory enhancement that uses visualization to organize and recall information.	As Greek soldiers would listen to a lecture about a battle, they would tie each important point to a locus, or place.
Keyword	Used to teach content specific vocabulary (Science, foreign language, high level English). The new word is recoded into a keyword that is concrete (easy to picture), already familiar to the learner, and acoustically similar to the target word. The keyword is then linked to the definition and an interactive picture which shows the keyword and the definition "doing something together."	The scientific classification ranidae (which refers to the family of common frogs), students could be given a "keyword" for ranidae, such as "rain" or "rainy day" that sounds like ranidae while simultaneously shown a picture of a frog sitting in the rain.
Pegword	Rhyming proxies for numbers and are used to remember numbered information.	One is bun, two is shoe, three is tree, etc.
Acronym	Summarize lists of information to be	To help students remember that the countries of the

	remembered.	Central Powers were Turkey, Austria-Hungary, and Germany, a picture can be shown of children playing TAG (acronym for Turkey, Austria- Hungary, and Germany in Central Park (keyword for Central Powers) (Scruggs & Mastropieri, 1989).
Reconstructive Elaborations	The reconstructive elaborations model employs keywords (acoustic reconstructions) for encoding unfamiliar information, symbolic pictures (symbolic reconstructions) for encoding familiar but abstract and literal pictures (mimetic reconstructions) for familiar concrete information.	An example of a symbol for familiar-abstract information could be scales for liberty, or a church for religion. Mimetic pictures for familiar, concrete information could include literal pictures of information such as worms, birds, or pioneers.
Phonic	A letter next to an object whose first sound is represented by that letter sound.	The letter "a" next to a picture of an "apple" as the "a" is drawn to resemble an apple.
Spelling	Used in drawing firm associations in content or skill areas where the relationships are arbitrary.	The word "cemetery," could be spelled in a variety of ways that all capture the appropriate vowel sounds, but is spelled with three e's. An example of how students could remember this is by remembering, "She screamed 'E-E-E' as she walked by the cemetery." Students who retrieve the sentence can remember the correct spelling of "cemetery."

Number-Sound	This type of mnemonics is used to recall strings of numbers, such as telephone numbers, addresses, zip codes, locker combinations, social security numbers, or historical dates. To use them, learners must first learn the number-sound relationships: 0=s; 1=t ; 2=n; 3=m; 4=r; 5=l; 6=sh, ch, or soft g; 7=k, hard c, or hard g; 8= f or v; and 9=p.	To remember the date 1492, the learner uses the associated consonant sounds, t, r, p, and n, and inserts vowels to create a meaningful word or words. In this case, "terrapin" could be used (there is only one r sound, even though two r's are represented in "terrapin").
"Yodai"	In Japan, school children are taught a variety of mathematical procedures using rhymes and visual imagery.	If a rhyme used is "POOL (i.e. put together) shirts (numerators) to shirts, patches (denominators) to patches." Students are shown a picture of a swimming pool in the shape of the multiplication symbol. A jogger, wearing shirt and shorts (with patches), is on each side. The numerator of a fraction is shown on each shirt, with the denominator on the patches.

King-Sears, Mercer, and Sindelar (1992), studied keyword mnemonics as a strategy for science vocabulary instruction for students (n = 30) with LD and students with EBD (n = 7) in 6th to 8th grade. In this study, teachers were randomly assigned to conditions where all students were taught the same four units of 12 vocabulary words (for a total of 48 words) each week over a period of three weeks, but keyword mnemonics were used in only two of the three instructional procedures taught. By using results from weekly tests from matching word assessments an

ANCOVA analysis was conducted to compare between groups outcomes. The researchers found that students' scores improved for both imposed and induced mnemonics keyword methods for students with LD or EBD.

Graphic organization *(M = 0.93).* Graphic organizers involve presenting content to students through visual organization by providing explicit and direct instruction including modeling, making an example organizer as a class, and then instructing the students to make their own ("I do, we do, you do"). Knight et al. (2013) conducted a single subject, multiple probe, design to study the use of graphic organizers to teach science concepts to students with ASD and ID. Students were taught various scientific concepts related to convection (e.g. precipitation, condensations) via systematic instruction that included constant time delay and multiple exemplars of a teacher-directed graphic organizer. The study found a functional relationship was demonstrated between the graphic organizer with systematic instruction and students' number of correct steps on the task analysis for both the students with ASD and ID. The authors concluded that the use of explicit, verbally directed graphic organizers can be an effective tool when teaching science vocabulary and concepts to middle school students with ASD and ID.

Peer mediation (*M =0.86*). Using student classmates as another support to deliver instruction, peer mediation interventions include a variety of techniques such as peer modeling, peer monitoring, and peer tutoring (Ryan, Pierce, & Mooney, 2008). Table 4 describes studies found for peer instruction in the secondary science classroom for students with LD.

Mastropieri, Scruggs, and Graetz (2005), studied 10 students with LD in an experimental condition where they participated in class-wide peer tutoring of important content using mnemonic and other verbal cues. They were interested in determining if this approach

influenced how well students answered specific questions on a factual and comprehension based post-test. Using factual and comprehension content assessments, the researchers found that the students in the experimental condition (vs. traditional instruction) outperformed the students in the traditional condition on factual item assessments. Results showed that gains on the post-tests of the students with LD exceeded those of typically achieving students. However, students with LD scored higher on factual items but not as well on comprehension items.

Table 4
Peer Instruction For Students With Disabilities In Secondary Science

Author	Participants	Intervention	Analysis	Outcomes
Mastropieri, Scruggs, & Graetz (2005)	n=10, LD	Peer mediated (tutoring). Mnemonics.	ANOVA	Students in the experimental condition outperformed students in the traditional condition and gains of students with LD exceeded typically-achieving students on content specific post-test assessment questions.
McDuffie, Mastropieri, & Scruggs (2009)	n=63, (33 LD, 2 LD+EBD; n=13, LD+OHI; n=6, ASD; 2 ID, n=1, SL, 2=OHI, n=3, 504)	Peer mediated (tutoring).	ANCOVA	The peer-tutoring intervention was associated with improvements in student performance on what X variable

Note. EBD – Emotional/Behavioral Disability; LD – Learning Disability; ID – Mild Intellectual Disability; OHI – Other Health Impairment; ASD – Autism Spectrum Disorder; SL – Speech and Language Disability

Hands-on activities (*M = 0.63***).** Studies using hands-on activities have consistently found that students with EBD perform higher on post-tests (e.g unit exams) after hands-on

activity interventions (Scrugg, Mastropieri, Bakken, & Brigham, 1993; McCarthy, 2005). For students with disabilities, hands-on activities can increase motivation and engagement. Specifically, for students with EBD and ADHD, hands-on activities enable the material to become more accessible and material becomes more relevant instead of learning through text, where these students considerably struggle.

Mastropieri et al. (2006) conducted a research study of 213 8th grade students, 37 who had LD and seven with EBD, and compared peer tutoring using differentiated hands-on activities to teacher-directed instruction based on teacher administered unit tests and proficiency scores of state high-stakes tests. Thirteen classrooms were matched by classroom teacher and randomly assigned to either an experimental control or condition. The six experimental classes received units of differentiated peer-mediated hands on instruction compared to the five control classes. The results support the effectiveness of using differentiated learning activities with peer partners in middle school inclusive science classes, not only on content posttests, but also on high-stakes end-of-year tests. Specifically, by analyzing (via ANCOVA) post-test and high-stakes exams, the researchers found that collaborative hands-on activities facilitated learning, and that overall, students enjoyed the intervention activities.

Assistive technology (*computer-assisted instruction, M =0.63*). Historically, one use of AT for students with LD has been to promote social skill development (Cummings, 2010), it also has a potential to engage students in academic instruction. Examples include using vocabulary software on the iPad, science websites and games, and math applications on computers and mobile devices (Marino, 2010). Table 5 describes a sample of studies around the use of AT in secondary science and math classrooms.

Horton and Lovitt (1994) compared two methods of administering group-reading inventories to 72 students, including four students with LD. In one condition, students read textbook passages presented on a computer and in the other condition, the same students read passages from their textbooks to determine if there would be any difference on the number of correct answer on a factual based 15-item test. After completing the test either on the computer or using a pencil and paper, the authors found that secondary students with LD generally scored slightly higher when presented on computer as when presented from a textbook.

Haydon et al., (2012) conducted a study comparing iPads and worksheets on math skills for three high school students with EBD. Using an alternating treatment design, the authors evaluated the effects of a worksheet condition and an iPad condition on math fluency and active academic engagement. The study addressed the research question: (a) Do students have greater accuracy in solving math problems under a mobile learning technology (iPad) or traditional worksheets conditions?; and (b) Do students demonstrate higher rates of academic engagement under a mobile learning technology (iPad) or traditional worksheet conditions? Using visual analyses of the performance data, the authors found that the students solved an increased number of math problems correctly (worksheet M=0.66, iPad M=3.24) in less time and demonstrated higher levels of active engagement (worksheet M=81.4, iPad M=98.9) in the iPad condition when compared to the worksheet condition.

Table 5
Assistive Technology Use In Instruction For Students With Disabilities In Secondary Science and Math

Author	Participants	Intervention	Analysis	Outcomes
Horton & Lovitt (1994)	4 LD	Students read textbook passages presented on a computer, completed study	ANOVA	Secondary students with LD generally comprehend information as well when

		guides, and took 15-item test on computer vs. traditional textbook pencil/paper.		presented on computer as when presented from a textbook.
Haydon et al. (2012)	3 EBD	Students completed problems on a worksheet or presented on an iPad	Single subject, alternating treatment design.	Students solved problems correctly in less time, demonstrated higher levels of active engagement, and preferred the iPad condition.

Note. EBD – Emotional/Behavioral Disability; LD – Learning Disability

Theoretical Framework

There is no one size fits all constructivist-support-model for students with disabilities. Complicating the matter further, there is controversy and disagreement around the best theoretical framework on how to teach science, not only to students in general education but, specifically to students with disabilities.

While there are various definitions and approaches to constructivism, the starting point for all of them is for a child to learn by using prior knowledge and experiences. Little research has been conducted around why students with disabilities may struggle with constructivism, but a theory is that many students with disabilities lack the prior knowledge required for a foundation of the constructivist model. Similarly, Harris and Graham (1994) discuss many of the issues around the movement toward constructivism in general and special education. In the article, the authors acknowledge meaningful context for learning through the constructivist model, however, they also recognize that providing explicit instruction for students may be necessary to gain important skills, as a prerequisite for learning.

In a study conducted in the content area of science, Mastropieri, Scruggs, and Butcher (1997) studied the academic progress of students (n=18, LD; n=16, ID) through a series of questions about the motion of pendulums and the levels of coaching a student would need in order to answer the question correctly using a constructivist, inquiry based, method. In this study, students were individually provided with guided coaching, intended to promote induction of the association between pendulum length and pendulum motion in a junior-high science class. By using a nonparametric Kruskal-Wallace test and Mann-Whitney U test, the authors found that 50% of the students with LD, but none of the students with ID, provided the correct induction. Also, the authors found that the students with LD and the students with ID were less likely to correctly answer transfer of knowledge questions.

Similarly, in a meta-analysis of 70 experimental or quasi-experimental studies on academic interventions for students in special education, Scruggs et al. (2010) found that explicit instructions were associated with the highest overall mean effect sizes (M = *1.68*). The authors explain that this approach also resulted in higher achievement gains in content assessments than by students taught by more constructivist principles (McCleery & Tindal, 1999; Rosenshine, 1987). Therefore, while a limited amount of direct research has been conducted to determine how well students with disabilities learn via a constructivist approach in the science classroom, research suggests that students with disabilities need appropriate academic interventions to both build the foundations of science content as well as to appropriately differentiate the content curriculum.

Research to practice problem. In 2007, Scruggs and Mastropieri reviewed the research around constructed versus instructed learning. They state the theoretical position, that while constructed knowledge might be very effective for many students (e.g. students in general

education), constructivist learning models are less appropriate for many students with disabilities, who may be less efficient in drawing appropriate or useful inferences and who might benefit from more explicit instruction. Similarly, Hodson and Hodson (1998) explained that while constructivist theories are generally considered the norm for effective science learning, other theories, such as Vygotsky's ZPD might be more appropriate for students with disabilities due to the formation of scaffolding into lessons to support a student's individual needs by a teacher.

Even though research exists on how best to teach students with disabilities, a gap between research and practice exists in supporting students with disabilities in the science classroom. Because most science teacher education programs are founded in the constructivist model (Rutherford & Ahlgren, 1990), science teachers often do not incorporate theoretical frameworks that may benefit students with disabilities.

A Critical Analysis Of The Literature

The best practice on how to teach science to students with disabilities is controversial. With the pressures of new national standards and high stakes exams, many educators are scrambling to implement effective means of teaching science to students with disabilities. However, with such little research in the topic, both science and special educators have more questions than answers. Lynch et al. (2007) reviewed studies that describe some areas of research that have shown promise in science education for students with disabilities such as hands-on and inquiry-based learning (e.g., McCleery & Tindal, 1999, Mastropiri et al., 2006). However, they also note that Dalton, Morocco, Tivnan, and Rawson Mead (1997) suggest that simply providing access to manipulations of materials has not been found to be sufficient enough to bring about conceptual change. Similarly, Villanueva et al. (2012) conducted an analysis of

current research of science education for students with disabilities (special needs) and report that inquiry instruction can improve state science proficiency scores for students with disabilities. They were clear, however, that those improvements required appropriate scaffolds and supports. While much promise exists in the field of special education for how to best teach secondary science to students with disabilities, few studies have actually used designs that provide evidence for the effectiveness of specific interventions for students with disabilities in the science classroom, let alone students with LD at the secondary level.

As the literature shows, scaffolding is a critical necessity for students with disabilities in the science classroom. Additionally, various academic interventions can be viable tools for students with disabilities to access general education science curriculum. The studies also show, however, that not all accommodations are appropriate for all disabilities, and that the research community does not yet know which interventions are most appropriate for the various components of a secondary science lesson. Even more challenging, of the studies that do exist, the research literature tends to use constructs in general terms (e.g., hands-on, inquiry-based, active-learning, explicit-instruction). While these terms may be familiar to both researchers and educators, without clear implementation methods and effective interventions, these constructs are not replicable for the practitioner in the science classroom. As a result, many students who require special education supports and services in their science class continue to be at risk for school failure because appropriate academic interventions are not yet known.

Table 6
Participants, Measures, Analyses, And Outcomes Of Qualifying Science And Special Education Literature

	Setting and Participants			**Research Design**					
Article	**Participants**	**Disability Category**	**Sample Grades**	**Assignment**	**Intervention Type**	**Intervention Description**	**Assistive Technology**	**Dependent Variable**	**Outcome**
McCleery and Tindal (1999)	57	14 LD	6	Students assigned non-randomly. Descriptive statistics were used. A Kruskal-Wallis nonparametric analysis was also used because the standard deviation for the pull-away group was zero.	Constructivism. Hands on vs. explicit.	2 experimental conditions - a pull-away and Period A & B group. A received hands-on constructivist instruction with explicit rule basis, the control group did not receive instruction emphasizing concepts or explicit rules, and B received hands-on constructivist activities.	N/A	Immediate post-test	Significant difference over just hands-on constructivist activities not anchored in concepts or not explicitly delivered through rules.

Scruggs, Mastropieri, Bakken, & Brigham (1993)	26	LD	7-8	Counterbalanced, within-subjects crossover design. Students received both treatments.	Inquiry based learning.	Instructions of two science units (magnetism and electricity, and rocks and minerals) via either an activity based, inquiry-oriented approach or a textbook approach.	N/A	Immediate & delayed post-tests	Students performed significantly higher on immediate and delayed unit tests when they had learned by the inquiry-oriented approach. Vocabulary acquisition was limited in both conditions.
King-Sears, Mercer, & Sindelar (1992)	37	30 LD, 7 EBD	6-8	Teachers assigned at random to conditions. All students taught the same four units of 12 vocabulary words (total of 48 words) each week over a period of 3 weeks. Group means on the last 3 weeks of instruction were	Vocabulary (Mnemonics)	Keyword mnemonics were used in two of three instructional procedures taught to teach definitions of unfamiliar science terms. 48 science vocabulary words were taught. Systematic teaching and in induced	N/A	Weekly tests	Favorable results for imposed and induced keyword methods were obtained.

analyzed using repeated measures ANCOVA. IQ was the covariate, and written and matching performances were analyzed separately. Three scores from the fourth week of instruction, 1 week after instruction, and 3 weeks after instruction were analyzed in a repeated measures ANCOVA by using student scores.	keyword method (taught by using the IT FITS strategy) were compared.

Boyle (2011)	104	28 LD	6-8	Non randomized. All participants drawn from seven science classes at two different middle schools. A multivariate analysis of variance (MANOVA) was conducted.	Note taking.	Strategic note-taking on note-taking and achievement of students with and without LD.	N/A	Post-tests. Post-intervention Immediate Free Recall (IFR) measures.	Students trained to use strategic note-taking performed better than students who used conventional note taking on immediate recall land comprehensi on.
Seifert & Espin (2012)	20	LD	10	Within-subject design.	Reading (vocabulary).	Effects of 3 types of reading interventions on science text reading: Text reading, vocabulary learning, text reading plus vocabulary learning.	N/A	Effects on reading fluency, vocabulary knowledge, & comprehensi on. Post-intervention reading aloud/counti ng errors.	Text-reading and combined interventions had a positive effect on reading fluency and vocabulary knowledge. Vocabulary intervention had a positive effect on vocabulary knowledge.

Berkeley, Mastropieri, & Scruggs (2011)	59	LD	6-12	Randomly assigned. Pre-post experimental design with a 6-week delayed posttest.	Reading.	Students assigned to one of three treatments: RCS+AR, RCS, or a Read Naturally.	N/A	Post-test: Comprehension summarization test, passage-specific content test, Meta-Comprehension Strategy Index (MSI), and Reading Attribution Scale (RAS).	Compared to the comparison group, both strategy instruction groups performed better on a summarization measure of comprehension after treatment producing large effect sizes.
Mastropieri, Scruggs, & Graetz (2005)	39	10 LD	9-12	Non randomized. ANOVA was used to analyze data of the two conditions by group by type.	Peer medicated (tutoring). Mnemonics.	Students in the experimental condition participated in class wide peer tutoring of important content including Mnemonic and other verbal cues. Students in control participate in traditional instruction.	N/A	Post-test	Students in experimental condition outperformed students in the traditional condition and gains of students with LD exceeded those of typically achieving students. Students without LD outperformed students with

									LD and students scored higher on factual items than on comprehensi on items.
Mastropieri, Scruggs, & Butcher (1997)	54	18 LD, 16 MID	7-9	Non-randomized. A nonparametri c Kruskal-Wallace test and Mann-Whitney U tests were used.	Inquiry based learning.	Students were provided individually with guided coaching intended to promote induction of the association between pendulum length and pendulum motion.	N/A	Post-test for providing the correct induction.	75% of normal achieving students and 50% of students with LD, but none of the students with MR, provided the correct induction. Students with LD and MR were less likely to correctly answer transfer/appli cation questions.

Jimenez, Browder, Spooner, & Dibiase (2012)	5	MID	6-8	Non-randomized. Single-subject, multiple probe, design.	Peer mediated.	Effects of peer-mediated time-delay instruction to teach inquiry science and use of knowledge chart to students with MID.	N/A	Post-test.	All 5 students increased the number of correct science responses across all science units but three students required additional support by the special education teacher to reach mastery.
Knight, Spooner, Browder, Smith, & Wood (2013)	3	ASD & MID	6-8	Non-randomized. Single subject, multiple probe, design.	Graphic Organizer.	Students were taught various scientific concepts related to convection (e.g. precipitation, condensations) via systematic instruction that included constant time delay and multiple	N/A	Number of correct steps completed on the task analysis.	A functional relation was demonstrated between the GO with systematic instruction and students' number of correct steps on the task analysis.

						exemplars of a teacher-directed Graphic Organizer (GO).			
Carnahan & Williamson (2013)	3	ASD	7-8	Single-subject reversal design.	Venn Diagrams/ Graphic Organizer.	Evaluated the use of a compare-contrast strategy.	N/A	A content analysis comparing the number of meaning units in passages to the number of meaning units in student-completed Venn diagrams was conducted for both the treatment and maintenance phases.	Instruction in the compare-contrast text pattern was effective in increasing participants' comprehension. A content analysis of Venn diagrams revealed a decrease in number of recorded meaning units during the maintenance phase while passage comprehension remained high.

Rogevich & Perin (2008)	63	32 EBD, 31 EBD+ADHD	7-10	non randomized. Quasi-experimental using a matched comparison group design. Using a repeated measures multivariate analysis f covariance (MANCOVA) to compare the four groups (BD/intervention, BD+ADHD/intervention, BD/Practice, and BD+ADHD practice).	Self-Regulation.	Students participated in a self-regulated strategy development adding written summarization, focusing on self monitoring, and using only science text.	N/A	Reading comprehension as measured through written summarization.	Participants in experimental group showed significantly greater gains than control group. The difference in the amount of gain between BD and BD+ADHD was not significant. However ADHD appeared to interfere with the participants' ability to apply the newly learned literacy skills to different tasks.

McDuffie, Mastropieri, & Scruggs (2009)	203	63 (33 LD, 2 LD+EBD, 13 LD+OHI, 6 ASD, 2 MD, 1SL, 2 OHI, 3 504)	6-8	Randomized. Four co-taught classes and four non-co-taught classes were assigned to either peer-tutoring or non-peer-tutoring conditions. ANCOVA design - 2 condition by 2 settings by 2 types of students analysis of covariance with pretests as covariates.	Peer medicated (tutoring).	In the peer-tutoring condition, students received the same traditional instruction with the exception that students participated in a 10 minute warm up of peer tutoring.	N/A	Dependent measures included (a) academic content measures, (b) observational measures of teacher-student interaction and teachers instructional behavior, and (c) assessments of teacher and student perceptions of instruction and materials.	The peer-tutoring intervention was associated with improvements in student performance, and students in co-teaching settings perform better than those in non-co-teaching settings, but no additional value was added when peer tutoring was implemented in co-taught classrooms.

Mastropieri, Scruggs, Noland, Berkely, McDuffie, Tornquist, and Connors (2006)	213	37 LD, 7 EBD	8	Classrooms were matched by classroom teacher and randomly assigned to either an experimental or control condition. Posttest data were entered into a 2 condition (experimental vs. control) x 2 group (special education vs. general education) ANCOVA with pretest as covariate and with classrooms treated as a nested factor within conditions.	Peer mediated. Hands on.	Experimental classes received units of differentiated, peer-medicated, hands-on instruction. Control classes received traditional science instruction.	N/A	Post test and state high-stakes tests.	Students in experimental condition outperformed students in the traditional condition and on high-stakes test.

Horton & Lovitt (1994)	72	4 LD	7	Non-randomized. A three (class) x two (group reading inventory) ANOVA with repeated measures on the last factor was conducted for factual questions.	Assistive Technology.	In one condition, students read textbook passages presented on a computer, completed study guides, and took 15-item test on computer. In the other condition, the same students read passages from their textbooks, completed study guides, and took 15-item test with pencil and paper.	Computer. 30 Apple II E computers were used. A computer program was developed by the research staff.	15-item test either on computer or using pencil & paper.	Secondary students with LD generally comprehend information as well when presented on computer as when presented from a textbook.

Chapter 3: Method

Setting

This study was conducted in a high school biology classroom at a public high school in the Seattle area. Overall school enrollment included approximately 1,211 students in grades 9-12. The school's population is approximately 1.4% Native American/Alaskan Native, 25.7% Asian, 0.8% Native Hawaiian/Other Pacific Islander, 26.5% Asian/Pacific Islander, 18.6% Black, 15.1% Hispanic/Latino of any race(s), 34.9% White, 3.5% Two or more races, a free or reduce-price meal rate of 46.7%, and 11.6% qualifying for special education services (OSPI School Report Card: retrieved on 11/29/2013).

The participants for this study were in two high school biology classrooms within this school. In this school, students primarily take biology during the 10th grade. The curriculum used is assigned by the district and follows a textbook that is founded around inquiry-based instruction. The instructional setting for biology was small group. Students participated in the general education class with one student receiving support from a para-education professional.

Participants

After recruitment from district and school administration, data, parent permission and student assent to share data in published reports were collected for 3 students enrolled in a biology class. Students were identified for special education services under the category of LD and were selected by the administration and faculty. Special education records by faculty for each student were used to verify eligibility. Table 7 summarizes the demographic information for each of the three participants.

Katie. Katie (pseudoname) is a White, sixteen-year-old female student at the time of the study, in 10th grade. She receives special education services under the category of LD for reading and writing.

Ashley. Ashley (pseudoname) is an African American, sixteen-year-old female student at the time of the study, in 10th grade. She receives special education services under the category of LD for reading and writing.

Lisa. Lisa (pseudoname) is a Vietnamese American, sixteen-year-old female student at the time of the study, in 10th grade. She receives special education services under the category of LD for reading and writing.

Table 7
Student Demographics

Participant	Gender	Ethnicity	Age	Grade	Special Education Category
Katie	Female	White	16 years	10th	LD
Ashley	Female	African American	16 years	10th	LD
Lisa	Female	Asian	16 years	10th	LD

Note. LD – Learning Disability

Justification for the Use of the Test of Vocabulary

Challenging for students, science has its own set of vocabulary with terms usually based in Greek and Latin roots. This vocabulary enables scientists, regardless of native language or location to communicate and express ideas. Unfortunately, this vocabulary is increasingly difficult for students to master, especially for students that struggle with literacy and memorization, such as many students with LD do. Of particular challenge for students in a science classroom is that secondary level science textbooks have been determined to contain a vocabulary load higher than that is recommended for junior high

and high school foreign language courses (Yager, 1983). A compounding concern is that, specifically, biology has a larger vocabulary that any other branch of science (Herr, 2008). Additionally, compared to other content areas, the vocabulary used in a biology class can be categorized as words whose frequency of use is quite low and often is limited to the specific domain (e.g. Tier three words) (Beck, McKeown, & Kucan, 2002). In order to be successful in science learning, all students, but in particular, those with disabilities, must be provided ongoing vocabulary instruction to develop the necessary language comprehension skills and to become competent content readers.

Justification for the Use of Imposed Keyword Condition Material

Imposed keyword condition is an intervention technique that already has a strong research base showing it as effective. Therefore, the intervention tested is the determination of the effects in the acquisition of science content vocabulary words presented through traditional instruction medium compared to the acquisition of vocabulary presented through an AT device; the goal was not to test mnemonic interventions, but the use of the AT device.

In the keyword mnemonic strategy, the keyword refers to a chosen word to represent a given vocabulary word. The keyword mnemonic strategy pairs the keyword with an illustration demonstrating how the keyword is related to the vocabulary word. The keyword and illustration are used as a prompt for students to redevelop the correct definition of the represented vocabulary word (Atkinson, 1975). King-Sears et al, (1992) modified this condition in their research study by using two cards. The first card had the vocabulary word on one side and the keyword on the other side. On a second card there was the keyword, the vocabulary word, its definition, and an illustration of the keyword

and term.

Instructional Procedures

Experimental design.

An alternating treatment design (Gast, 2010) was used to compare the effects of two (independent variables) instructional conditions (i.e., vocabulary intervention via flashcards or iPod touch) on student, tier three vocabulary acquisition, academic engagement and disruptive behavior. The design incorporated 5 phases (Baseline, A_1, B_1, A_2, B_2) with 3 probes per phase where A = Traditional flash cards and B = iPod touch. At least three times per phase, students were assessed for vocabulary acquisition, academic engagement, and disruptive behavior. During the baseline data collection period, students were given 3 probes of biology vocabulary words used in lessons from their textbook and provided curriculum ("Business as usual"). Additionally, academic engagement during class and disruptive behavior during normal class-time was assessed. All vocabulary for the experiment was provided by the teachers or taken from the current chapter of the students' biology textbook. Students met with the researcher in an empty prep-room adjacent to the classroom for approximately 5 minutes at the start of the period, during "warm up time."

Study phases. The study began in April of the 2013-2014 school year, and was conducted over a period of 7 weeks. The baseline phase was for 3 days. The intervention phase lasted 6 weeks and was implemented for approximately 5 minutes/day. Follow up data were collected during the first week of June.

Student screening. Student screening began in March of the 2014 academic year and resulted in identifying 3 students meeting the criteria for inclusion. Students meeting

the criteria were offered an invitation to participate in the study. Prior to baseline, students completed a 10-word matching vocabulary quiz to assess prior vocabulary and content knowledge. Students that received above a 60% were excluded from the study, as only students that have room to detect improvement were included.

Independent Variables

Traditional (flash cards). 3 x 5 index cards were used. Following the demonstration of three sample words on Day 1 of the study, the researcher provided students index cards of 5 vocabulary words. Modifying the procedures by King-Sears et al. (1992), each index card had a vocabulary word on one side as well as the keyword. On the second side, there was the keyword, the vocabulary word, its definition, and an illustration of the keyword and term. For consistency, the researcher created the flash cards online using the app, "quizlet", printed each side, and glued the information to each side of an index card. Students were given the index cards and were allowed to study as much as they wanted for up to 5 minutes.

High-tech AT device (iPod touch). For the iPod touch, the researcher uploaded digital flashcards to each AT device (via app, e.g. *quizlet*) that matched the look, vocabulary level, keywords, definitions, and pictures in the traditional condition. Therefore, the only difference was the delivery method of the vocabulary learning activity.

Dependent Variables

Measures.

Vocabulary probes. To determine the acquisition of science content vocabulary words, students were assessed on how many vocabulary words they learned via a short, 5

words, vocabulary probe (matching). Students were given a probe every two days. For example, a vocabulary schedule consisted of 5 new words on Monday and 5 minutes to rehearse. Students were then given an additional 5 minutes to rehearse the same words on Tuesday, followed by the vocabulary probe. Wednesday the students would be given 5 new words. A final probe that included words from each treatment phase was given at the end of the study to assess vocabulary retention via each acquisition method. Words from each method were flagged for comparison.

Teacher assessments. The researcher requested traditional exam, unit, and quarter grades from teachers. These grades were used to measure if the intervention translated into a change in academic grades for each student.

Behavior. The researcher used DBR (Direct Behavior Ratings) to measure students' academic engagement and disruptive behavior during the intervention. DBR is an evidence based rating assessment that is accurate, reliable, and does not require a second observer (Chafouleas et al, 2013). Nonetheless, to increase reliability, a second researcher observed 40% of all probes. The researcher measured the percentage of total time the student exhibited each target behavior of being academically engaged as well as the percentage of disruptive behavior observed.

Academically engaged behavior. Academically engaged behavior was defined as actively or passively participating in the intervention activity by writing, raising his/her hand, answering a question, talking about a lesson/vocabulary, listening to the teacher/researcher, reading silently, or looking at instructional materials. For example: flipping through the flash cards (either via traditional or on the AT device) or taking the vocabulary probe.

Disruptive behavior. Disruptive behavior was defined as a student action that interrupted the regular school or classroom activity, or intervention. For example: out of seat, fidgeting, playing with objects, acting aggressively, talking/yelling about things that are unrelated to classroom instruction.

Surveys and social validity. Surveys were used to measure teacher and student perceptions and academic growth. The surveys, adapted from Flanagan, Bouck, and Richardson (2013) asked various questions about their knowledge, use, and training around science vocabulary and AT. Students were also asked to perceive their experience using the index cards and iPods after the study was complete. Additionally, teachers were asked around their interest in continuing to use and integrate AT in the classroom after the study.

Threats to validity. Creswell (2009) addresses various types of threats to both internal and external validity. In this experiment, threats to internal validity included regression and mortality. I addressed each of these threats. I selected 3 students with regular attendance for the study to lower the chance that any student dropped out of the study before all data had been collected. Additionally, I offered the iPod touches to the teacher after data collection had been completed to provide an opportunity for other students to use them. A threat to external validity is the interaction of setting and treatment (e.g. because of the characteristics of the setting and participants in the experiment). In response, in the future, I may need to conduct additional experiments in new settings to see if the same results occur as in the initial setting.

Procedural Fidelity

The primary experimenter and a secondary observer independently reviewed 40% of probes and complete a checklist of experimental procedures. Additionally, intervention adherence was assessed using a checklist describing the procedural steps involved in the intervention for 100% of sessions. For the traditional condition, the adherence checklist included: (a) distribute flashcards and review instructions, (b) students review words for up to 5 minutes, (c) return the flash cards to the researcher. For the iPod touch condition, the adherence checklist included: (a) distribute iPod touches and review instructions, helping students get to the appropriate application and providing instructions, (b) have students review words for up to 5 minutes, (c) return iPod touches to the researcher.

Inter-observer agreement. Inter-observer agreement was assessed for 40.0% of observation sessions and was collected by a university graduate student that did not play a role in the study other than conducting inter-rater reliability. The researcher trained the second observer to collect data on dependent variables – percent of engagement and disruptive behavior that took place during the treatment conditions and the number of correct vocabulary words each student scored for each probe. Interscorer agreement was assessed for 40.0% of academic, engagement and disruptive behavior probes with an agreement of 100% on all probes.

Data Analysis

Visual analyses was the primary method for interpreting the results of the study. In single subject methodology, visual analysis is typically used to document experimental control. The visual features mostly used to assess graphed data are level, trend, and immediacy of effect after the intervention has been implemented. In addition to visual

analysis, mean values for dependent variables and ranges were reported. Data were assessed during each phase of the study – using at least 3 data points and measured for stability and trend.

Chapter 4: Results

The data were interpreted using a combination of visual inspection and analysis of surveys from teachers and students. Data analyses and results are presented in the following sequence in accordance with the study's research questions: a) vocabulary acquisition, b) academic engagement and disruptive behavior, c) perception of intervention mediums.

Vocabulary Acquisition

Research Question 1: Is there a difference in the acquisition of science content vocabulary words presented through a traditional instruction medium compared to the acquisition of vocabulary presented through an assistive technology (AT) device?

Acquisition mediums. Figure 1 provides a visual representation of the number of correct responses per probe for each participant across baseline and the two experimental conditions. The percentage of correct responses was highest during both Treatment A_2 and B_2 using both conditions for all three students. All participants improved their percentage of correct vocabulary terms from initial pre-baseline and baseline probes. As a group, the mean scores on the pre-baseline probe and baseline probes were 6.6% and 15% respectively with an overall group increase of 75.67% at treatment A_1 (traditional 1), 64.39% at treatment B_1 (iPod Touch 1), 84.56% at treatment A_2 (traditional 2), and 84.56% at treatment B_2 (iPod Touch 2) from baseline. Table 8 provides a summary of the means and ranges for number of vocabulary words each student correctly acquired in each condition.

Table 8

Means and Ranges for Number of Correct Vocabulary Words In Each Condition

Student	Baseline Percent Correct M (Range)	Index Cards[1] Percent Correct M (Range)	iPod Touch[1] Percent Correct M (Range)	Index Cards[2] Percent Correct M (Range)	iPod Touch[2] Percent Correct M (Range)
Katie	6.66 (0 - 10)	73.33 (60 -100)	73.33 (60 - 100)	100 (100 - 100)	100 (100-100)
Ashley	13.33 (0 - 40)	100 (100 - 100)	60* (60)	100 (100 - 100)	100 (100-100)
Lisa	26.66 (0 - 40)	100 (100 - 100)	86.33 (60 - 100)	100 (100 - 100)	100 (100-100)
Mean	15.44	91.11	79.83	100	100

* Note: Ashley only completed one probe due to absence. Not calculated in mean.

Vocabulary probes. All participants displayed low percentage scores for vocabulary acquisition during the baseline phase with a group mean of 15.44%. When the treatment A_1 intervention was implemented for all three participants, an immediate change in vocabulary acquired was noted. The mean score for the traditional phases was 95.56% and the mean score of the AT treatments was 89.92%. Following all treatments, all participants continued to display a gained understanding of the vocabulary from the previous probes with a mean score of 73.33%. The following section details the results of each participant in Figure 1.

Katie. During baseline sessions (n=3), Katie displayed a lack of vocabulary acquisition in conditions of the usual class environment earning a 6.66% mean correct answers on baseline probes. Once treatment A_1 was implemented, there was a clear and instant change in her vocabulary probe scores. Katie's mean score for treatment A_1 of the intervention was 73.33%. Likewise, her mean score for treatment B_1 was also 73.33%. During the second traditional intervention phase, treatment A_2, her mean score was 100%. Likewise, during treatment B_2, the second AT phase, Katie's mean score was also 100%. When comparing the pre-intervention screening quiz to the post intervention

probe, Katie correctly answered 80% more words correctly, with an initial quiz score of 0% and a post intervention probe score of 80%. On the post intervention probe, when specifically comparing if the vocabulary words were from either the traditional or AT intervention phases, Katie earned 80% correct from words in the traditional phases and 80% from words in the AT phases.

Ashley. During baseline sessions (n=3), Ashley displayed a low percentage score for correct answers for vocabulary acquisition in her usual class environment earning a mean score of 13.33% on baseline probes. Once treatment A_1 was implemented, there was a clear and immediate change in her vocabulary probe scores. Ashley's mean score for treatment A_1 was 100%. Ashley was absent for two of the three probes during the first AT intervention phase, treatment B_1, but earned a 60% on her one probe that was taken. During treatment A_2, her mean score was 100%. Likewise, during the second AT treatment, Ashley's mean score was 100%. When comparing the pre-intervention screening quiz to the post intervention probe, the student's growth of correctly answering the probe was 60%, with an initial quiz score of 0% and a post intervention probe score of 60%. On the post intervention probe, when specifically comparing if the vocabulary words were from either the traditional or AT intervention phases, Ashley earned 40% correct from words in the traditional phases and 80% from words in the AT phases.

Lisa. During baseline sessions (n=3), Lisa displayed a lack of initial vocabulary acquisition earning a 26.66% mean on baseline probes. Once treatment A_1 was implemented, there was a clear and instant change in her vocabulary probe scores. Lisa's mean score for treatment A_1 was 100%. Similarly, her mean score for the first AT intervention, treatment B_1, was 86.66%. During treatment A_1, her mean score was 100%.

Likewise, during treatment B_2, Lisa's mean score was 100%. When comparing the pre-intervention screening quiz to the post intervention probe, her growth of correctly answering the probe was 60%, with an initial quiz score of 20.0% and a post intervention probe score of 80%. On the post intervention probe, when specifically comparing if the vocabulary words were from either the traditional or AT intervention phases, Lisa earned 80% correct from words in the traditional phases and 80% from words in the AT phases.

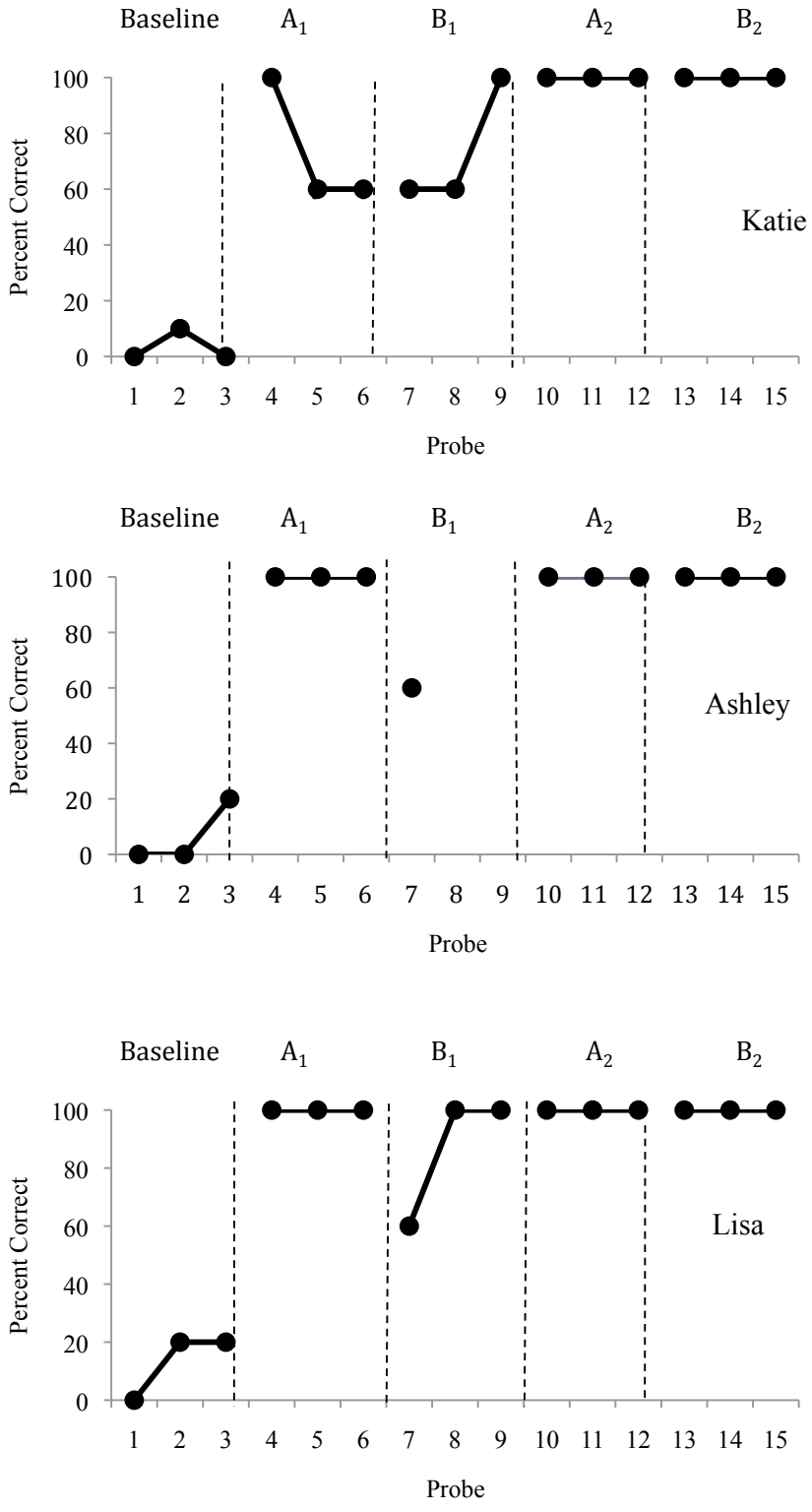

Figure 1. Vocabulary probes per student.

Course quizzes, exams and reported grades.

Katie. This intervention began the first day of the 4th quarter. Katie's 3rd quarter grade was a 65.58%. Katie often did not turn in or complete her assignments. In the 4th quarter, she missed 3 out of 9 assignments and 1 out of 2 assessments. Of the work that Katie did complete, she earned an average score of 80% on assignments and 65% on assessments. Her final quarter grade was an F at 36.80%.

Ashley. Ashley's 3rd quarter grade was a 70.63%. She did not complete 3 out of 9 number of assignments and 1 out of 2 assessments in the 4th quarter. Of the work that was completed, she earned an average score of 85% on assignments and 65% on assessments. Her final 4th quarter grade was an F at 37.64%.

Lisa. Lisa's 3rd quarter grade was a 51.88%. She did not complete 5 of the 15 assignments and did complete all of the assessments given during the 4th quarter. Of the assignments she did complete, she earned a 78.09% on her assignments and a 49.71% on her assessments. Her final grade for the 4th quarter was an F at 45.51%.

Research Question 2: When compared to traditional teaching tools, does assistive technology increase engagement and decrease disruptive behaviors for students with LD?

Academic engaged behavior. Figure 2 provides a visual representation of the levels of academic engagement per probe for each participant across baseline and the two experimental conditions. The percentage of academic engagement for all students was higher during the intervention phases compared to the baseline phase, with the highest mean of academic engagement during the AT treatment conditions. As a group, the mean scores on the baseline probe was 74.44% of academically engaged time during

observation with an overall group increases to 96.66% for treatment A_1, 98.33% in B_1, 97.77% in A_2, and 98.33% in B_2. The increase percentage of academically engaged time between the mean baseline probe and the mean index card phases was 22.78%. The increased percentage of academically engaged time between the mean baseline probe and the mean AT phases was 23.89%. The Table 9 provides a summary of the means and ranges for academic engagement time for each student earned in each condition.

Table 9

Means and Ranges for Academic Engagement In Each Condition

Student	Baseline Academic Engagement M (Range)	Index Cards[1] Academic Engagement M (Range)	iPod Touch[1] Academic Engagement M (Range)	Index Cards[2] Academic Engagement M (Range)	iPod Touch[2] Academic Engagement M (Range)
Katie	73.33 (60 – 80)	96.66 (90 – 100)	96.66 (90 – 100)	96.66 (90 – 100)	100 (100-100)
Ashley	63.33 (40 - 80)	93.33 (80 – 100)	80* (80)	96.66 (90 – 100)	96.66 (90-100)
Lisa	86.66 (80 - 90)	100 (100 – 100)	100 (100 – 100)	100 (100 – 100)	100 (100-100)
Mean	74.44	96.66	98.33	97.77	98.33

* Note: Ashley only completed one probe due to absence. Not calculated in mean.

Katie. During baseline for academic engagement, Katie displayed a mean of 73.33% (range = 60% - 80%). Once treatment A_1 was introduced, academic engagement increased by 23.33% to 96.66% (range 90% - 100%). Her academic engagement remained at 96.66% for both the first iPod Touch phase (B_1) as well as when the instruction medium returned to index cards for A_2 (range 90% - 100%). Her engagement increased to 100% when the condition returned to AT during treatment B_2.

Ashley. Ashley displayed a mean for academically engaged behavior of 63.33% during baseline probes (range = 40% - 80%) and after implementing the intervention in treatment A_1, the percentage increased by 30% to a mean of 93.33% (range = 90% - 100%). When the iPod touch was introduced in B_1, Ashley was interested in taking

pictures of herself, which explains the initial drop in academic engagement during probe 7 (80%). Ashley was absent for probes 8 and 9. Her engagement increased to 96.66% for both A_2 and B_2 (range = 90 – 100%).

Lisa. Lisa's percentage of academically engaged time was consistent throughout the study. Her baseline of 86.66% was the highest of the three students. Once the treatment A_1 was introduced, she maintained an academically engaged behavior of 100% for all phases of the intervention, through both instructional mediums.

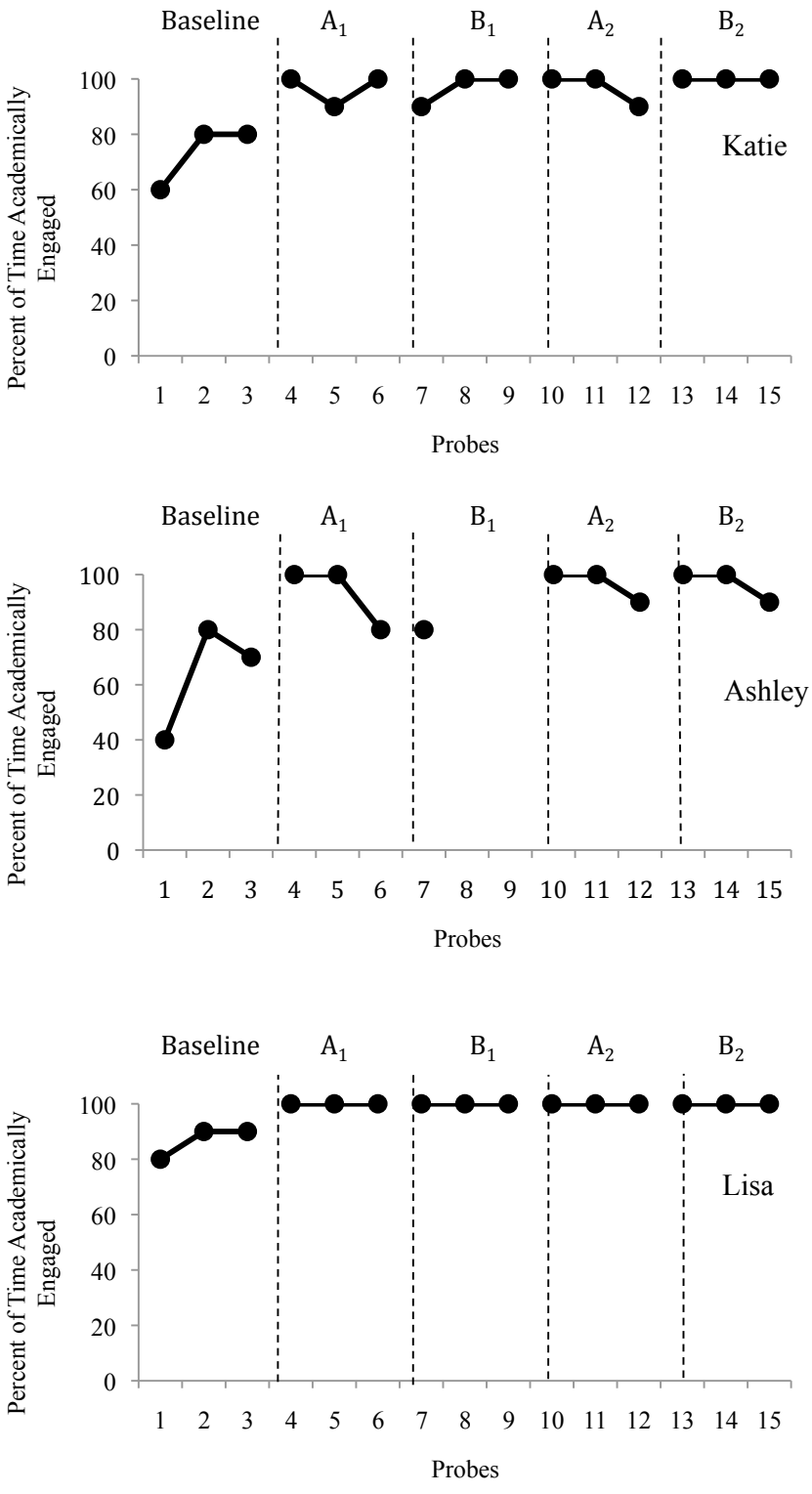

Figure 2. Academic Engagement probes per student.

Disruptive behavior ratings. Overall, disruptive behavior was low for all three students. Figure 3 provides a visual representation of the levels of disruptive behavior per probe for each participant across baseline and the two experimental conditions. During baseline the mean disruptive behavior was 4.44%. Once the intervention was introduced, the disruptive behavior percent remained at 0%. Table 10 provides a summary of the means and ranges of disruptive behavior for each student in each condition.

Table 10

Means and Ranges for Number of Disruptive Behavior In Each Condition

Student	Baseline Disruptive Behavior M (Range)	Index Cards[1] Disruptive Behavior M (Range)	iPod Touch[1] Disruptive Behavior M (Range)	Index Cards[2] Disruptive Behavior M (Range)	iPod Touch[2] Disruptive Behavior M (Range)
Katie	10 (10 – 10)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0-0)
Ashley	3.33 (0 – 10)	0 (0 – 0)	0* (0)	0 (0 – 0)	0 (0-0)
Lisa	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0-0)
Mean	4.44	0	0	0	0

* Note: Ashley only completed one probe due to absence. Not calculated in mean.

Katie. During baseline, Katie consistently displayed disruptive behavior 10% of time during the first 5 minutes of class (i.e. getting out of her seat). During each phase of the intervention, once the researcher provided the intervention medium, she did not display any disruptive behaviors.

Ashley. Ashley displayed one day of disruptive behavior at 10% for a baseline mean of 3.33% (range 0% - 10%). Once the interventions were introduced, regardless of the instructional medium of index cards or iPod Touch, she did not display any additional disruptive behaviors.

Lisa. Lisa did not display any disruptive behaviors at any point during this study, including baseline and all intervention phases.

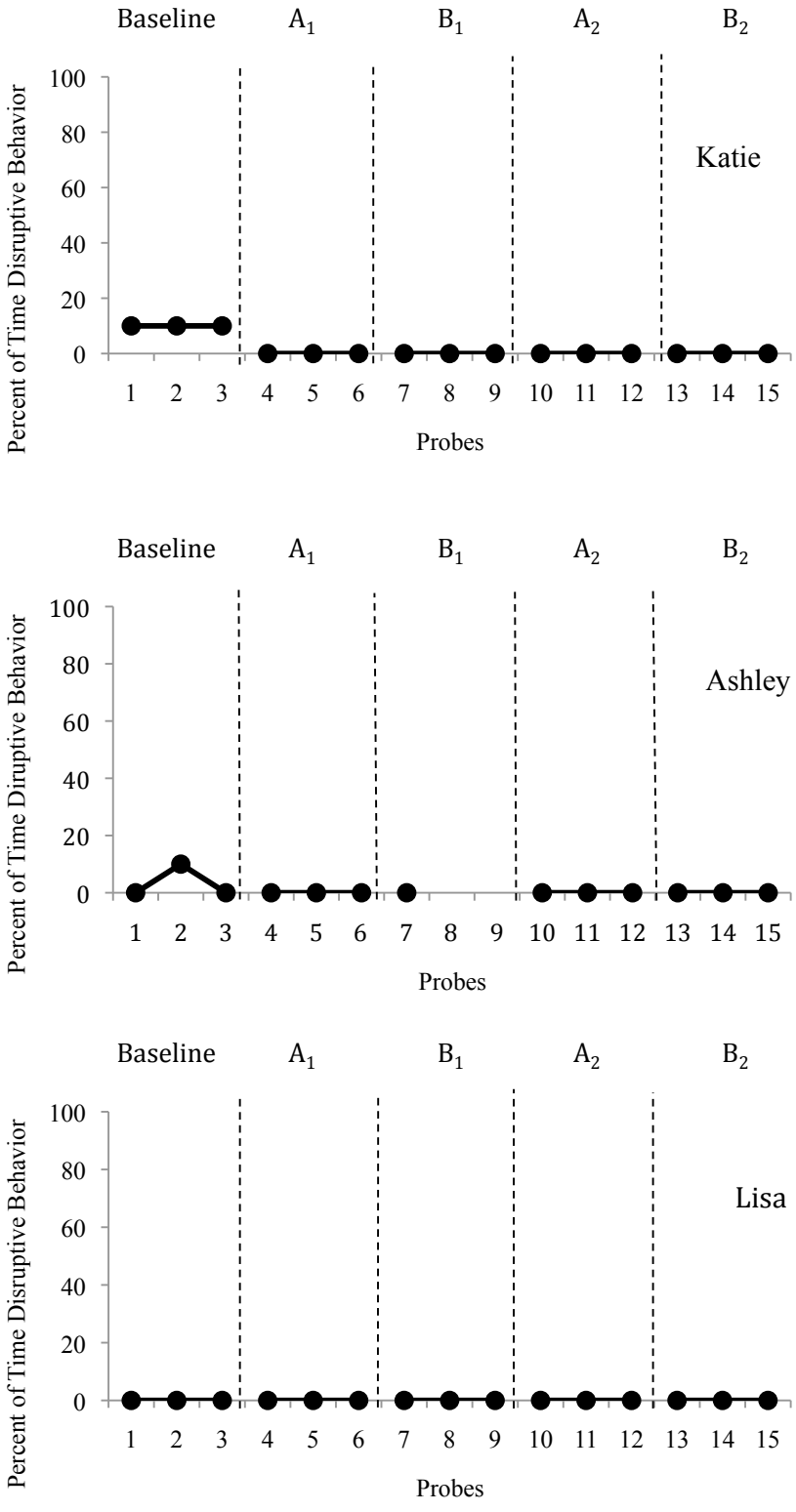

Figure 3. Disruptive Behavior probes per student.

Research Question 3: Is there a difference in how students with LD and their teachers perceive the social validity of the traditional or AT instructional mediums to learn general education core content words and definitions?

Social validity surveys. Both summative and formative social validity data were collected on each student and teacher's perception of the use and perceptions of assistive technology as well as the intervention. Before the study, all three students indicated that they sometimes use AT devices in class to help learn (compared to daily, or never) and indicated that it sometimes helps them learn. All three students responded that they agree that technology could make them more engaged in class and strongly agreed of their wanting to use technology in class. After completing all phases of the interventions, for both the traditional and AT phases, students indicated that they still agreed that AT devices help them be more engaged in class. All three also shared that they enjoyed using the iPod more than the index cards.

Prior to the study, both teachers completed a survey, however the teachers differed in how often they use technology. Both teachers indicated an agreement in willingness to use AT and strongly disagreed with statements of having access and training around AT to support students with high incidence disabilities. After all phases of the study, teachers indicated that they agreed that integrating AT into instruction can help improve the academics for their students.

Katie. In her pre-study survey, Katie indicated that she sometimes uses, Word prediction software, Internet search (e.g. Google), and a smart phone (e.g. iPhone, android, windows) in class to help her learn. When asked what types of devices does she think could help her learn science, she indicated interest in Internet games, iPod touch,

and an eReader (i.e. Kindle eReader, BN Nook). When asked if technology could make her more engaged in class, compared to traditional instruction, she agreed. Similarly, she agreed with the statement that technology could improve her grades. When asked if she would want to use technology in class, Katie strongly agreed. In the post-study survey, Katie indicated that she specifically is interested in using the iPod touch more to both her grades and engagement.

Ashley. Ashley indicated, in her pre-study survey that she sometimes uses a SMART Board, Internet search, and a smart phone in class to help her learn. She answered that she would be interested in Internet games, iPod touch, and an eReader as technologies that could help her learn science. She agreed with statements that technology could make her more engaged in class and technology could help improve her grades. She marked that she strongly agrees with the statement of wanting to use technology in class. In her post-study survey, Ashley reported that she wants to use the iPod touch more to increase her grades and engagement in class.

Lisa. In her pre-study survey, Lisa indicated that she sometimes uses word prediction software, Internet search, Internet games, and a smart phone in class to help her learn. When asked what types of devices she would be interested in using in her science class, she answered that she would be interested in using a projector with presentation software (e.g. PowerPoint, Keynote), Internet search, a tablet computer with Apps (e.g. iPad, Kindle Fire), and an iPod touch. When asked if technology could make her more engaged in class she agreed, but she neither agreed or disagreed if technology could help improve her grades or she if wants to use technology in class. According to

Lisa's post-study survey, she reported that, when comparing the index cards and the iPod touch, she thought the iPod touch helped more and worked better.

Kelly. In her pre-study teacher survey, when asked how often she or her students use AT and which devices are used, Kelly answered that she daily uses Internet search and smart phones, projector with presentation software 3 to 4 times a week, and concept mapping/outline software & word prediction software less than once a week. When asked which devices are effective in her instruction and/or influence student learning in science she replied that concept mapping/outlining software, word prediction software, projector with presentation software, internet search, and smart phones could be effective. When asked what factors hinder using any type of AT during instruction, she indicated that high cost, additional training/no training, no knowledge of how to use each product or what is for, a lack of access, and devices not being available as limitations to their use in her classroom. For factors that encourage using any type of AT, she answered that AT has the ability to assist students individually, are quick to set up or customize for a student, can be used with more than one student, are easy for students to use and easy to integrate into the classroom and instruction. Kelly agreed with the statement that AT can potentially help students improve academics and that she wants to use AT in the classroom. She strongly disagreed with all statements around having access, preparation, and training of AT. Additionally she commented that she would like recommendations on how and which technology can be used in the classroom and to share those recommendations with the school's special education faculty as well as the school and district's administration to increase access and training for AT. In Kelly's post-study survey, she reported that she agrees that AT can potentially help improve academics for

her students and wants to continue to use the iPod touch in the classroom but also reported that to effectively integrate the AT into her instruction she would require more options and information.

Owen. In Owen's pre-study survey, he indicated that he and his students use screen magnifiers, word prediction, projector with presentation, and Internet search daily. Spell check and smart phones were used 1 to 2 times a week. Concept mapping/outlining software, electronic dictionaries, multimedia software, and Internet games were used less than once a week. When asked which devices are effective in instruction or influence student learning in science, he responded that audio books, communication devices and/or Boardmaker (or other picture symbols software), concept mapping/outlining software, electronic dictionaries, instructional software (e.g. a reading software program), multimedia software, word prediction software, SMART Board, projector with presentation software, internet search, tablet computer with apps, iPod touch, smart phone, and eReader could be effective. He indicated that he does not feel that adaptive keyboards/mice nor AlphaSmart or similar devices would be effective in instruction or for student use. When asked what factors hinder using any type of AT during instruction, Owen answered high cost and that they require additional time to set up as limitations. When asked what factors encourage using any time of AT during instruction, he responded that ease of integration into classroom and instruction promote AT use. He agreed with statements that AT can potentially help improve academics for his students, that he wants to use or continue to use AT in the classroom and that he feels that he has had sufficient training in how to use AT in general. However, he disagreed with statements of having easy access to information around AT and training around how to

specifically use AT to support students with disabilities. In Owen's post survey, he indicated that he had no opinion around continuing to use AT in the classroom but agreed that he can effectively integrate the AT into his normal instruction.

Chapter 5: Discussion

This study extends the literature on how students and teachers use and perceive the use of technology. Noteworthy, it is the first study to specifically study the use and perceptions of AT in the science classroom. One aspect of this study was to explore the influence of the iPod touch as opposed to the influence of index card/flash cards on the vocabulary acquisition of three adolescents in a biology class when using a keyword mnemonic intervention. Data collected illustrated these students' academic success and engagement, as well as their disruptive behaviors. Specifically, three research questions were investigated: a) Is there a difference in the acquisition of science content vocabulary words presented through an index card medium compared to the acquisition of vocabulary presented through an AT device? b) When compared to an index card intervention method, does AT increase engagement and decrease disruptive behaviors for students with LD? and c) Is there a difference in how students with LD and their teachers perceive the social validity of the index card or AT instructional mediums to learn general education core content words and definitions? This study operated under the belief that improving science vocabulary knowledge involves the use of systematic review and can be taught through the use of mnemonics (Mastropieri et al., 1994; Scruggs & Mastropieri, 2000).

Several important findings emerged from this study. First, all students' acquired the content vocabulary equally well when using an AT device when compared to an index card method. Second, when using the AT, students' engagement increased compared to baseline conditions. Additionally, all students exhibited the most engaged percentage during the AT condition. Third, it was clear that the students had a strong

interest in using AT to increase their grades and engagement, however the teachers had little access and training on using AT to support their students with disabilities.

Success in the science classroom is dependent on students being able to both access and engage in the curriculum. The development of learning the content vocabulary is critical to the learning process, especially in a vocabulary dominant subject such as biology. As stated earlier, the available research on interventions for students within the science classroom is limited, with just one study focusing on the use of AT to increase the learning and engagement of students in the science classroom (Horton & Lovitt, 1994). With such few studies focusing on teaching students with disabilities in the science classroom, it is not surprising that students with disabilities, specifically students with LD, continue to struggle in the science classroom. The lack of evidence-based studies to promote the learning of science for students with LD makes the instructional strategies for both general and special educators not only difficult.

Vocabulary Acquisition

This study provided support for the use of keyword mnemonic interventions to promote vocabulary acquisition. More importantly, this study furthered the support of the intervention by bringing its use to technology not available when the intervention was established. Previous studies around this methodology have used various types of ink and paper delivery methods and current AT devices (e.g. iPod touch) did not yet exist. The first area of interest in this study was how students acquire content vocabulary and to compare two delivery models: index/flash card and AT compared to traditional instruction. Given that the intervention has previously been shown to be effective through the use of index cards (King-Sears, Mercer, & Sindelar, 1992) it served as a

foundation to compare a new delivery method; the new delivery method would have to demonstrate equal or better results than the traditional model to be deemed effective. Three important findings are highlighted with regards to improved vocabulary acquisition: a) the success of a keyword mnemonic intervention via a index card method of delivery compared to the pre-intervention quiz and baseline, b) the success of a keyword mnemonic intervention via an AT method of delivery compared to the pre-intervention quiz and baseline, and c) the comparison of success between the two conditions.

Prior to this study, all three students received their vocabulary and content instruction consistent with teacher directed, inquiry-based, lessons. In doing so, students were expected to learn biology content vocabulary and concepts through traditional science instruction, primarily by teacher-guided readings, activities, and written assignments out of the textbook. For students with LD, whom struggle with reading and writing, unsurprisingly, this method is difficult. During the intervention however, the vocabulary was provided to the participants during the standard warm up time (the first five minutes of class) through a keyword mnemonic intervention delivered via index cards or an AT device (iPod touch) in an alternating treatment design.

Acquisition presented through index cards. The instructional intervention, when presented via index cards, the outcomes were consistent with previous research (King-Sears, Mercer, & Sindelar, 1992; Mastropieri & Scruggs, 1992; Mastropieri et al., 1994); all three students, when presented with the index card vocabulary intervention, increased their vocabulary acquisition when compared to their pre-study quiz and baseline probes. As the participants completed the baseline phase of the study, their

initial lack of vocabulary knowledge was remarkably low, with mean scores for all three at 15.44%. Having a clear baseline is critical in establishing the effectiveness of an intervention with the hopes that once the intervention is introduced, an obvious and immediate increase of scores will follow. As shown in Figure 1, for the measurement of the first dependent variable (vocabulary probes), all three students immediately earned a 100% on their first probe after baseline. All three students continued to earn scores clearly above baseline for the rest of the traditional phase (A_1) and again earned 100% for all three probes when the condition returned to the index card treatment (A_2).

While the results of this treatment was productive to strengthen the research base around using flash cards as a keyword mnemonic strategy, as stated earlier, the goal was to determine if there were differences between student performance in the keyword mnemonic intervention when compared to the use of an AT device for students with LD.

Acquisition presented through an AT device. As mentioned earlier, the goal of the first research question was to compare the vocabulary acquisition when presented through the iPod touch compared to the index cards. Interestingly, when the students were introduced to the first AT phase (B_1), all three students earned a 60% on their first probe of the phase. However, by probe 8 for Lisa, and 9 for Katie (Ashley was absent for probes 8 and 9), the students' scores returned to 100% and remained there, including when the treatment condition returned to the AT device (B_2). A possible explanation for the initial drop in scores is that students might require a few days to acclimate to the AT device as an academic tool and not a social device. This was clearly observed as Ashley initially used the iPod Touch for taking pictures when the first AT treatment was introduced. However, once the transition was completed, and once the AT treatment was

reintroduced (B_2), all three students earned a 100% on vocabulary probe #13. The data illustrate the importance of allowing time for transition and adjustment when introducing an AT device as students may need time to transition from perceiving the device as a social mechanism to an academic tool.

When comparing the visual analyses of the student's scores between the two delivery methods (index cards vs. iPod touch), the scores from both conditions were both clearly above baseline. Additionally, when comparing the means, between the two treatment conditions, both were similar (95.56% for the index card condition and 89.92% for the iPod Touch condition). Additionally, when comparing the scores from both the second treatments (A_2 and B_2), all three students earned a 100% in both conditions. Therefore, these findings suggest that an AT device, compared to a traditional index card keyword mnemonic intervention, is equally effective for the acquisition of science vocabulary, once the students learn how to effectively use the AT device. Additionally, students may need some training and orientation if a more sophisticated system is used.

Course grades. After analyzing all three student's academic progress over the 4th quarter and despite the acquisition of the content vocabulary, none of the students passed their biology class. While both Katie and Ashley passed the third quarter, Lisa did not pass either quarter. However, when exploring why the students failed their courses, it was apparent that the students struggled with completing assignments; all the students would have passed their courses if their grades were based on the work that they had completed. This finding is consistent with past research that has revealed results that students with LD do not consistently complete their assignments that are based out of textbook reading and writing (Bryan et al., 2001; Parmar, DeLuca, & Janczak, 1994;

McCleery & Tindal, 1999; Scruggs, Mastropieri, & Marshak, 2012). This finding also points to the need for classroom teachers to not only introduce new engaging instructional procedures that are individualized to students needs, but to also closely supervise and monitor homework. For example, a teacher could teach and promote self-monitoring strategies to increase the amount of completed assignments. If the classroom intervention and instruction is not the only task linked to grades, a comprehensive system must be in place to help students with LD receive a passing grade. This study demonstrates that effective interventions are not enough to promote a student passing a class, individualized interventions and appropriate curricula must be used concurrently. Future use of this intervention in the classroom should overtly correlate vocabulary and content knowledge to assignments and assessment formats more suitable for students with LD.

Academic Engagement and Disruptive Behaviors

Problems with academic engagement, linked to the difficulty for students with LD who may ignore external stimuli, creates many challenges for these students to succeed academically (Pullen et. al, 2011). The second research question focused on whether AT increases engagement and decreases disruptive behaviors for students with LD when compared to the traditional intervention model. Because engagement is a major concern when teaching students with LD, three important findings are highlighted with regards to improved academic engagement: a) the engagement and disruptive behaviors of the students during the keyword mnemonic intervention via a traditional method of delivery, b) the engagement and disruptive behaviors of the students during the keyword

mnemonic intervention via an AT method of delivery, and c) the comparison of student engagement and disruptive behaviors between the two treatment conditions.

All three students demonstrated higher levels of academic engagement, compared to baseline. Interestingly, small patterns of engagement performance emerged for each participant: Katie's level of engagement fluctuated, Ashley had 100% engagement during the first two probes of each condition and then dropped to 80% for the third probe, and Lisa's percentage of engagement remained consistent at 100% for all the treatment conditions. It is hypothesized that Ashley struggles the most with engagement and attention and loses interest in an activity once it is no longer new. Nonetheless, even when her engagement level dropped, it was only slightly. Furthermore, except for the small levels of off task/non-engaged behaviors, a major problem for students with LD, none of the students presented problem behaviors during the study. This is consistent with the literature, as research has consistently demonstrated the relationship between academics and behaviors (Lane et al., 2008; Barriga et al., 2002). A hypothesis for the increased engagement is twofold: a) Students may have become more interested in the topic as the gained access to the understanding of the key words and concepts; and b) Students may have had more interest in the intervention due to an individualized approach. These findings are noteworthy as teachers often complain about the lack of engagement for students with LD (Grolnick & Ryan, 1990; Stone, 1997). Therefore, expanding individualized instruction so students with LD can gain access and understanding to curricula may promote the engagement of students with LD – even more so than in a traditional setting or in a group setting. While disruptive behavior was

measured and of interest, these students did not demonstrate general behavior problems. Therefore, task engagement became the main interest.

Social Validity

Student surveys. The present study demonstrated the social validity of using AT as an intervention method for teaching students with LD via a keyword mnemonic vocabulary strategy. As stated earlier, prior to the study, students were asked about their current use and desire to use AT in the classroom. Students were also asked if they believed AT could improve their grades as well as increase their engagement in class. Interestingly, even though both the index cards and the iPod touch were effective, on the post-study survey, all three students noted that they either enjoyed more or thought the iPod touch delivery system worked better. While that data show that both intervention mediums were effective, student buy-in was centered on the desired continued use of the AT device. This study points directly to the students perception of an intervention that they would want to use. It is clear from the surveys that not only do the students have an interest in technology, but specifically believe that incorporating technology into their instruction will improve both their grades and their engagement. In previous literature, Marino (2010) reported that handheld devices had great promise as students become more and more used to using their smartphones and iPads for learning activities. Further, Edyburn (2013) explained, as technology is changing, it is crucial for interventions to progress alongside the advancement of AT. With the ability of AT to both increase the academics and engagement behaviors of students, much promise exists in the use of technology. As Rodriguez, Strnadová, and Cumming (2013) noted, AT is important for student engagement in academic tasks and the students in this study were in agreement

with these studies and found the iPod touch to be more appealing than the typical index card method.

Teacher surveys. When looking at what types of technologies the teachers and students currently use, teachers reported using technology, however, they also reported not using or knowing how to use AT to support or engage their students with disabilities. This suggests that regardless of how effective an intervention is, if teachers and students cannot access or use AT, it cannot be beneficial to the teacher or student. Interestingly, one teacher, Kelly shared that previous to the study, she had attempted to use flash cards with her students, but the students found writing all of the words and definitions boring and strenuous, and quickly lost interest.

Prior studies have noted this lack of access and professional development for teachers around AT content (Okolo & Diedrich, 2014). It appears that in-service training should focus on the use of iPad and iPod so that content teachers can leverage this approach. Flanagan et al. (2013) conducted a survey to study the perceptions and use of AT by teachers in literacy instruction and found similar results. In their study, they found that while teachers perceived AT to be an effective tool, they reported that training and experience were large barriers, limiting a teacher's use.

A considerable advantage to creating flash cards via an AT application (e.g. quizlet) is ease of use. While not calculated on the amount of time saved, creating the AT flash cards alone takes less time than creating the flash cards, printing them and gluing them to each set of index cards per student, or having students write them out by hand. By creating one set online (through the application's online website), and then allowing the mobile application to utilize the words from the "cloud," not only is time

saved, but in this study, each student gained access to the intervention on their own iPod touch via the app.

Implications

Future research should be conducted to determine the effectiveness and efficiency of instruction in a group setting or in typical classrooms. Because students with LD typically spend most if not all of their time in an inclusive setting, it is important to establish effective interventions appropriate for the general education environment. It is important to study the practicality of implementing the interventions for both students and teachers. Additionally, as just one component of a science lesson, future research should determine how this intervention could be incorporated within larger curricula. For example, research could study how these findings would translate to other parts of a science lesson (e.g. lab experiments, assessment review, components of the scientific method). Once these questions are addressed, future research should expand on these findings to enhance work in other content areas, including other STEM subjects. Additionally, these findings should be translated to studies across other disability categories that share characteristics of students with LD (e.g. EBD and ADHD) as well as the teacher training needed to support the interventions.

The results of this study demonstrate four important practices for teachers working with students with LD. First, implementing an intervention that supports the acquisition of content vocabulary through an AT device is as effective as an index card model. Secondly, while using index cards can be effective, students prefer to use the AT delivery method to improve both their grades and levels of engagement. Third, as teachers are increasingly pressured to maximize instructional time, with little time to

prepare lessons, this study supports the efficiency that an AT device can bring when compared to flash cards and traditional instruction. Fourth, most students have access to either school issued AT or personal smart phones that can access apps similar to the one used in this research, therefore providing access to both the intervention as well as the curriculum.

Limitations

This study had a number of limitations that should be considered and might limit the generalization of the findings: sample size, instructor bias, and intervention setting. First, this study included only three participants, all of whom were female. This intervention was only tested on one sample of three students in 10th grade. A more ideal approach to the sample would have been to randomly assign a large sample of students to two groups, and compare that data between them. However, since the inclusion criteria was set to specifically study the effects of the intervention on a specific population of students (students with LD in the biology classroom), a larger sample size was difficult to obtain.

Second, since the author of this study implemented all the interventions and probes, instructor bias cannot be ruled out. To address this concern, vocabulary was specifically taken from the students' teachers as well as the textbook. Additionally to address any bias the researcher may have had while conducting and grading the probes, a second observer was utilized to measure and score 40% of all probes.

Third, the intervention took place in a teacher prep-room outside the classroom and not during normal instruction. All the students in this study were taken out of their regular classroom during the first five minutes of the classroom period and worked with

the researcher in a room that connected the two classrooms. This potentially limited any distractions that the students might have in the normal classroom environment, such as distractions from peers and classroom materials. Additionally, this enabled the students to receive close attention and support from the researcher, which is atypical of the inclusive classroom environment.

Conclusion

The intent of this project was to add to the existing knowledge concerning the academic and behavioral supports for students with disabilities. Prior to this study, limited research existed on providing support for students with disabilities within the science classroom. Even fewer studies existed on how to use AT to teach science to students with disabilities as part of a general education curriculum. This study provides preliminary research on the effectiveness of a keyword mnemonic intervention used through an AT device to improve the acquisition of biology vocabulary for high school students with LD. There is little doubt that continued research is warranted and needed on this topic, not only to support students with LD, but across all disability categories and across the various STEM subjects. The promising outcomes from this study, however, only demonstrate the potential that our students with disabilities have within the sciences.

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