2016

The Role of Virtual Avatars in Supporting Middle School Students from Culturally and Linguistically Diverse Backgrounds on Science in After School Programs

Benjamin Gallegos
University of Central Florida

THE ROLE OF VIRTUAL AVATARS IN SUPPORTING MIDDLE SCHOOL STUDENTS FROM CULTURALLY AND LINGUISTICALLY DIVERSE BACKGROUNDS ON SCIENCE IN AFTER SCHOOL PROGRAMS

by

BENJAMIN GALLEGOS
B.I.S. University of Texas at El Paso, 2007
M.Ed. University of Texas at El Paso, 2012

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the College of Education and Human Performance
at the University of Central Florida
Orlando, Florida

Summer Term
2016

Major Professor: Lisa A. Dieker

ABSTRACT

Students who receive additional educational supports in afterschool programs were the focus of the investigation. This study was conducted to measure what effects a TeachLivE avatar, a mixed-reality virtual environment, used in combination with a video game, had on the activation of prior knowledge in science for students in rural middle school. The delivery of the biology science lessons on cell structures and processes were delivered using the video game, Cell Command. The TeachLivE adult avatar was customized as a biologist who spoke to students in the treatment group about science concepts prior to playing the science video game.

Unexpected attrition rates and low numbers of participants in the targeted area of research providing consent affected the original research design to conduct the research study. Therefore, a pivot was made from the original research design. The initial target population was students with a learning disability who were culturally and linguistically diverse from low socioeconomic backgrounds in rural communities. By the end of the study, only one student with a learning disability consented and completed the study, with attrition rates in the original school approaching 90% due to various factors, which are discussed. Descriptive statistics were used to measure the effects between students in the control group who only played the Cell Command video game, compared to students in the treatment condition who played the Cell Command science video game, and had four, five minute conversations with a TeachLivE avatar. The analysis indicated varied differences between the treatment and control conditions. The analysis of a STEM-CIS survey, that measures career interests, sum means were included in the descriptive analysis along with the unique challenges presented in conducting research in a rural Title I school.

This dissertation is dedicated to the people in my life I draw strength from, who believe in me. My parents, Abelardo and Yolanda Gallegos, for continually providing me examples of perseverance, humility, and hard work. Mom and dad, through the years of my kindergarten through 12th grade schooling, you received calls, invitations, and reprimands in the context of my academic shortcomings and struggles in the classroom. Through it all, you two never doubted my pursuit of enrolling and earning college degrees. Your love, encouragement, and enduring life lessons are a reflection of who I am during challenges, opportunities, and success. You taught me to never be ashamed of who I am or where I come from and to be grateful for everything I have.

With gratitude and admiration to my wife, Elissa Gallegos; since the time we met you have been by my side. When I was working three jobs to save money to go to college, Elissa, you always told me that you had my back. You met me when college was not on my horizon. You had every opportunity to inform me during those times that I was nowhere near meeting my goals of enrolling in school. Instead you were excited for my pursuit of earning a college degree when I enrolled at El Paso Community College. You inspired me to take risks, overcome doubts, and to go after what I was willing to work for. Thank you for being the powerful mother, and wife that you are.

To my beautiful daughter Michelle Kristina "Boo Boos" Gallegos. You are a powerful little one. Each day I am blessed to watch you grow, and I am inspired by your inquiry and persistence to everyday tasks. I see how hard you work with ballet, capoeira, school, and when you write and read stories to mom and me. I love that every time I head off to school you tell me "Daddy, listen to your teacher and do good in school." Michelle, thank you for always asking me if I need help with my homework and assisting me when I am on the computer. I love you and want you to know that you are powerful and loved.

For my big brother RB, I am thankful and have a deep respect for your service and commitment to our country by serving as a soldier in the United States Army. You are an exemplary individual who sees through their commitments from being a family man to serving our country. I admire how you have always looked out for me and still let me know how proud of me you are, regardless of how I do in school.

For my little sister Sabi, you have encouraged me through your excitement and how proud you have been for me since I began my journey in college. You have provided me courage through your examples of remaining cool and calm in high pressure situations when you competed in golf. Your focus and determination has resulted in where you are now as a photographer. I keep that in mind as I navigate through my own work.

To my grandma Yolanda Parra, you are a rock and a testament for me on persevering through faith, hard work, and compassion. You always told me and everyone we know, "Watch out, my Ben will one day do something great. I just know it. His mind is powerful and he will be called to do great things." Grandma, you raised a family by yourself and to this day still look out for all of us. Your strength overcame odds, barriers, and challenges only the strongest-willed can triumph over. I love you.

Ese mi Wuelito y Wuelita! To Jesus "Che Che" and Thomasa Gallegos, thank you for your love, support, and being a beacon of strength I draw from. You two have never complained or shied away from work. Your only concern and priority was providing for the family. I have taken on every task and challenge set before me during my doctoral studies and kept you two in mind. My goal was to approach work as you both did by ensuring I put forth effort to see that the job was done right. Wuelito y Wuelita, more importantly, you have taught me to be grateful for every day I get to wake up and do it again.

Lastly, this is dedicated to my cousins, and all the youth in my family. Regardless of how you perform in school from making the A/B honor roll, Fs and Ds, or dropping out. You are made of a fabric designed with compassion, humility, and strength that is built to weather the storms. Do not believe what is often said by people that “School is not for everyone.” Keep in mind neither is poverty, oppression, prejudice, or ignorance. Continually look to empower yourselves and others. ¡Sí Se Puede!

ACKNOWLEDGMENTS

Thank you to the middle school students, teachers, staff, and school district for partnering with me for this study. I want to acknowledge my dissertation committee for their leadership and guidance. Thank you to my dissertation chair, Dr. Lisa Dieker, who since being at the University of Central Florida always, regardless of task, held me to a high expectation and provided me support. She convinced me I was able take on all projects and tasks expected of a doctoral student. Dr. Dieker allowed me to be a part of projects, and encouraged me to apply for opportunities, and not once explained or hinted to me about why I might not get what I was applying for or not have the qualifications to be accepted. Her unwavering leadership, support, and work ethic has inspired me on how I will serve in my future roles.

Dr. Matthew Marino, you have been gracious in allowing me to take part in your research and work. You provided mentorship and research opportunities that will serve me well in the work that I will do. I am grateful that you brought me along for different experiences on developing community partnerships, pursuing grants, submitting for publications, to teaching at the university level. Dr. Marino, thank you for serving as a role model and taking the time to mentor me.

Dr. Eleazar Vasquez, thank you for providing me guidance and advice on different research designs and the importance of publications. I won a national research award thanks to the critical feedback and expertise you provided during coursework. I was able to take the knowledge you provided and develop an award-winning research presentation.

Dr. Charlie Hughes, thank you for letting me be a part of your labs and providing me a lens of the possibilities of using virtual simulation for the benefit of supporting individuals with disabilities. Dr. Hughes, I am grateful that you allowed me into your labs and took the time to support me in my work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AI- Artificial Intelligence

CLD- Culturally and Linguistically Diverse

EL- English Learner

ELL- English Language Learner

IEP- Individual Education Program

LD- Learning Disability

MR- Mixed-Reality

NAEP- National Assessment of Education Progress

NGSS- Next Generation Science Standards

STEM- Science, Technology, Engineering, and Math

STEM-CIS- STEM-Career Interest Survey

SWD- Students with Disabilities

TLE- TeachLivE™

UDL- Universal Design for Learning

CHAPTER 1: INTRODUCTION

The need for all students to be proficient in reading and STEM is important (Helman, Calhoon, & Kern, 2015). The need for students with disabilities (SWD) is critical, as is the need to support students with culturally and linguistically diverse (CLD) backgrounds in achieving College and Career Readiness Standards (CCRS) to increase employment outcomes. This study focused on students who are SWD and CLD in science by examining two technologically-based tools to support students in a rural community in two, after school programs. This chapter provides a synopsis of the current literature regarding SWD and CLD in science. The synopsis is followed by research questions, a summary of the study, and a list of definitions used.

The current status of performance of SWD from CLD backgrounds is limited. In the National Assessment of Educational Progress (NAEP), reading and science assessment outcomes for SWD and students who were identified as Hispanic were below proficient. In the NAEP eighth grade reading assessment, the scaled scores went from 0 to 500, and scaled cut scores were 243 for (basic), 281 (proficient), and 323 (advanced). SWD were below the basic cut score of 243, scoring at 232 compared to students not identified with disabilities who received an average score of 272 (NAEP, 2013). In the NAEP (2013), reading average, scaled scores for eighth grade students, identified as Hispanic, received a reading average score of 256. Comparatively, White students averaged 276, Black 250, Asian/Pacific Islander 280, American Indian/Alaska Native 251, and two or more races 271. For eighth grade students who had a disability and identified as being from a CLD background, their NAEP reading average scores were 202 compared to students who were not under either category with an average of 274.

In the NAEP (2011) eighth grade science, the scaled scores were from 0 to 300. Three ratings of students' assessment performance results were based on a set of cut scores: basic (141), proficient (170), and advanced (215). Students with disabilities or on a 504 plan had a below basic rating average score of 124. Students not identified with a disability or not being served on a 504 plan had an average science score within the basic range of 155. In the school-reported race and ethnicity category, students identified as Hispanic were below the basic range with an average of 137, along with students who were black at 129. Students reported under the other race and ethnicity categories were either at or above the basic range: American Indian/Alaska Native averaged 141, Asian/Pacific Islander averaged 159, and White students averaged 163. Students who were identified as both having a disability and as an English Language Learner (ELL) had an average scaled score below the basic range at 86. The results for students who were not identified as having a disability or being a student identified as an ELL were within the basic rating range of 157.

Two populations of students underrepresented in science, technology, engineering, and mathematical (STEM) related fields are SWD (NSF, 2014), and students from CLD (i.e., Latino/a) backgrounds (Santiago, Galdeano, & Taylor, 2015). Lu (2015) reported that Latino males were reported as the individuals who were least likely to earn a STEM degree (e.g., science) among racial/ethnicity groups. Females (e.g., Latinas) and Latinos were considered the two groups with the highest association of not completing or attaining a STEM-related degree (Simpkins, Price, & Garcia, 2015). This disparity is magnified for students who live in rural communities, and who are too often affected by the two most influential indicators towards post-secondary college and career interests: (a) parents' college attainment, and (b) living in poverty

(Peterson, Bornemann, Lydon, & West, 2015). Latino/a students from rural communities, with or without a disability, were identified as the most disadvantaged group entering college (Byun, Irvin, & Meece, 2012). One of the reasons is the lack of access, specifically in science-related areas, along with challenges in understanding and engagement within the curriculum (e.g., science textbooks and teaching methods; Peterson et al., 2015). Students with disabilities and students from CLD backgrounds must be provided up-to-date, 21st Century STEM learning tools and supports, or the bleak trend of under-representation in STEM post-secondary degrees and professional careers will continue (Street et al., 2012).

A 21st Century tool with potential to impact SWD and students who are CLD, both of whom lack background knowledge to comprehend science text at the middle school level (Helman, Calhoon, & Kern, 2015), is the use of technology. For example, the use of virtual simulation, in mixed-reality environments (i.e., virtual and real life settings combined), could provide SWD and those from CLD backgrounds with educational learning supports through a model of individualized learning coupled with personalized performance feedback (Zhu, Moshell, Ontañón, Erbiceanu, & Hughes, 2011).

Students with disabilities, specifically those with learning disabilities (LD) in reading, often lack the ability to comprehend higher-level science text (Marino, Coyne, & Dunn, 2010). Creating technology learning modalities and supports as alternative tools, compared to traditional teaching materials (i.e., textbooks), have the potential of invoking students' engagement and increasing science academic reading comprehension (Marino & Beecher, 2010). All students', including SWD, involvement with technology in the classroom for learning supports should foster deeper understandings and inquiry of developing new technologies that can become change agents in improving issues and conflicts in the 21st century (National Assessment Governing Board, 2014). Increasing comprehension of concepts in STEM (e.g., science) and increasing interest in post-secondary degrees for SWD is critical (Street et al., 2012).

Creating facilitation and inquiry-based learning environments for students who are of culturally and linguistically diverse (CLD) populations (e.g., Latino/a) is equally important to the field of STEM, as this population is also underrepresented in these career areas (Camacho & Lord, 2011). Using a range of technology learning modalities for students who are Latino/a could enhance their personal investment and interests in the science content (LeBlanc & Larke, 2011). LeBlanc and Larke (2011) added that students from CLD backgrounds benefitted from cooperative learning, peer collaboration, and using digital technology to virtually visit real locations and sites and interact with real world environments, locally and globally. A shift from old science standards and practices (e.g., scripted and follow the directions of project-based learning, scripted lessons, teacher led, and paper pencil based learning tasks) to imbedding inquiry-based learning is the expected norm, as found in the Next Generation Science Standards (NGSS), and has been shown to be beneficial for all learners, including SWD and those who are CLD (Marshall, 2014).

If students who are CLD are provided inquiry-based science instruction, they then have the ability to utilize their own personal lens in constructing meaning in their scientific inquiries in and outside of school (Johnson & Fargo, 2014). The importance of a personal lens for diverse learners is critical to consider, related to the broader impacts on post-secondary opportunities. A disconnect for students who are CLD often exists in STEM-related curricula due to a lack of cultural diverse elements within the content, not responsive to the student's personal background knowledge (Stokes, Levine, & Flessa, 2015). Latino/a students have the highest college enrollment rates compared to other diverse groups, yet is the lowest group, along with African Americans, represented in the STEM workforce at 5% (Santiago, Galdeano, & Taylor, 2015). The rate for SWD was found as low for undergraduate STEM-related degree programs, with only one in five SWD pursuing a STEM-related degree (NSF, 2014). The continued challenges for students who are CLD from rural communities, receiving adequate STEM curriculum instruction, role-models, and encouragement to enter a STEM-related field, still needs attention both in research and in novel approaches to practice (Peterson et al., 2015).

Shift in Practice

With new science curriculum and standards being implemented through the Next Generation Science Standards (NGSS), students will no longer be expected to approach science as a memorization practice activity from a textbook. Instead, they will be required to extend their personal experiences and apply deeper understanding on science issues affecting human sustainability (Kirchgasler & Feinstein, 2015). According to the National Assessment of Educational Progress (NAEP, 2011), eighth grade science scaled scores for SWD was 124, which is well below the achievement average of students without disabilities, with an average score of 155. Students with disabilities, and especially those with learning disabilities (LD) in reading comprehension, need proper supports and knowledgeable personnel within the STEM subject areas to potentially consider a career path in these shortage areas (Dunn, Rabren, Taylor, & Dotson, 2012) and reading tools to support their comprehension of complex science texts (Curry, Cohen, & Lightbody, 2006).

Students with LD make up 2.4 million of the 6.4 million SWD population (Kena et al., 2014). According to the U.S Department of Education's (2006) definition of specific LD, 34 CFR 300.8(c)(10) is defined as students with deficiencies in attaining grade level success as a result of poor reading skills, fluency, and comprehension. Incorporating technology as a support for enhancing students with LDs' academic performances in schools is not a novel idea. Using computer simulation technology to teach SWD, specifically students with LD, emerged in curriculum and pedagogical practices as early as 1973 (Lerner & Schuyler, 1973). Limited research, though, has been conducted investigating digital technology interventions for enhancing students with LD and their comprehension within science content (Marino et al., 2010). Marino and colleagues (2010) discussed how students with LD, who lacked prior knowledge in science content along with unfamiliarity with new science concepts, added to reading comprehension struggles for this population. Building upon the struggles of students who are CLD, who are identified as LD, and who are from rural communities, the researcher used an innovative technology tool in an attempt to increase interest in STEM careers and increase student learning in science content. Specifically, the researcher addressed the need of further empirical research on digital technology interventions for enhancing students with LD who are (CLD) in their comprehension and prior knowledge of science content.

Statement of the Problem

Middle school students who struggle to read are taught primarily out of a science textbook, and 75% to 80% of those students were not able to read nor comprehend the textbook content (Carnine & Carnine, 2004). Though curriculum textbooks are often used for learning science concepts, students with LD can benefit from an educator who knows the students' learning needs and can assist them in pre-surveying the content (Israel, Maynard, & Williamson, 2013).

Further, a disparity in intervention research studies exist examining SWD who are CLD at the secondary level. The lack of empirical studies on students who are CLD with disabilities impedes the development of evidence-based practices needed to serve this student population (Vasquez et al., 2011). A meta-analysis of the literature from 1984 to 2006 on special education interventions at the secondary level was conducted by Scruggs, Mastropieri, Berkeley, and Graetz (2010). The researchers examined published articles (N = 70) and reported a decrease in intervention research after 1996. They further reported that out of the 70 articles reviewed, only 35 researchers in their studies identified the race or ethnicity of SWD. Out of those 35 studies, only 6.2% identified students who were Hispanic. The researcher attempted to address the problem on the lack of intervention research by conducting a study that looked at SWD who are CLD at the secondary level on science content.

Justification

The purpose for this research study was to provide middle school students with LD of CLD backgrounds from rural communities (i.e., Latino/a students, specifically those from low socioeconomic status) with facilitated support by activating prior knowledge and discussing 'big ideas' prior to completing a life science video game. A virtual avatar, representing a science professional, provided background knowledge on the learning in a science video game used by students who are CLD in a rural community, in an afterschool program, before the students played the video game. The following research questions were used to guide the research.

Research Questions

1) What effects does prior knowledge, activated by a virtual avatar of a STEM-related professional, have on increasing skills of culturally and linguistically diverse, middle school students with learning disabilities in video game-based science assessments?
2) What effects does a virtual avatar playing the role of a STEM-related professional have on increasing middle school students', who are CLD with learning disabilities, STEM career interests as measured by the STEM-Career Interests Survey?

The research study investigated middle school students from sixth to eighth grade, enrolled in their schools' afterschool programs, under the same district, and located in a rural community. The middle schools served a high number of SWD who are also CLD (i.e., Latino/a). The students were provided technology tools to increase their science outcomes and STEM college and career interests during the afterschool program. The study's setting was originally proposed to take place in a Title I middle school's after school program. The middle school's after school program, at the beginning of the school year, had an enrollment of 70 middle school students from sixth to eighth grade. During the initial meetings with the district and school personnel on recruiting potential students enrolled in the after school program, potentially 60 participants were enrolled at the time of the initial meetings. The school's personnel informed the researcher many of the after school participants were SWD and CLD. After preliminary agreement from the school district for the researcher to conduct the study, the researcher went through the state and district's background check clearance process to conduct the study, which took over four weeks.

Once the researcher received clearance to conduct the study, the researcher began recruitment visits for two weeks. During the first recruitment visit, student attendance in the after school program had significantly dropped, but over 50 students enthusiastically took slips and appeared to want to participate. After two weeks of recruitment, the numbers of students attending continued to decrease significantly to about less than 22 students attending the program, and with only two out of 50 students originally interested in the study returning signed consent forms to participate, despite contacts made numerous times. The issue was not willingness to participate but daily attrition rates of attendance. The researcher was told by different school personnel that their middle school, during spring time, saw many students leave or move away from the community due to their family's livelihood as migrant farm workers. The researcher was informed that the students' attendance in the school would further drop as the spring semester progressed, and the number of students participating in the after school program would also be affected by the decreasing number of students' attendance.

Additional recruitment trips and extensions were in place in order to garner more participants. The number of participants who consented was about 25% of the 70 potential students, and the number of participants who completed the study was only eight, indicating an approximate 90% attrition rate for this targeted school population. The targeted area of participants who were students with a LD who were CLD dropped even further to only one student participating in the study. In order to continue to conduct the study, a second middle school in the same school district with the same after school program model was included in the study with efforts to recruit more SWD who were CLD from a rural community. This school did produce additional participants, but attrition rates were high too in this site and will be discussed. Despite multiple recruiting efforts, extensions toward increasing participants, and adding a second middle school, only one SWD consented to participate in the study and 23 students completed all phases of the study.

The initial research design was employed as an experimental control group design with a multivariate analysis of covariance (MANCOVA). The suggested G*Power analysis for a repeated measures multivariate was N= 34. After the recruitment and distribution of consent forms from both middle schools, and at the conclusion of the study, the number of participants did not meet power adequate enough to be analyzed with a MANCOVA. The researcher reported the groups' and individual's results using descriptive statistics. The research study conducted did continue to be a control group pretest design, but the reporting of results occurred using descriptive statistics. The Participants were assigned to either a control or treatment group during their activities of playing the Cell Command video game. The treatment group received the intervention of speaking to an avatar before playing the Cell Command game.

Definitions

Artificial Intelligence:

Artificial Intelligence (AI), when a computer program is written to function, respond, and make decisions like those reflected as a human would (Turing, 1950).

Universal Design for Learning Framework (UDL):

The operational definition for the facilitating of science comprehension was based on the UDL Version 2.0 Multiple Means of Engagement Principle III checkpoint 7.2 (CAST, 2011). The researcher in this study used the digital format to meet students' targeted for varying learning supports and needs through the UDL framework.

Prior Knowledge:

The operational definition for prior knowledge is the activation of prior knowledge through activation within the content (Bransford & Johnson, 1972).

Florida Science Standard:

The seventh grade science standard was taken from the state of Florida's CPALMS state standard SC.7.N.1 "D: Scientific knowledge is based on observation and inference; it is important to recognize that these are very different things. Not only does science require creativity in its methods and processes, but also in its questions and explanations." (CPALMS, 2015).

Culturally and Linguistically Diverse:

Culturally and linguistically diverse students are from homes where English may not be their native language or their family's native language, and are of a minority background (e.g., Latino/a: Cummins, 1991).

Title I Schools:

Title 1 schools are primarily made up of students who are disadvantaged (e.g. low-income, migratory, limited English language learners, and disabilities) and need additional supports (U.S. DOE, 2004).

Free and Reduced Lunch:

Students who are from low-income homes who qualify for a meal program in their school settings, at little to no cost, to alleviate their hunger and gain nutritional supports are considered on free and reduced lunch (USDA, 2015).

Mixed-Reality:

Mixed-Reality (MR) is the combination of two environments: (a) virtual reality, and (b) real-world settings infused for an individual to experience a mixed-reality (Hughes, Stapleton, Hughes, & Smith, 2005).

TeachLivE Avatar:

A digital puppet that is displayed over a digital screen (e.g., computer, tablet, or television), manipulated and speaking through the puppetry of a human interactor, portraying the role of the avatar, while interacting with a real human participant (Zhu et al., 2011).

CHAPTER 2: REVIEW OF LITERATURE

The conceptual framework of Universal Design for Learning (UDL; CAST, 2011) serves as the construct for the literature identified to support the delivery of traditional academic content for students with learning disabilities (LD), via simulation technology, with the purpose of activating students' prior knowledge in content (Bransford & Johnson, 1972). The UDL framework has also been identified or referred to as a theoretical framework (Basham, Meyer, & Perry, 2010; Hall, Vue, Strangman, & Meyer, 2004; Jimenez, Graf, & Rose, 2007; Kennedy, Thomas, Meyer, Alves, & Lloyd, 2014; Messinger-Willman, & Marino, 2010; Strangman, Hall, & Meyer, 2004). Implementing UDL with the intent of meeting diverse students' needs to accessing academic content must utilize 21st century digital technology formats (Edyburn, 2010).

The current status of services for students with and without disabilities, in relation to the National Assessment of Educational Progress (NAEP) eighth grade reading and science scores, are summarized. Literature is summarized on the unique challenges of education in U.S. rural communities. Activation of prior knowledge in science is further explored. The literature on activating prior knowledge through the use of a UDL framework and digital supports is provided in relation to traditional materials (i.e., textbooks). The potential to address the activation of background knowledge in science for students with LD through UDL is discussed, including the unique opportunities this framework offers for students who are CLD. The chapter concludes with the intersection of the importance of activating prior knowledge with digital supports for science literacy and the potential of mixed-reality technology simulations might offer to enhance students' science comprehension.

Conceptual Framework

Preparing students for learning and problem solving skills in the 21st century, with traditional learning materials (i.e., textbooks, worksheets, and paper/ pencil tasks), currently does not include an inclusive model for learning in multiple means, as emphasized through a UDL framework (Dalton & Brand, 2012). The use of the UDL framework, specifically principle III multiple means of engagement checkpoint 7.2, provides the conceptual framework for this investigation. The UDL framework has been referred to in the literature as having advantageous properties for enhancing all learners', specifically SWD, access to learning academic content (Rose, Harbour, Johnston, Daley, & Abarbanell, 2006).

The UDL framework was developed with three means of how students and teachers interact with the academic content with an emphasis of access for all learners: (a) representation, (b), expression, and (c) engagement (Rose & Meyer, 2000). A major part of the UDL principles is that students have access to academic content coupled with technology (e.g., computer simulations; Jimenez, Graf, & Rose, 2007). In the means of engagement principle, the emphasis is on creating students' background knowledge and culture for cultivating and activating students' own culture and learning processes (CAST, 2011). When the ability to access text is comprised of primarily reading for students with LD, mastery of content knowledge can be a challenge (Schumaker, & Deshler 1992).

Activating Background Knowledge

This study emphasized activating prior knowledge before learning content (Christen & Murphy, 1991) in science for students of CLD (i.e., Latino/a) with an identified LD. The researcher conducted the study to influence science comprehension using an expert (avatar) in science content in two, rural afterschool programs. The purpose was to engage students in science content discussions with the avatar being used to enhance background knowledge in hopes of increasing comprehension of science content. The increase in content knowledge was measured through an online game, Cell Command. Cell Command was developed as an interactive video on cell structures and processes. Game Players are required to play different stages in the game that are themed and revolve around different functions and processes of a cell.

Reading for Content Access and Learning Disabilities

When creating reading supports for students with LD to access content, support must be addressed within individualized and evidence-based instruction (Deshler et al., 2001). When a student is not successful at reading or comprehending text and has already been given instruction in evidence-based reading practices and individualized instruction, the lack of success may indicate the student has a reading disability (Wanzek & Vaughn, 2009). As students with LD who have received instructional and individualized supports advance in grade levels, their reading deficits become more apparent through the rigorous expectations of the literacy skills needed (Bulgren, Graner, & Deshler, 2013). Issues with comprehending information through reading are not unique just to students with LD. Students from different cultures can also struggle comprehending text through traditional means.

Culturally and Linguistically Diverse Latino/a Students

Students with disabilities who are minorities (e.g., CLD) are still at the front and center of inequity and justice in the field of education (Artiles, 2011). Research on students who are CLD with a disability is sparse, and there is a call for remediation among researchers to be aware, and better yet, proactive to understanding why more empirical research is needed for the purpose of serving SWD who are CLD (Trent et al., 2014; Vasquez et al., 2011). The research available on SWD (e.g., CLD) lacked rigor, and recommendations for future research studies must be deliberate on serving SWD who are CLD in the educational settings (Sullivan & Artiles, 2011). Researchers in the field of special education, have arguably, either ignored or made little effort on identifying students' culture in their research, due to the researcher's inability to identify with students' cultures or backgrounds (Arzubiaga, Artiles, King, & Harris-Murri, 2008).

Students who are CLD (e.g., Spanish speaking homes) often are encouraged by a teacher to use their cultural and personal experiences to strengthen comprehension of text using prior knowledge (O'Connor & Orosco, 2011). O'Connor and Orosco (2011) noted students' personal background and culture are crucial pieces that adhere to their comprehension-building capacities, as opposed to interventions shown to be insignificant to students who are CLD. Yet, the backgrounds of students who are CLD often are varied, like all students, and may be limited in U.S. context areas like social studies and science (Hughes, Page, & Ford, 2011). Common factors students from CLD backgrounds experience are over-identification in special education and underrepresentation in gifted education due to poor academic supports not sensitive to their cultural lenses or backgrounds (King, Kozleski, & Lansdowne, 2009). Tapping into students' prior knowledge is a culturally relevant teaching practice that can enhance the students' background knowledge and views of their community in the classroom (Kozleski, 2010). Successful inclusive, culturally relevant teaching models use students' culture in the learning environment and are strengthened when the teacher plays the role of a facilitator (Kozleski &

Waitoller, 2010). The use of culturally relevant practices are at the core of using and building upon students' prior knowledge and experiential backgrounds (Gay, 2002).

From an exhaustive review of the literature, when students are CLD from a Latino/a (i.e., Mexican American) background and are SWD, no clear best practices or interventions have been developed or researched (Evans, 1974). To further identify the historical condition of special education for Latino/a students, the identification of students of Mexican descent, among other Latino groups, had the highest identification of being categorized with a LD (Bell-Mick, 1983). In a meta-analysis report on studies with interventions for SWD at the secondary level, only 6.2% of those studies identified including students from a Hispanic demographic group (Scruggs, Mastropieri, Berkeley, & Graetz, 2010). Currently, a lack of clear research is missing on the current knowledge base of more diverse populations, and researchers have historically ignored the specifics of ethnicity and culture in intervention research. Artiles (2015) advocates for a paradigm shift towards showing reverence in research for students and their unique culture to better serve and understand the needs of students who are CLD. Students' culture, socioeconomic status, and placement in special education was a highly contested argument among researchers' research-based views on students' backgrounds (Artiles et al., 2010).

Students who are CLD (e.g., Mexican background) face challenges beyond their classroom walls and often are isolated by discrimination experiences reflective of their involvement in schools (McHatton, 2007). Students with disabilities who are CLD still do not receive appropriate access to content or interventions that meet their needs (Cramer, 2015). The impact of students with CLD, or students with LD, and their performance in reading and science is evident in the overall, current status of their educational outcomes in national assessments.

The indication of the need for SWD was evident with the latest NAEP scores falling below the proficient and basic science (124) and reading scores (232). Amongst the dire national assessment scores, students from rural communities, especially SWD who are CLD, face inequities from poverty, education, and healthcare issues (Mullen, & Kealy, 2013).

Rural Communities

Students who live in areas identified as rural communities face unique challenges, and these issues are further compounded when a student in these communities is CLD and/or LD. Students who live in rural communities in the U.S. make up approximately one-fifth of all students. Further, of all the counties identified with the highest poverty levels in the U.S., 96% of them are rural communities (Fishman, 2015). Fishman (2015) explained that rural communities in poverty are faced with being treated in isolation, and yet held to the same expectations of suburban, and urban communities, despite not having the resources, personnel, or academic attention associated with those comparative communities. Rural schools have been found, nationally, to spend more money on their education and resources, but the spending is due to the high-needs rural schools face and the lack of integrated services found in larger communities, requiring higher amounts of funding (Levin, Manship, Chambers, Johnson, & Blankenship, 2011).

Students living in low socioeconomic communities, including rural communities, are likely to be at an educational and economic disadvantage (Mattingly, Johnson, & Schaefer, 2011). Rural communities, combined with large minority populations, tend to be the neighborhoods or towns where the majority of residents are of low socioeconomic status (Bryant, Moss, & Zijdemans Boudreau, 2015). The achievement gap among students who are minorities, compared to students who are non-minority, continue to present a disparity in outcomes (Hanselman, Bruch, Gamoran, & Borman, 2014). Students labeled as minorities, regardless of community, have historically faced obstacles in education from the days of segregation to the present day dearth of supports for students who are CLD (Ladson-Billings, 2013).

Schools in rural communities, with high poverty rates, have had, over the decades, many inequalities, including skill level of teachers, supplies, poor conditions of the students' daily bus rides, and overall learning gains. Students who are racially and ethnic minorities (e.g., Latino/a), from rural poor communities, often are affected by their daily bus ride due to poor riding conditions and the vast amounts of time away from instruction (Howley, 2001). Many students in rural communities spend over an hour and a half, one-way, on a bus ride to get to school every morning (Zars, 1998).

The lack of overall educational structures and supports for students living in poor rural communities has had a negative impact on their future economic status (Ulrich, 2011). Those economic issues may include, for students in rural communities, missing school due to supporting their families' economic needs. Families of youth in rural communities may expect their children to contribute to their families' economic needs by working during seasonal farm or crop work (Azano & Stewart, 2015). In Azano and Stewart's (2015) study, teachers who taught in rural schools were interviewed. One teacher commented on the regular occurrences of students missing school days due to hunting and helping during different crop seasons.

This type of research on children and youth who are CLD, and their participation (e.g., academic performance, attainment, and post-secondary outcomes) in school settings is crucial to the economic impact of the United States (Vasquez-Salgado & Chavira, 2014). Students who are minorities (e.g., Latino/a) were found to regularly encounter school personnel who did not respond in ways to alleviate the students' academic struggles or needs (Espino, 2016). Students who are CLD (e.g., Latino/a) bring value and unique culture into U.S education, but they also are part of an educational system that has underserved them (Verdugo, 2006). Students who are CLD (e.g., Latino/a) from high poverty communities often were identified (Musti-Rao, Cartledge, Bennett, & Council, 2015) as being illiterate in reading. Blank (2013) noted that students from low socioeconomic communities often come from schools with limited science instruction in their classrooms. A disproportionate number of schools' students in low SES communities were found to provide inadequate science instruction (Darling-Hammond, 2012). Further, Darling-Hammond (2012) noted these schools also lacked teaching staff, materials, and enriching activities in content areas, like science.

Blank (2013) found students' socioeconomic status and backgrounds were factors to how, or if, students were interested in or pursued a STEM degree. A large portion of Latino/a students who pursued a post-secondary degree (i.e., community college) came from low socioeconomic communities and homes (Chacon, 2013). This fact is important to consider as students from disadvantaged communities were found to lack having a member in their family who had attained a STEM related degree or career and also had limited science instruction in their classrooms (Blank, 2013).

Students with disabilities from rural communities need the necessary academic supports to increase their well-being and academic performance (Gabriel & Davis, 2015). For students living in the rural settings, Zeichner (1993) found a lack of educational support, capitalizing on the students’ community and learning needs. In addition to the lack of educational supports and array of issues present in many rural communities, limited research is available on the supports that could be added to instruction to develop a strong sense of community and parental support for students from CLD backgrounds (Berry & Gravelle, 2013). This shift in approaches is critical, as students who are CLD (i.e., immigrants) from rural communities were found to thrive in schools supported by family and teachers being sensitive and responsive to their learning needs (Montemayor, Kupczynski, & Mundy, 2015).

National Assessment of Educational Progress

Reading NAEP assessment.

In the NAEP reading framework report, “Text comprehension is influenced by readers’ ability to apply the essential components of reading: phonemic awareness, phonics knowledge, fluency, and understanding of word meanings or vocabulary” (National Assessment Governing Board, 2012, p. 3). The report described readers’ comprehension as a result of prior knowledge, and how they experienced their own reading materials. Students entering eighth grade were noted to be arriving with a lack of reading skills, which is reflected in their NAEP eighth grade reading assessment scores, which were below proficient (Dogan, Ogut, & Kim, 2015). A critical issue noted to affect students who are struggling readers and from lower socioeconomic status is those students are twice as likely not to attain a high school diploma or finish on time (Hernandez, 2011). Hernandez (2011) also reported that Hispanic students who were poor and considered proficient readers were still eight times more likely to drop out of high school or not finish on time than all other learners (33%). His report indicated that Hispanic students were mostly living in poverty, from disadvantaged communities, and going to schools that lacked proficient indicators or ratings on their students' academic performances.

Science NAEP assessment.

In the last NAEP (2011), students who had qualified for a free or reduced school lunch program were below the basic rating, with an average score of 137. Students who did not qualify were in the basic range, with an average science score of 164. Students who were identified as both having a disability and as an ELL had an average scaled score below the basic range at 86. The results for students who were not identified as having a disability or being a student identified as an ELL were within the basic rating range of 157. These outcomes for all students are an area of focus in the U.S., but the dismal outcomes for students who are LD and those from CLD backgrounds are areas in need of further consideration in research studies for these populations.

Activation of Prior Knowledge

One critical area of need that might be addressed to impact both reading and science performance for both students who are LD from CLD is activating prior knowledge. Activating prior knowledge for students with LD is a vital skill not always considered when teaching concepts and content (Deshler, 2014). Students with LD may have strategies and coping mechanisms for literacy practices, but significantly lack comprehensive understanding after reading content (Gersten, Fuchs, Williams, & Baker). Reading is an important skill students need to successfully navigate through multiple content areas (Vasquez et. al., 2011). Reading demands and tasks are no longer regulated to paper and print materials (e.g., textbooks, worksheets, and handouts), but have shifted to digital texts and online content (Ho, Tsai, Wang, & Tsai, 2014). Students with LD are now faced with challenges for reading traditional and digital texts (Curcic, 2011; Leu et al., 2015). For students with LD, the transition from being in the primary to secondary school settings requires more textbook reading and comprehension to accomplish traditional learning outcomes (Berkeley, Mastropieri, & Scruggs, 2011). Reading comprehension and literacy skills are not only needed for the sake of reading, but also required to meet the demands and complexities associated within the different academic content areas (Davis & Guthrie, 2015). Table 1 provides a summary of the current research used to frame this literature review. The studies considered are seminal, related to supporting students with LD and students who are CLD in reading science textbooks and the potential of UDL to address these populations.

Table 1. Research on LD and CLD in Reading Science Text and Outcomes

Experimental Studies Identified in this study	**Sample Size**	**Question**	**Results**
<u>UDL</u>			
Rappolt-Schlichtmann et al. (2013)	621 fourth graders	On average, do students in classrooms using support-rich, UDL science notebooks learn and understand more about science than similar students in similar classrooms using traditional paper-and-pencil science notebooks?	Overall increase in content knowledge posttest means for treatment group (M = .42, SD = .9) compared to control group (M = .01, SD = .9)
Katz (2013)	631 K-12 students	Is there a significant difference in students' academic engagement following the implementation of an instructional pedagogy based on the Three Block Model of Universal Design for Learning?	A large effect size of .05
Metcalf, Evans, Flynn, and Williams, (2009)	12 second grade students	Does UDL supports coupled with Direct Instruction benefit students' spelling lessons?	UDL and Direct Instruction group (M = 90.8) Direct Instruction only group (M = 55.3)

Experimental Studies Identified in this study	Sample Size	Question	Results
Hall, Cohen, Vue, and Ganley (2015)	284 students with an average age of 11 years 6 months	Is the technology-based approach to monitor student performance in reading more effective in improving student performance on standards-based measures of reading comprehension?	Students with LD in the treatment group had an increase from pre to posttest scores of 10%, and those in control group had an increase of 6.58%
Dalton, Proctor, Uccelli, Mo, and Snow (2011)	106 Sixth grade students	What is the effect of ICON condition (comprehension strategy vs. vocabulary vs. combination) on fifth-grade students' comprehension and vocabulary learning within the ICON SDR? What is the effect on students' standardized reading achievement test performance?	Overall effect size of .33 for ICON comprehension strategy effect size of .27 Vocabulary effect size of .27 Combination of both strategies effect size of .48

Experimental Studies Identified in this study	Sample Size	Question	Results
Knight et al. (2015)	Four middle school students with autism	What effects do various modifications of Book Builder™ on measures of vocabulary, literal comprehension, and application questions?	The highest overall means for vocabulary questions was with BB + EI 2 (M = 64.16), The highest overall mean for correct comprehension questions was BB + EI 1 (M = 62.5) The highest overall mean for correct application questions was with BB + EI 2 (M = 67.5),
<u>Culturally, Linguistically and Diverse (CLD) Studies</u>			
Dieker, Grillo, and Ramlakhan (2012)	108 middle school students	What impacts did a science, technology, engineering, and mathematics (STEM) summer camp, based on virtual and simulated environments, have on self-confidence of diverse secondary science students from low socioeconomic backgrounds who were considered gifted with strong potential in future STEM fields?	At pre-test, 58% of students could define one part of the acronym STEM, and only 39% of the students able to identify a STEM career. The post-test results were 100% of students identified the STEM acronym and 95% could identify a profession identified in the STEM field.

Experimental Studies Identified in this study	Sample Size	Question	Results
<u>Learning Disabilities Studies on STEM</u>			
Aydeniz, Cihak, Graham, and Retinger (2012)	5 students in 4th and 5th grade	What are the effects of this inquiry-based curriculum on students' conceptual and application-based understanding of simple electric circuits?	Students' overall baseline went from 4.7% to 76% during intervention
Bakken, Mastropieri, and Scruggs (1997)	54 eighth grade students	What are the compared effects of comprehension – fostering strategies (a) test-structured based strategy, (b) paragraph restatement strategy, and (c) traditional instruction?	Text-structured 3.43 compared to traditional and .68 compared to paragraph restatement
Sullivan, Mastropieri, and Scruggs (1995)	137 fourth and fifth grade students	What effects does coaching active reasoning have on students with LD	Coached explanation with immediate explanation (M = 13.72), Coached explanation with immediate target explanation (M = 12.47), and no explanation condition with delayed feedback (M = 2.56)

Experimental Studies Identified in this study	Sample Size	Question	Results
Scruggs, Mastropieri, Levin, and Gaffney (1985)	56 junior high school students	What effects does mnemonic, direct instruction, and free study control conditions have on students with LD on learning mineral attributes?	Mnemonic for hardness level (M = 65.2), color (M = 82.1), and use (M = 60.7) Direct instruction hardness level (M = 14.3), color (M = 33.0), and use (M = 25.0)
Dalton, Morocco, Tivnan, and Mead (1997)	172 students with 33 with LD	What are the effects of two variations of hands-on science to fourth grade students with and without disabilities?	Supported inquiry science group posttest mean results (M = 30.93) outperformed the activity based science group (M = 24.65)
Seifert and Espin (2012)	20 tenth grade students with LD	What effects does text reading, vocabulary learning, and combined approaches have on improving reading of science text?	The combined effect size of a combination of vocabulary knowledge and reading fluency was 1.12
<u>Prior Knowledge Studies</u>			
Tarchi (2015)	166 seventh and eighth grade students	Is an intervention based on the activation of specific dimensions of prior knowledge, more effective than an intervention based on the activation of generic prior knowledge?	Tarchi reported the effect size of .36 of both treatment combined with activation of prior knowledge and reciprocal teaching

Experimental Studies Identified in this study	Sample Size	Question	Results
Tarchi (2010)	131 seventh graders	How does each prior knowledge component specifically contribute to reading comprehension performance?	Reading comprehension effect size was .55
Chen, Chen, and Sun (2014)	60 first year senior high school students	What effects of prior knowledge with social tagging methods to assist reading comprehension have on students studying English?	Treatment group's posttest mean was (M = 59.0), and outperformed the control group (M = 43.33)
Chang, Quintana, and Krajcik (2010)	271 seventh grade middle school students	Whether the understanding of the particulate nature of matter by students was improved by allowing them to design and evaluate molecular animations of chemical phenomena	There was an effect size of .94 when students design, interpret, and evaluate, versus design and interpret science models
Note. Results reported from studies were presented in percentages, means, and effect sizes.			

Early work by researchers in the late 1990s indicated when questioning practices were used for activating prior knowledge for students with high incidence disabilities, participants had better outcomes than if they only received direct instruction (Scruggs, Mastropieri, & Boon, 1998). One particular study conducted by Sullivan, Mastropieri, and Scruggs (1995; see Table 1), with 137 fourth and fifth grade elementary students with LD, assessed participants on active reasoning by activating students' prior knowledge. The students were assigned to three different treatment conditions: (a) coaching (i.e., students had reciprocal conversations with experimenter), (b) explanation (i.e., experimenter provided participants answers and reasoning plus had students repeat the answers), and (c) no explanation (i.e., same as first two treatments only the students were asked to repeat the information provided to them minus being provided the answer or explanation). The researchers found students in the coaching condition outperformed the other two conditions in active reasoning. A survey was conducted in the study, and the researchers found 100% of the students in the coaching condition engaged their thinking process, and 75% of all participants reported they preferred to think independently when interpreting information rather than directly being provided the information.

Building prior knowledge reading supports at an early age through vocabulary recognition and teacher read aloud activities, have been found to be beneficial to enhancing students' reading comprehension. Students who were not provided those supports often struggled with reading comprehension throughout their K-12 education (Kaefer, Neuman, & Pinkham, 2015). In order for students to be successful with acquiring new content or knowledge, prior knowledge must be presented and activated to build on the introduction of new concepts and knowledge (Costley & West, 2012). When students talk about content or literature with peers or teachers, the process activates their prior knowledge based on their personal perspective or experience (Pittman & Honchell, 2014). Activating students' prior knowledge through reciprocal conversations with classmates and the teacher enhances comprehension of the content (Palincsar, Parecki, & McPhail, 1995).

Students who were considered struggling readers had difficulty with reading informational text and gaining reading comprehension when they lacked prior knowledge in the content areas (Davis & Guthrie, 2015). In Davis and Guthrie's (2015) study, the authors investigated if there was a correlation between (a) global structure (e.g., the theme of the text), (b) concept words (e.g., vocabulary specific to the content), (c) phenomenon (e.g., relationship between words or phrases for meaning), (d) searching for information in text, (e) student generated questions (e.g. skim passage then construct four questions on what may be in text), and (e) students' prior knowledge. The sample population was 176 third grade students from the mid-Atlantic region of the U.S. (further demographic information or if SWD were part of the sample were not provided). Science content reading passages were used as the assessments.

Davis and Guthrie (2015) reported global structure did not correlate at a level of significance with prior knowledge, or student-constructed questions. For correlations in concept words, statistical significance was found with both prior knowledge and student-constructed questions. In the phenomenon (relationship with words) results, correlated statistical significance was reported with only prior knowledge. Davis and Guthrie (2015) explained students who were at the beginning levels of reading might have struggled due to their lack of knowledge with vocabulary within the content areas, background knowledge, and inferential thinking processes. Beginning or struggling readers were affected with comprehending the global structure of informational text, resulting in missing the big idea or theme of the readings. The researchers reiterated students who have emerging reading comprehension skills are typically at the understanding stage of their reading comprehension of content. On the contrary, students who have proficiency to advance reading comprehension skills were able to bypass the understanding stage of the content, and instead construct meaning from the text and add to their reading comprehension.

International studies on activating prior knowledge.

In Tarchi's (2010) study, prior knowledge was a pivotal construct for seventh grade students on retaining reading comprehension of informational science passages. This study was international and conducted in Italy. The results (as reported in Table 1) from Tarchi's (2010) investigation looked at multiple variables throughout the study, and three were specific to prior knowledge: (a) domain in science, (b) facts in science, and (c) meanings in science. The researcher's stated purpose was to see how prior knowledge affected seventh grade students' reading comprehension after reading science and history passages. The participants were seventh grade students (*N* = 149), and the results reported in the study were taken from 131 participants. Tarchi (2010) indicated that 18 students with LD who were struggling readers were not included in the analysis and results in his article.

Students who have background knowledge on the core ideas in science content, prior to reading the informational science materials, have been shown to have a statistical significant gain in comprehension (Tarchi, 2010). Tarchi (2010) mentioned how important it is for students to understand concepts by having prior knowledge, specifically within the science discipline. He reiterated students need to understand and gain reading comprehension when reading science texts.

Tarchi (2010) discussed the critical nature of prior knowledge for students to acquire new knowledge from expository texts. He explained that prior knowledge and reading comprehension are well-documented in previous literature and research, but that studies looking at prior knowledge as being a multi-dimensional (e.g., inferential, content based, implicit, and explicit comprehension of content) thinking strategy were limited. Tarchi (2010) looked at "inferential-making skills" (e.g., referring to previous parts of a reading to understand meaning, or using information outside of the text to understand the reading) as a possible dimension to consider when looking at prior knowledge. He referred to inferential skills as having two parts: (a) lexical (i.e., understanding a word in the text, based on the context of the sentence or paragraph) and (b) semantic inference (i.e., using knowledge outside of the text for understanding). His theoretical framework for conducting this study was to look at prior knowledge and inferential thinking as two "higher-order" skills that increase reading comprehension. He pointed out both prior knowledge and inferential thinking need to be addressed concurrently rather than separately.

In Tarchi's (2015) study the participants, 186 seventh and eighth grade students from three different schools, were separated into control (reciprocal teaching) and treatment (peer-to-peer prior knowledge strategy) groups. The control group followed a procedure of repeatedly addressing each paragraph with questions pertaining to the reading and predicting the theme of the next section of text. The treatment group was instructed, prior to reading assigned texts, how to activate their own prior knowledge according to the text features (e.g., title, subtitles, and pictures), and then amongst their small reading groups, they were to share their prior knowledge with each other before reading the texts. Both groups were provided the same text passages in history and science. Reading assessments were given to measure comprehension of the passages. Tarchi (2015) indicated students identified as LD, immigrants, and struggling readers were not included in the data analysis and results sections. Thus, results reported in his study did not reflect or report the effects that prior knowledge had on students with LD or CLD and their reading comprehension performance with science texts. Tarchi (2015) found for the general population, after running a Multivariate Analysis of Variance (MANOVA), participants in the treatment group had outperformed the control group across assessment measures. The prior knowledge group outperformed the reciprocal teaching group with statistically significant differences on increased reading comprehension. The same results were found in relation to inference and metacognition task assessments. In the lexical inference assessment both groups' scores were similar and neither showed statistical gains in performance. Tarchi's (2015) study supports teachers serving as facilitators to students activating prior knowledge during peer-to-peer group work.

Another study with an international lens on students' reading comprehension and prior knowledge was conducted in Taiwan. Chen et al. (2014) investigated building on students' prior knowledge by increasing their reading comprehension through passages presented with a digital adaptive (e.g., digital software that responds to users' activities with suggestions, cues, and tutoring) reading software. Sixty students from Taiwan were provided test preparation styles of lessons, with minimal emphasis on use of their prior knowledge for gaining new knowledge to increase reading comprehension (Chen, Chen, & Sun, 2014). The software was called TAK and its main features were reported as being developed with the purpose of users having the ability of tagging (e.g. users interacting with digital items and having those interactions available for later viewing) items in the passages for later review and to receive recommendations on the content from TAK.

Chen et al. (2014) chose science articles and reading passages based on the difficulties associated with the content and activating students' prior knowledge. Two treatment groups were created: (a) control (i.e., received same digital reading passages without prior knowledge assistance), and (b) treatment group with same passages as the control group but with prior knowledge tagging abilities. A paired sample t-test showed a statistically significant difference between the control and treatment group. The treatment group outperformed the control group on the science reading comprehension passages. In the study, students who received supports in activating and creating prior knowledge increased their reading comprehension of science passages.

Further analyses were conducted and reported on the amount of time participants of both groups spent completing the reading passages (Chen et al., 2014). The researchers' indicated their concern with participants using TAK prior knowledge features increased the time it took to read a passage. The researchers reported no statically significant difference ($p >. 05$) was found in the amount of time spent by participants in the control and treatment groups when reading the science passages. According to the researchers, the results have implications on digital software with tagging abilities geared towards students' prior knowledge during science reading passages to increase their reading comprehension, as the experimental group significantly outperformed the control group.

Prior knowledge in reading.

Tapping into a student's prior knowledge may hinder the reader's advantage to increase reading comprehension (Lipson, 1984). This factor depended upon whether the student lacked reading skills associated with building prior knowledge or did not accept accurate information that countered their prior knowledge (Lipson, 1984). Reading, regardless of different formats of texts (i.e., print or digitally), requires the use of prior knowledge for reading comprehension (Coiro, 2011). In one study, students who were struggling readers, yet had sufficient prior knowledge in the text they were reading (at their reading level) for comprehension, were still not able to answer, make connections, or understand inferential questions (e.g., big ideas) within passages (Holmes, 1983). Prior knowledge and reading comprehension go hand-in-hand as to whether an individual understood the text they had read (Johnston, 1984). Having prior knowledge in a topic before reading the texts had an effect on the reading skill of word identification, thus contributing to the skills needed for reading comprehension (Priebe, Keenan, & Miller, 2010). Reading practices, including the combination of peer-to-peer interactions, educator facilitation, prior knowledge building, and educator feedback, have bolstered students' reading comprehension (Vaughn et al., 2013).

Prior knowledge in science.

The power of impacting students' prior knowledge in reading, and specifically science, is a developmental process. Science education and meeting the needs of students' understanding in science concepts requires initiatives beyond fact recall and memorization of concepts. Teachers need to develop lessons and curriculum incorporating students' life experiences through inquiry and prior knowledge to understand complex reading material (Magnusson & Palincsar, 1995). According to the National Assessment Governing Board (2010), "Several caveats about learning progressions are in order. First, learning progressions are not developmentally inevitable but depend on instruction interacting with the student's prior knowledge and construction of new knowledge. Thus, learning progressions need to invoke assumptions about instruction" (p. 86). Focusing on students' prior knowledge in science around problem-based learning, with an emphasis on students' everyday lives outside of school, has a strong correlation to increased learning outcomes (Rivet & Krajcik, 2008). Students from CLD backgrounds who are identified as LD in reading needed scaffolding supports in accessing their prior knowledge in science to better understand vocabulary and learn science concepts (Helman, Calhoon, & Kern, 2015). Learning content (i.e., science concepts) through social settings in the classroom have benefits for students with LD on peer-to-peer learning, activating prior knowledge, and literacy skills (Palincsar & Klenk, 1992). In science inquiry-based activities a student with LD may be using traditional learning materials to convey their comprehension and may appear they are struggling with the activity, yet their struggles may only be seen through discussions with peers or educators (Palincsar & Collins, 2000).

Many models and learning approaches to increasing students' science content knowledge through multiple representations exist (e.g., the 5 E Learning cycle), but in order for students to gain the highest level of comprehension (e.g., constructing meaning for problem solving) depended on their level of prior knowledge (Won, Yoon, & Treagust, 2014). Providing students with scaffolding (e.g., teacher modeled or assistance to learning tasks) in learning supports and lessons can help the student become independent in their problem solving and comprehension (Davis, 2015).

Emphasis in science inquiry and students' notions and understandings of the academic content can be influenced by their prior knowledge from outside of their classroom walls, yet applying the prior knowledge to classroom learning was found to be a struggle for students (Nakhleh & Krajcik, 1991). Teachers who teach science content needed to be aware of different ways of presenting the science curriculum content by upholding the critical key ideas in each of the content areas when they teach (Magnusson & Krajcik, 1993). Teachers in science classrooms tended to expect memorization of facts rather than inquiry-based activities, and methods that required significant, prior knowledge from the students (Eslinger, White, Frederiksen, & Brobst, 2008). For teachers to create a science learning environment to reach their diverse learners, knowing the students' prior knowledge should be considered when looking to enrich the learning experiences (Basham & Marino, 2013).

Universal Design for Learning and Science

Sinha, Rogat, Wiggins, and Silver (2015) discussed, in their study, cognitive engagement of seventh graders at different cognitive levels, grouped for peer-to-peer engagement, using virtual simulated science activities. The researchers indicated, whenever collaborative group activities in science are assigned, teachers need to ensure the activation of students' prior knowledge is built into the lessons. Sinha and colleagues (2015) found when students reached the conceptual-to-consequential engagement (e.g., problem solving using previous knowledge in different academic content to applying all of it towards real-world situations) they were constructing knowledge from prior experiences to create solutions rather than retelling facts or concepts. Further analysis of their results showed a correlation between cognitive engagement and conceptual-to-consequential engagement. Sinha and colleagues suggested improving the inquiry activities in technology-enhanced environments by including interactions to include prompts, cues, and higher-order thinking communication between the computer and students.

Digitally Interactive Learning Tools in Science

Interactive learning tools through digital technology can engage students (Chang, Quintana, & Krajcik, 2010). Chang and colleagues (2010), in their study examined two types of digital animation presentation modalities: (a) open-ended (e.g., ability of interacting, constructing, manipulating, or communicating with the digital science content), and (b) less open-ended (e.g., presentation only, non-interactive, and not created by the student). The purpose of their study was to see what effects and impacts different modes of digital science-based chemistry content had on 271 seventh grade, public, middle school students from the Midwest region. Three types of digital content were deployed to three different treatment groups: (a) fully interactive, where the students design, interpret, and evaluate, (b) design and interpret only, and (c) teacher created, non-interactive animation with a viewing-only function for the students.

In the Chang et al. (2010) investigation, the researchers included students' prior knowledge and inquiry process as the variable that affected students' learning of science content. A statistically significant difference was found of higher performance results from the treatment group who created, interpreted, and evaluated their digitally animated, chemistry content. Chang et al. (2010) discussed how students who were struggling learners could benefit by interacting with science content provided in an animated and interactive visual representation, effective towards constructing meaning for the students' comprehension of science concepts. They made the point that animation and visual representations provided instant meaning to the student as opposed to text-based representation in which students needed phonemic awareness first in order to gain an effective learning experience. The final point made by Chang and colleagues (2010) was how students benefited the most when they were presented science content they could design, interpret, and evaluate through peer-to-peer interactions and evaluating each other's work.

Universal design for learning, science, and students with learning disabilities.

Students with LD benefit from evidence-based learning strategies to comprehend science content (Scruggs, Mastropieri, Levin, & Gaffney, 1985). Thirty years ago, Scruggs, Mastropieri, Levin, and Gaffney (1985) studied 56 seventh, eighth, and ninth grade students with LD in public schools, from the western part of the U.S. In their investigation, 95% of the students were reported as being Anglo, and five percent being Hispanic, and Native Americans. The purpose of the study was to determine the effect of three different teaching methods with middle school students with LD, during a science lesson on minerals, based upon (a) hardness level, (b) color, and (c) use. Three groups of participants were randomly assigned to three teaching instructional conditions: (a) mnemonic (i.e., students associating science vocabulary and content to non-related items as an information recall strategy), (b) direct instruction (i.e., systematic instruction on the content directed by the teacher), and (c) free study (i.e., participants study with paper and pencil materials, and content as they chose).

After all three instructional groups completed the study, the researchers found the mnemonic group significantly outperformed both the direct instruction and free study group in all three mineral measures (Scruggs et al., 1985). Furthermore, the researchers also measured how the groups performed on learning mineral attributes, using their assigned instructional strategy, amount of time, and the mineral attributes. The researchers wanted to see how the mnemonic and direct instruction groups would perform on learning minerals' attributes given the same amount of time, but with a different amount of minerals' attributes to learn based on instructional group. The mnemonic group was provided 24 attributes of minerals, compared to the direct instruction, who were given a reduced-list of attributes to learn. The researchers found when the same amount of time was allotted to participants learning and mastering the mineral attributes, those using the mnemonic strategy learned 17 out of 24 attributes compared to the direct instruction participants who were provided a reduced list and were only able to master six out of 12 mineral attributes.

Scruggs and colleagues' (1985) researched a facilitated teaching and learning model on science instruction provided to students with LD. The results from their study show how different teaching and learning instruction models can aid middle school students with LD in learning science content knowledge. Scruggs and colleagues (1985) prefaced the importance of continuing research on instruction modalities, deemed as the most appropriate for SWD, and compared how the instructional models measured to other instructional models like mnemonic instruction.

Traditional science textbooks and the need for change

In many schools across the nation, textbooks are still the gatekeepers for academic content (Bruhn & Hasselbring, 2013). In Bruhn and Hasselbring's (2013) report, the authors discussed the need for textbooks to be developed with accessibility features for SWD, and the importance of making sure the texts are relevant for those from CLD populations and could build on students' prior knowledge. The authors emphasized the importance of promoting a paradigm shift on how textbooks are developed and used in the classroom. One of the many points made was the incorporation of different repertoire features and tools available within digital technology devices and integrating and embedding these tools within textbooks. The researchers indicated when students with LD do not have prior knowledge and interests in the content they are reading, there is an overwhelming possibility the students will not read nor understand the content. Testing students with LD (who are also CLD), who struggled with reading in the content areas, still required the students to read content to take tests, which resulted in indirectly testing their ability to read material rather than comprehend content (Moll, Kunze, Neuhoff, Bruder, & Schulte-Körne, 2014).

Providing Supports for Activating Students' Prior Knowledge

The critical importance of activating background knowledge for all students has been recognized for decades in the general education setting (e.g., Bransford, & Johnson, 1972; Christen, & Murphy, 1991; Holmes, 1983; Neuman, Kaefer, & Pinkham, 2014), and clearly the need for students with LD or students who are CLD to have background knowledge is of the utmost importance. Providing that knowledge in a digital world is still emerging. A recommendation Bruhn and Hasselbring (2013) used for countering the effect of students' limited, prior knowledge or interests in the textbooks were from the world of videos that emerged using anchored instruction. Young and Kulikowich (1992) described anchored instruction as visual imagery, multimedia presentation tools, and real life experiences. Bruhn and Hasselbring (2013) suggested, to activate background knowledge, science content must be engaging and go beyond traditional print materials.

Implementing science, pre-reading comprehension strategies were considered time-laden and not feasible for teachers when it came to creating and providing those strategies to their students on a daily basis (Bakken, Mastropieri, & Scruggs, 1997). Bakken, Mastropieri, and Scruggs (1997) investigated three reading strategies: (a) text-structure-based Strategy, (b) paragraph restatement strategy, and (c) traditional instructional strategy on eighth grade middle school students with LD (N = 54). Of the 54 students in their investigation, three were identified as Latino/a. An Analysis of Variance (ANOVA) was used to analyze the data and report the results.

The purpose of Bakken and colleagues' (1997) study was to see what effects three reading strategies had on students with LD, pertaining to their reading comprehension for expository science reading passages. The dependent measures were taken in three different assessments, including (a) immediate recall (i.e., expected after four days of instruction with teacher), (b) delayed recall (i.e., surprise test on fifth day after the fourth day test), and (c) transfer recall (i.e., same as immediate recall but science content applied to a social studies' passage) for each condition group.

Participants assigned to one of the three reading strategies all received instructions and the same learning materials during the research. The text-structure-based strategy included the coverage and importance of students being able to apply prior knowledge, big idea identification, inferential thinking, teacher led, and independent practice to deconstructing the passages' text structure. In the paragraph restatement strategy, students received, first, teacher led knowledge, followed by independent practice on writing their gathered knowledge from reading the passage. This strategy required students to write out their findings throughout the passage. In the traditional instructional strategy group, the participants were given the passages and instructed to answer the questions after reading the passages (Bakken et al., 1997).

The researchers reported a statistically significant main effect on strategy and on the assessment types among the three condition groups. After post hoc analyses were conducted, the text-structure-based strategy group had higher overall means in all three assessment types: (a) immediate recall (M = 32.83), (b) delayed recall (M = 14.67), and (c) transfer recall (M = 44.33). The paragraph restatement strategy had the next highest means across assessment types: (a) immediate recall (M = 26.00), (b) delayed recall (M = 8.44), and (c) transfer recall (M = 34.94). The traditional instruction strategy group had the lowest overall means scores across assessment types: (a) immediate recall (M = 12.61), (b) delayed recall (M = 1.83), and (c) transfer recall (M = 18.00).

Students reported on their perceptions through a pre-post survey, before and after practicing the science reading strategies they were assigned (Bakken et al., 1997). The pre-post survey results showed the students in the text-structure-based strategy had increased their view on a survey item asking them about reading as something you do to learn (pre-survey results being 72% and post-survey result at 100%). Another survey item asked the participants to indicate what they felt needed to be learned when reading science content with 'main idea' as one of the options they could choose. The survey response option of 'main idea' as being what someone needed to learn when reading science passages went from 33% to 78% for the text-based-strategy group.

Constructing Meaning in Science for Enhancing Prior Knowledge

In order for students with LD to meet the Next Generation Science Standards (NGSS), students need educators to create academic supports focused on students' prior knowledge, incorporating new knowledge, and their ability of constructing meaning, hence content enhancements (CEs; Puttick & Mutch-Jones, 2015). Puttick and Mutch-Jones (2015) reflected, in their article, on a study they had previously conducted using CEs and the effects they had on students with and without disabilities (i.e., LD) in the secondary science classroom units. In their article they discussed the importance of tying the "Big Idea" as the holistic lens students with LD must grasp in order to understand the what, why, and where science content applies to their personal learning.

Puttick and Mutch-Jones (2015) created Content Enhancements (CEs) for addressing science content and making it accessible for all learners. According to the researchers, the implementation of CEs in science units during the study had statistical significance on both students with and without disabilities' academic performances on unit lessons, plus reported high student engagement during intervention. The researchers summarized their article by supporting the use of CEs for enhancing students' learning needs required in the NGSS.

Any time students are required to problem solve in science, they build on their knowledge base by speaking to others and using materials particular to the problem (Krajcik, Blumenfeld, Marx, & Soloway, 1994). In an investigation completed by Dalton, Morocco, Tivnan, and Mead (1997) on science learning models in diverse classrooms across urban and suburban schools, the researchers compared the effects of supported inquiry science (SIS; i.e., students are able to be hands-on and verbally problem solve with others to “unify concepts” for self-understanding), and activity-based science (ABS; e.g., discrete, procedural, communication with peers is prescriptive, and assumed that students understood previous steps), and found SIS groups had higher gains. The researchers also found the SIS groups outperformed the ABS groups in all concept and diagram electricity measure assessments (e.g., simple circuits, conductors, series circuits, and parallel circuits), and the students with LD from diverse backgrounds had higher gain scores than those in the ABS groups.

Students Engagement in Science Lessons

The strength of hands-on lessons is supported by Clough, Berg, and Olson (2009). The authors recommended science lesson plans or content delivery may be represented in a way that does not activate students’ prior knowledge or is not relating to them, which results in undesirable behaviors and academic outcomes (Clough, Berg, & Olson, 2009). When using effective learning materials for students in science inquiry and learning, facilitation and building students’ knowledge base need to be provided in the instructional strategies (Fogleman, McNeill, & Krajcik, 2011). Providing scaffolding supports in science reasoning and building understanding for students’ learning should stem from disciplinary core ideas with the scaffolding supports faded with the ongoing learning process so students may internalize their understanding in scientific problem solving (McNeill, Lizotte, Krajcik, & Marx, 2006). Students often are the victims of constant science reforms and initiatives created as talking points rather than activities that are practical, applicable, and internalized, and reforms do not address science issues in students' daily lives outside of the school settings (Krajcik & Merritt, 2012).

Teachers improving students' learning outcomes in science classrooms has shifted from memorization and non-active learning to hands-on, problem based learning, and teacher facilitated lessons (Yoon & Onchwari, 2006). If science content, materials, general and special education teacher collaboration, and evidence-based practices are in place, students with LD can benefit from problem-based learning (Scruggs, Brigham, & Mastropieri, 2013). A facilitated peer-tutoring model with an adapted differentiated instruction model, as opposed to the traditional delivery of science content, indicated an increase of students' approval and positive results when they had to supply the correct answer (Simpkins, Mastropieri, & Scruggs, 2009). When students with LD and the teaching of science concepts are provided, questioning sessions with a teacher who provides parameters and guidance to the content, students' ability to understand and recall science facts is advanced (Brigham, Scruggs, & Mastropieri, 2011).

Research on the general education students' productivity on science inquiry-based curriculum (i.e., kit-based) has occurred, but few investigations have been conducted on how students with LD performed in science inquiry-based curriculum (Aydeniz, Cihak, Graham, & Retinger, 2012). Aydeniz, Cihak, Graham, and Retinger (2012) included research on why students with LD had difficulties with learning and accessing science content. Aydeniz et al. (2012) added their reasoning to what hindered the students with LD's academic successes in science in conjunction with already existing literature on barriers to science learning. The authors stated the lack of scaffolding supports and the time for students with LD to process the science content prevented success. According to the researchers, this hindrance of non-engaging, practical, and non-relevant science approaches to students with LD learning will have long-lasting, negative effects to how the students view science and their future academia performance.

Digital supports for comprehension

Using technology as a form of instruction for students with LD to strengthen their literacy skills should be evaluated by meeting the individual supports students need to learn (Kennedy, Deshler, & Lloyd, 2015). The state of education has entered the digital age with tools to personalize education, yet a dearth of evidence-based research and classroom interventions have emerged for PK-12 classrooms on combining digital supports for comprehension-based learning (Dalton, Proctor, Uccelli, Mo, & Snow, 2011). In Dalton and colleagues (2011) study, technology was used to provide reading strategies for (a) comprehension, (b) vocabulary, and (c) combination of both for students of CLD backgrounds in activating their background knowledge. Up to 45% of the 106 participants in the study were of a CLD background, and 57% were on free lunch or reduced lunch. The majority of the CLD participants were Latino (n = 21). The researchers indicated learning experiences in the digital realm with animated coaches (e.g., technology imbedded, computer-based avatar characters solely interacting based on the programming of their software) were limited and unable to respond as a human would when interacting with the students. The authors concluded in their discussion section that a need exists for surmountable technology development to create educational technology (e.g., animated coaches) with the ability to respond to students during learning activities, and a pedagogy shift in using such individualized learning supports needed to be pursued.

With a single subject, multiple-probe design, five elementary students ranging from fourth to fifth grade with LD were provided simple electric circuits lessons to measure the effects of activity-based interventions (Aydeniz et al., 2012). During the non-activity-based simple electric circuits lessons, the students overall mean of correct responses to problems was 4.7%. During the intervention phase of the activity-based, simple electric circuits kit lessons, students had an increase overall mean to 76%. The researchers included the Scientific Attitude Inventory (SAI-II) at baseline, and again after the study, to measure the students' attitudes towards science. The students' overall combined SAI-II results indicated a significant increase on the students' attitudes towards science from baseline (M = 96.8) to post intervention (M = 129.2). Aydeniz et al. (2012) concluded their study by emphasizing the benefits students with LD receive when they have scaffolding supports, time to discuss and problem solve with teachers and peers, and are provided differentiated instruction from traditional textbook and worksheet activities.

Universal Design for Learning: Emerging Research for Students with Learning Disabilities

Currently, scholarly studies on universal design for learning (UDL) are emerging, but studies investigating UDL with students with LD and from CLD backgrounds is limited. In an investigation on the use of UDL, the treatment group (UDL with science-embedded, digital notebooks) of fourth grade students (M =.42, SD =.9) performed better on a magnesium and electricity content knowledge assessment than the control group (traditional paper pencil science notebook; M =.01, SD=.9) on the posttest (Rappolt-Schlichtmann et al., 2013). Rappolt-Schlichtmann and colleagues (2013) reported almost 35% of the fourth graders were minority students (i.e., CLD) and 10% were served through an individualized education program (IEP). The researchers also reported on their qualitative investigation on results taken from the students' and teachers' perceptions of using UDL, aligned with digital science notebooks. Both students and teachers reported engagement, excitement, and high interests in the science activities due to the technology aspect of interacting with the learning tasks. Another data point taken in the qualitative results was students reporting their increased confidence in accessing the learning materials and instructions to the activities without having to ask the teacher or misunderstanding what was needed to complete the learning tasks successfully.

Using UDL for the benefit of all learners, including those with a CLD background and from rural communities with high poverty, holds promise (Evans, Williams, King, & Metcalf, 2010). Katz (2013) found students (N = 631) in first to 12th grade, in urban and rural communities who were CLD (with and without disabilities), had significantly higher engagement in the learning activities when teachers used UDL principles. Metcalf, Evans, Flynn, and Williams (2009) found six, second grade students who were provided instruction using the principles of UDL coupled with direct instruction (M = 90.8) in spelling practices and skills outperformed six, second grade students given only direct instruction (M = 55.3). Knowing the emerging evidence and literature on students having unprecedented access to learning materials through digital technology using UDL principles could continue to increase personalized learning for students from diverse backgrounds through UDL (Izzo, 2012).

Research of students from diverse backgrounds, learning through use of non-traditional, digital, and innovative academic content support is emerging (Hall, Cohen, Vue, & Ganley, 2015). Hall and colleagues (2015) found that an online reading program with automated features (e.g., virtual avatar characters appearing on the screen to provide hints and assistance to students) increased reading comprehension compared to offline supports (i.e., traditional paper and pencil learning tasks) for middle school students. The researchers assigned 284 middle school students, ranging from sixth to eighth grade, to either a control (i.e., offline, through traditional paper/pencil tasks monitored and graded by the teacher) or treatment (i.e., online, monitored and graded through the online program) condition. Twelve percent of the students in the study were identified as Hispanic, 48% on free and reduced lunch, and 23% of the students were identified as LD. Among the different research questions asked in the study, one focused on whether digital content and automated features improved students' reading comprehension in curriculum-based measures. The researchers reported students with LD in the treatment condition had statistical significance ($p < .05$) and an increase of 10.4% from pre to posttest scores. The control group results were not statistically significant and had an increase of only 6.58% from their pre and posttest measures. The researchers concluded supporting students with UDL principles increased reading comprehension.

Science textbook and digital enhancement supports.

Many of the difficulties middle school students with LD face having to read science textbooks is that the books do not have features or accessibility supports to aid in a lack of literacy skills (Seifert & Espin, 2012). Seifert and Espin (2012) conducted a study on science textbook reading interventions for 20 secondary students with LD, from five different schools, within close proximity of one another. The purpose of the study was to investigate the effects of interventions on fluency, vocabulary knowledge, and comprehension. The reported ethnic representation percentage for each of the five schools was less than 10%. The researchers found when the participants' vocabulary and fluency were intervened on and assessed, their outcomes improved in their fluency and vocabulary knowledge, but had little effect on increasing reading comprehension scores. Science vocabulary and fluency interventions have been found to help increase students' reading of science text content, but did not enhance reading comprehension (Seifert, & Espin, 2012).

Students with disabilities, and with a range of reading levels, struggle to use their science background knowledge efficiently towards comprehending science texts (Knight, Wood, Spooner, Browder, & O'Brien, 2015). In Knight, Wood, Browder, and O'Brien's (2015) study, the researchers used a multiple probe design to investigate science text comprehension with four middle school SWD (i.e., autism spectrum disorder) using Book Builder (i.e., e-text software) as a digital reading support. Within the study's treatment conditions, explicit instruction with or without book builder was used as the intervention. The researchers found three out of the four participants increased their science content comprehension with explicit instruction. Knight and colleagues (2015) pointed out their study was conducted to explore feasibility, and to see what effects a modified and unmodified version of Book Builder had with students. They also described how participants were engaged in their reading due to having an animated coach embedded in the reading software. The researchers emphasized the need for more studies that explored the effects of embedded supports in virtual learning environments (e.g., animated coaches).

Dalton and colleagues (2011) used the UDL framework to identify how students responded to multiple means of representation and engagement of concepts. In their study, three groups of students were assigned to a strategy group (i.e., receive coaching from teachers and the digital characters), vocabulary group (i.e., receive prior knowledge supports to linking new vocabulary words by making personal connections), or a combination group (i.e., using both strategy and vocabulary) for the study (Dalton et al., 2011). The researchers reported that the students assigned to the vocabulary group ($F_{2, 104} = 8.04$, $p = .001$) outperformed the strategy and combination group. They also found the strategy only group was the lowest performing. In this study the interactive digital characters embedded in the reading program provided only hints and guidance based on students' actions with the software rather than real-time, interactive responses to the students' questions or choices (Dalton et al., 2011). These students provide evidence of the potential for UDL with embedded supports to assist SWD in learning science content.

These studies provide the foundation for further discussion and analyses of the literature related to current performance and how the components of activating background, reading science textbooks, and using UDL principles could enhance learning science. The potential of introducing the novelty of avatars could further expand the comprehension of students with LD and those from CLD backgrounds in rural settings in science.

Mixed-Reality as a Learning Platform

Students with disabilities benefit from well-designed digital tools (i.e., virtual simulation) developed for the purpose of accessing and learning science content, regardless of learning needs (Marino, Tsurusaki, & Basham, 2011). For students with LD, the use of technology and virtual simulation could be a powerful means for accessing content and exploring learning interests rather than using limited and barrier-created, traditional learning materials (Wilson et al., 2011). Although inquiry-based and prior knowledge activities have been researched over several decades, the current technological learning tools developed or being developed bring metacognition and prior knowledge activities for all types of student learners to a different practice outside of the traditional learning materials (White & Frederiksen, 1998). According to Almond et al. (2010) development and research of scaffolds incorporated into digital supports needs further research.

TeachLivE™ mixed-reality avatar.

TeachLivE utilizes an interactive mode of virtual simulation through mixed-reality simulation (i.e., intersection of using both virtual and real world environments as the setting) where an avatar can respond to a person in real time, and be specific to the individual using the simulator during their training (Zhu et al., 2011). Zhu and colleagues (2011) wrote a paper explaining how interactions with virtual reality tools were becoming more mixed-reality based. They indicated how digital technology was advancing at a pace where virtual reality environments using artificial intelligence (AI; i.e., computer or computer programmed with abilities to respond, problem solve, and function as a human would interact) did not provide rapid responses from the digital agents in the system and lacked the abilities of providing detailed and individualized feedback to users in simulators.

The research and development team centered on the TeachLivE lab incorporated the use of AI for the avatar based digital characters, and a human in the loop served as a digital puppeteer who controlled and spoke through an avatar to a user in TeachLivE (Zhu et al., 2011). The researchers believed AI systems were not available or at the capacity to deliver genuine real-time interactions to humans in simulators. According to Zhu and colleagues (2011), a human in the loop within virtual reality simulation could provide an engaging, realistic, authentic, and believable experience for the user. The authors' paper served as a research proposal for the purpose of further developing the learning tool, TeachLivE, towards a mixed-reality tool of AI experiences intertwined with an inter-actor who was able to have the digital avatar express emotion through their movements while interacting with users.

Dieker, Grillo, and Ramlakhan (2012) documented experiences of local students with CLD backgrounds and identified as gifted and talented (N = 108). The purpose of the STEM camp was to expose students of marginalized populations to emerging technologies and to increase their awareness of college and career opportunities in mixed-reality environments. Through the exposure of TeachLivE, the research and development team aimed to increase the participants' self-confidence in STEM-related interests.

The camp provided the students a first-hand experience of mixed-reality simulation. The students were allowed to use the simulator by going behind the scenes of the TeachLivE lab (Dieker et al., 2012). Along with seeing how the lab was structured and run, the students were provided a mentorship on the possibility of future STEM careers and how mixed-reality environments had an impact in everyday use as future industry tools. There was a pre and post survey on the students' knowledge of the acronym 'STEM' and on the professionals and careers related to each section of the acronym. The results of the pre-test reported only 58% of students were able to report one letter in STEM, and only 39% were able to link a career with one of the letters in STEM. After exposure to TeachLivE, through use as a participant and viewing the background of the mixed-reality environment, the students' post survey scores results were reported to indicate 100% of the students knew what each letter in 'STEM' represented. Further results reported 95% of the students were able to describe the education process needed to enter a STEM college and career path. Dieker and colleagues (2012) reported an emerging theme collected from the students on their self-reported desire of having a mixed-reality tool in their class for engaging in science learning activities by their teachers rather than having to use standard textbooks.

TeachLivE is an emerging, educational mixed-reality tool for teaching and learning and needed additional studies to begin exploring its effects as a non-traditional learning space (Dieker, Rodriguez, Lignugaris/Kraft, Hynes, & Hughes, 2014). Use of a mixed-reality avatar provides flexibility to respond in real-time and provide instant feedback for the purpose of building prior knowledge techniques through scaffolding (Dieker et al., 2014). Dieker and colleagues (2014) found individuals who virtually rehearsed (e.g., practicing skills in the mixed-reality environment simulator) in TeachLivE for 10 minutes was equivalent to almost one hour in the real world environment. TeachLivE provides participants skills and concepts generalizable to their learning outcomes (Straub, Dieker, Hughes, & Hynes, 2014). Using TeachLivE as a supplemental tool for the students by receiving a simulated real world experience, coupled with teacher guidance and feedback (Judge, Bobzien, Maydosz, Gear, & Katsioloudis, 2013), could impact learning.

Virtual Environments in Rural Schools

The majority of students in the U.S. struggle in science content areas (Carnine & Carnine, 2004). Students who are LD and CLD (e.g., in rural communities) have further performed at a lower rate (Helman, Calhoon, & Kern, 2015). Students who are CLD and LD in rural settings are assumed to be low performers in science, but the research interventions available to support dualities of this kind is limited at best (Cramer, 2015). The academic issues and challenges SWD from CLD backgrounds in rural communities face are only magnified by the long-standing history of challenges in rural schools. One potential tool that deserves further examination in bringing background knowledge and prior knowledge to students, often isolated from a more global community, is the use of virtual environments. Providing students in the rural settings with virtual experiences may serve as an emerging research construct needed for this population (Vasquez et al., 2015). This push for more efficient online tools is evident for rural settings, and building research for teachers' use of virtual environments for curriculum and instruction is needed (Vasquez & Serianni, 2012). Recently promising empirical research has emerged on addressing special education teachers' needs in rural schools, using virtual environments (i.e., online professional development) to enhance teacher practices (Erickson, Noonan, & McCall, 2012). As researchers in the field conducted studies on the use of virtual environments in the education space, educators have not considered how these environments could be applied or implemented towards instructional delivery or as a learning tool for their SWD in rural communities (Ludlow, 2015).

Virtual avatars have the potential to serve as a supplemental academic support for SWD in rural settings (Zirzow, 2015). TeachLivE's research and development team has put emphasis on their research by looking at the effects and interactions with the simulator in schools in rural communities (Dieker, Hynes, Hughes, Hardin, & Becht, 2015). Dieker, Hynes, Hughes, Hardin, and Becht (2015) listed academic scenarios and situations found in rural communities that may lead to future research to address the pressing needs of SWD and their teachers. How this type of environment might apply to SWD from CLD backgrounds in rural schools is a question to be addressed.

CHAPTER 3: METHODOLOGY

This investigation was conducted to determine the impact of digital technology, coupled with UDL instructionally-designed, digital learning content, designed to have an emphasis on activating prior knowledge for students who are CLD with low reading skills, intentionally intended to be students with learning disabilities (LD), in a rural middle school, on science task performance through discussions with a mixed-reality avatar prior to playing a science video game. In this chapter a synthesis of the research conducted using the methodological components of (a) research design, (b) timeline, (c) research procedures, (d) dependent and independent variables, (e) data collection, and (f) data analyses are presented.

Research Questions

The researcher was guided by the following questions:

(1) What effects does prior knowledge, activated by a virtual avatar, playing the role of a STEM-related professional, have on increasing skills of middle school students with learning disabilities, from culturally and linguistically diverse backgrounds, in video game based science assessments?

(2) What effects does a virtual avatar, playing the role of a STEM-related professional, have on increasing middle school students, who are CLD with learning disabilities, STEM career interests as measured by the STEM-Career Interests Survey?

Participants

Participants were matched to the demographic criteria for this study, making it a convenient sampling procedure (Gall, Gall, & Borg, 2007). Criteria's for the participants were (a) sixth through eighth grade middle school students, (b) served in a monolingual English-only science classroom, and (c) enrolled in the school's 21st Century afterschool program model designated to provide students from low socioeconomic communities academic supports. The target population for the research was students from two, rural middle schools, who are CLD, enrolled in the school's afterschool program.

Settings

The study took place in two, rural middle schools from the same school district, located in the southeast region of the U.S., which serves a large Latino student population qualifying for a free and reduced lunch program. One of the middle schools met the Title 1 designation. Title 1 schools are primarily made up of students who are disadvantaged (e.g. low-income, migratory, limited English language learners, and disabilities) and need additional supports (U.S. DOE, 2004). The other middle school did not meet the Title I designation. The setting for this study was in two, rural middle schools' afterschool programs. The 21st Century afterschool program was created to support students from middle schools in low socioeconomic communities to enhance students' academic outcomes (i.e., math, science, reading, and writing). The students selected were from sixth, seventh, and eighth grades that were enrolled in the afterschool programs.

Research Design:

The research design selected to answer the research questions was a quantitative, quasi-experimental control group design with pretests and posttests. See table 2.

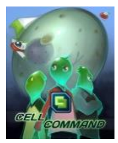
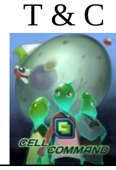
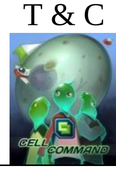
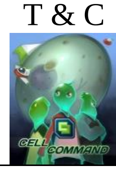
Table 2: Control Group Design

Groups	Pre-test Section 1a	Pre-test Section 1b Pre-STEM-CIS	Cell Game Play/ Section 1b 1	Cell Game Play/ Section 1b 2	Cell Game Play/ Section 1b 3	Cell Game Play/ Section 1b 4	Posttest Section 1a	Posttest Section 1b Post-STEM-CIS
Treatment n= 13	O_1	O_2	With avatar X	With avatar X	With avatar X	With avatar X	O_3	O_4
Control n= 10	O_1	O_2	No Avatar	No Avatar	No Avatar	No Avatar	O_3	O_4

Research timeline.

The duration of the study to provide intervention and measured science learning occurred for approximately 7 weeks of science activities on cells and processes cells go through (Table 3). The researcher began data collection using the web-based, interactive science video game, Cell Command, designed to explore cell structures and processes (https://www.filamentgames.com/cell-structure-and-processes-unit-cell-command; see Figures 1 and 2). The cellular structures and processes were in the life science unit all participants used for the duration of their participation in the study. The science content and material for the study was aligned with the science topics students were expected to learn.

Table 3: Research Data Collection Timeline

Data Collection Sessions		Participants T = Treatment C = Control	Avatar 	Data Collection	Week
Stem-CIS	Pre-Survey	T & C	-	Survey responses	1
Cell Command	Pre-test	T & C	-	Cell Command Game Assessment 1a & 1b	1
Cell Command	Video Game play	T & C 	T 	Diagram activity	2
Cell Command	Video Game play	T & C 	T 	Diagram activity	3
Cell Command	Video Game play	T & C 	T 	Diagram activity	4,5,6
Cell Command	Video Game play	T & C 	T 	Diagram activity	7,8
Cell Command (Oral & Diagram)	Post-test	T & C	-	Cell Command Game Assessment 1a & 1b	8
Stem-CIS	Post-Survey	T & C	-	Survey responses	8

Cell Command image from (http://www.sciencegamecenter.org/games?subject=Middle+School)

Research procedures.

The researcher attained Institutional Review Board (IRB) approval from the university, and approval from the school district where the study took place. Upon approval and collaboration with the district personnel, the respective school personnel were asked to assist with distributing and collecting consent forms. The consent forms contained an outline of the research and grant consent to participate from students and their guardians. Participants who met the study's participant criteria were assigned to either the control or treatment group by matched pairs. To control for threats to validity of treatment diffusion and compensatory rivalry, the control and intervention groups were separated when the treatment group was provided the independent variable.

Afterschool personnel were instructed to attend to students, however they felt was necessary, during the science video game activity. According to both middle school personnel, none of the participants in the study required, through their IEP, that content or materials be read aloud to them.

Dependent variables.

Two dependent variables were investigated in this study: (a) Cell Command video game built-in, performance-based measure assessments (e.g. cell structure diagram, and multiple-choice and opened-ended questions quizzes; see appendix F), and (b) STEM-Career Interest Survey responses (STEM-CIS; see appendix A). Performance-based measure scores assessed were taken directly from the Cell Command video game assessment materials.

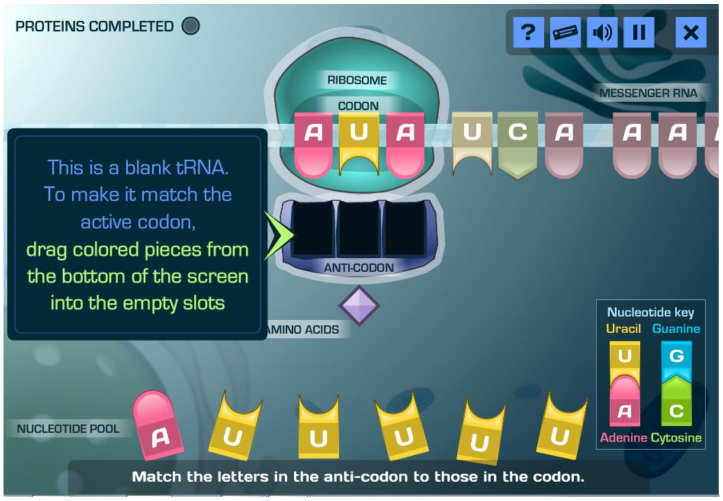


Figure 1: Screen Shot of Game Play

Figure 2: Screen Shot of Game Play

The STEM-CIS is a survey instrument to access students' interests within the fields, represented through each separate letter that makes up the acronym, STEM (i.e., science, technology, engineering, and mathematics). This survey was used to address the second research question. See Appendix A for a copy of the STEM-CIS.

Independent variable.

TeachLivE is a mixed-reality, virtual classroom created by three University of Central Florida faculty members. The characteristics of a TeachLivE avatar can portray a variety of roles and characters, from students to adults, according to the purpose of the virtual simulation experience requested. Mixed-reality simulation can build on learning skills and practices between the mixed-reality avatar and the human practicing their teaching and learning skills through the simulation (Zhu et al., 2011). The participants in this study interacted with a TeachLivE, adult avatar that served the role of a scientist in a STEM-related field and facilitated a conversation with students prior to playing the video game.

The TeachLivE avatar's role was to activate students' background knowledge through a three- to five-minute conversation with the treatment group participants. The avatar attempted to activate the participants' prior knowledge by previewing the material that was assessed for the science video game, Cell Command. The avatar spoke about the title of the video game and three, salient, content features displayed on the video game introduction page. The avatar concluded by asking the students what they believed content of the video game would be about in context to the discussion. The avatar also asked the students how they felt the information might have related to their own personal lives. The avatar's conversations were reciprocal in nature by asking participants open-ended questions pertaining to the content and on how it related to their personal lives and future STEM careers. During those three to five minutes, the avatar also discussed STEM professions and college degrees the participants believed could be tied to their specific video game activity. See Appendix D for the avatar discussion protocol. All interactions followed a script and fidelity of implementation checklist, listed in Appendix K.

TeachLivE Avatar

The independent variable was provided to the treatment group. Participants in the treatment condition interacted with the TeachLivE avatar (see Figure 3) using the protocol provided in Appendix D.

Figure 3: Stacey the TeachLivE Avatar

The TeachLivE (TLE) interactor, who controlled the avatar, portrayed a STEM-related professional in the field of science. The TLE avatar played a STEM-related professional whose discussion was tailored to the video game, life science unit theme of cell structures and processes. The conversations the avatar had with the students in the treatment groups (three groups of five students with each student asked the questions individually while in the group) before they began were highlighted by five open-ended questions: (a) I hear you all are going to play Cell Command. I want each one of you to tell me what you think the video game will be about., (b) What do cells have to do within your life/personal experiences?, (c) What kind of scientists look at cells?, (d) Which colleges do you know of where you can study cells?, and (e)

What degrees do you know of at universities that would involve studying or knowing cells? (See Appendix D). After the fifth question was discussed with each student, the avatar provided input to the group on the college degrees and STEM professions that could be involved in the topic participants were about to play in the video game. The purpose of these questions was to activate the background knowledge of the students prior to their play of Cell Command.

Pretests

A cell structure and cell processes pretest, generated from the Cell Command video game, had two sections: (1a) multiple choice questions (see Appendix F), and (1b) fill-in-the-blank, cell structure diagram were administered to all participants (see Appendix G).

Posttests

At the end of the Cell Command science unit, all groups took the built-in Cell Command video game assessment: (1a) multiple choice quiz (see Appendix F), and (1b) fill-in-the-blank cell structure diagram (see Appendix G).

Control and treatment groups

All students in the after school program in the control and treatment groups spent approximately 25 minutes each day they were engaged in the Cell Command video game for four days of data collection. Cell Command includes game tutorials for players to view and complete before gameplay. Cell Command video game, science performance tasks were conducted for the control group by following a business-as-usual model, related to students being involved by only playing the video game. The researcher followed the Cell Command business-as-usual distribution of video game play for the control group. The researcher had the treatment group involved in the same Cell Command video gameplay as the control group, but prior to gameplay, the treatment group participants spoke to the TeachLivE STEM, professional avatar.

Experimental control.

Participants selected were middle school students, identified as being served with afterschool education supports. Participants were matched in either the control or treatment groups by their latest standardized reading scores. This information was derived from the respective middle school personnel.

Instrumentation

Cell Command is an Institute of Education Sciences (IES), funded video game, played through an interactive website, presenting an array of educational cell structures and cell processes aligned to national science standards in multimedia video game forms. In the Cell Command video game, learning content is accessible with audio and closed captioning, along with tips and hints for students. Students may have their own login identification to access Cell Command. The video game provides task monitoring for the educator (e.g., each time students access the video game, progress monitoring student's online activities within Cell Command) to see how the students have been using Cell Command.

The STEM Career Interest Survey (STEM-CIS; see appendix A), is vetted as a reliably sound instrument that meets the criteria of being a valid psychometric instrument (Kier, Blanchard, Osborne, & Albert, 2014). Kier and colleagues (2014) reported that the STEM-CIS was specifically developed for students from the southeast region of the U.S., and in middle school, to measure their interests in pursuing a STEM-related career. The STEM-CIS contains four STEM categories with 11 questions per category. Students rate questions based on their career interests through a Likert-scale, ranging from strongly disagree to strongly agree, including not applicable. The STEM-CIS was used by the researcher to gather information on middle school students' interests towards pursuing a STEM career (Kier et al., 2014). The reported instrument reliability (Cronbach's alpha) ranged from .72 to .82 across all scales.

Validity.

The performance-based measure used for pretests and posttests were taken directly from the Cell Command video game. For the pretest, students' results were not provided until after they had finished the posttests and STEM-CIS (i.e., data analysis). Withholding of scores occurred to alleviate the participants' exposure to the content before the study began and to ensure a baseline was established before the science unit was introduced.

An integrity of validation training with the TLE avatar was used to measure the validity of prior knowledge activation by the avatar. The TLE interactor, playing the role of Stacey, rehearsed the virtual avatar discussion protocol with TLE research associates (see Appendix D).

Data collection

Fidelity of implementation was conducted for the avatar following the discussion protocol. Inter-observer agreement (IOA) between the researcher and research associate, regarding the avatar meeting the activation of prior knowledge questioning protocol, was set at 90%. The IOA was met at 100% for approximately 18% of data sessions.

Participants' pretests/posttests and mid-point assessment results were permanent products. All items used for these permanent products were collected by the researcher upon student completion. Each performance based measure consisted of items that were scored upon ratio scores (e.g., 4 out of 12 correct). The researcher rated the students' Cell Command assessment 1a and 1b pretests/posttests and performances following the Cell Command assessment answer key (see Appendix I).

Analysis

Three types of data were gathered and analyzed: (a) Cell Command paper and pencil performance assessment's 1a (see Appendix F) and 1b mean scores (see Appendix G), (b) 1b mid-point assessment (see Appendix G) mean scores, and (c) STEM-CIS (see Appendix A) questionnaire results that were scored, and then inputted into SPSS for statistical analyses.

For Research Question 1 on the TLE avatar effect, data analysis was reported for group and individual results through descriptive analysis in SPSS of pretest and posttest, science video game assessment-based measures.

For Research Question 2, using the STEM-CIS (see Appendix A), group and individual participants' pretest and posttest survey responses were analyzed with descriptive statistics in SPSS. The reporting of the mean for both the pretest and posttest responses was analyzed within the four STEM category responses.

Social Validity

Social validity was measured at the end of the study using three questions: (1) What were your thoughts about speaking to an avatar before playing a video game on science? (2) How would you describe playing a video game on science after speaking to an avatar?, and (3) What are your thoughts on using avatars in class?

CHAPTER 4: RESULTS

This research study was conducted to investigate students who are CLD, including those with LD, in rural communities. Participants were provided digital access to science content, through virtual environments, including a Cell Command video game and TeachLivE, a mixed-reality environment. The two dependent variables analyzed were (a) participant's Cell Command video game assessment scores, and (b) participants' STEM Career Interest Survey (STEM-CIS) results. The researcher employed an experimental design to investigate the independent variable of TeachLivE (i.e., a mixed-reality environment) using background knowledge in science content. The two following research questions guided the study:

(1) What effects does prior knowledge, activated by a virtual avatar, playing the role of a STEM-related professional, have on increasing skills of middle school students with learning disabilities, from culturally and linguistically diverse backgrounds, in video game-based, science assessments?

(2) What effects does a virtual avatar, playing the role of a STEM-related professional, have on increasing middle school students' who are CLD, including those with learning disabilities, on their STEM career interests as measured by the STEM-Career Interests Survey?

In this chapter an overview of descriptive statistics of the students who participated in the study is provided, along with the procedures used and the fidelity of implementation. The initial analysis for the research study was a multivariate analysis of covariance (MANCOVA). The research study was affected by differentiated attrition between the control and treatment group, resulting in a pivot of analyzing results from a MANCOVA to descriptive statistics. The differentiated attrition resulted in a smaller sample size at the end of the study and did not meet adequate power to detect statistical differences or significance from not meeting the G*Power analysis suggestion of 34 participants. Furthermore, assumptions of MANCOVA were not met due to the unequal number of participants in the treatment and control group, differentiation with participants' state assessment reading scores across both groups, grade levels, and classification between the two middle schools (i.e., Title I and non-Title I). The researcher specifically examines the statistical analysis for each research question using descriptive statistics.

Instrumentation

In this study, one assessment, composed of two sections (1a [see Appendix F] and 1b [see Appendix G]), served as pretests, four mid-point assessments, and posttests on cell structures and processes. A pre-survey/post-survey questionnaire on STEM career interests (see Appendix A) also was administered. The cell structures and processes assessment was taken directly from the Cell Command video game. The pretest/posttest STEM questionnaire used was a reliable and valid instrument created by researchers in the field. All the assessments and the questionnaire used in the study were paper and pencil based. The researcher took the one Cell Command video game assessment, consisting of two sections: (a) 1a comprised of five multiple choice questions, and (b) 1b, a cell diagram activity with 12 fill-in-the-blank items to identify the different parts within the cell diagram and provided it as two assessment components. The researcher took the one assessment composed of two different sections and used each section for pretest/posttest 1a (i.e., multiple choice questions) and pretest/posttest 1b (i.e., cell diagram activity with 12 blank labels).

Four mid-point assessments were administered (see Appendix G) to the students between all pretests/posttests. The four mid-point assessments were the cell diagram component of the assessment, 1b. For the pretest, 1b, both the treatment and control group students were not provided the word guide. For the mid-point assessments and posttest assessments, all participants were provided the cell diagram guide (see appendix H). The cell diagram guide did not provide hints or indicate where each of the labels went in the cell diagram, but simply defined the term and provided a word bank. Participants throughout the study were not provided any feedback or scoring on their assessment performance.

Scoring across all cell structures, section 1a and 1b pretests/posttests and section 1b mid-point assessments, were rated with a ratio score (i.e., number correct out of number of questions). Pretest/posttest assessments, 1a, were scored with number of questions correct out of five, and pretest/posttest assessments, 1b, were scored by number of blanks filled in correctly out of a possible 12. The pretest/posttest STEM questionnaire consisted of four separate sections, each with 11 questions (i.e., 44 total questions) rated using a Likert scale (see appendix A). The four sections of the STEM questionnaire represented one letter in the STEM acronym (i.e., science, technology, engineering, and mathematics). The 11 questions were rated from 1-strongly disagree, 2-disagree, 3-niether agree or disagree, 4-agree, 5-strongly agree, and N/A- not applicable. The students indicated if they felt they would or would not be successful, pursue a career, or interested in various STEM careers (see Appendix A). The participants' assessment scores were analyzed through a comparison of means, descriptive statistics, and individual analysis for SWD.

Data Analysis Procedures

The statistics software SPSS Statistics (Version 23) was used to input and analyze the participants who completed the study's pretests/posttests and mid-point assessments. Overall, 38 students provided consent to participate in the study. Only 23 students successfully completed the study. A further breakdown of the participants' demographics and attrition rates are provided in the student demographic section of this chapter.

The dependent variable in this study was the Cell Command video game (www.filamentlearning.com/products/cell-structure-and-processes-unit-cell-command) used as the science curriculum for both the control and treatment groups, and the independent variable serving as the treatment condition was a TeachLivE™ mixed-reality avatar named Dr. Stacey Rodriquez. The avatar's role was a STEM-related professional who spoke to students before they played the Cell command video game. The dependent measures for Research Questions 1 were (a) understanding cell processes, and (b) identifying cell parts and functions. Using descriptive statistics, analysis was done of the control and treatment groups' mean scores for each Cell Command assessments (1a and 1b) pretests/posttests and mid-point assessments (1b).

Participant Demographic Information

Both middle schools in the study were located in different rural communities in the southeast region of the United States. The latest, overall school demographic, student population for both middle schools, available at the time of this study, represent the previous school year. One middle school met the designation of Title I (see table 4) and the other middle school was not designated as Title I (see table 5). Despite differences in Title 1 designation, both schools had the same 21st Century afterschool program model created for middle school students in low socioeconomic communities. The afterschool programs in both schools were not only in place to support students from low socioeconomic communities, but also for addressing and creating supports for enhancing students' academic performances due to the schools' low performances on state standardized assessments (e.g., science, math, and reading).

Table 4: Middle School Designated as Title I 2014-2015 Student Demographics

Race/Ethnicity	Female	Male	Percentage %
White	111	122	32.7
Black or African American	95	84	25.1
Hispanic/Latino	135	128	36.9
Asian	Less Than 10	Less Than 10	Less Than 10
Native Hawaiian or Other Pacific Islander	*	*	*
American Indian or Alaska Native	*	**	**
Two or More Races	14	15	4.1
With a Disability	35	74	15.3
Economically Disadvantaged	313	299	85.8
ELL	14	20	4.8
Migrant	44	44	12.3
Female	358		53.3
Male		355	46.7
School Enrollment Total	713		

**No data were reported indicating zero students*
*** Subpopulation less than 10*

Table 5: Middle School Not Designated as Title I 2014-2015 Student Demographics

Race/Ethnicity	Female	Male	Percentage %
White	161	175	47.3
Black or African American	46	64	15.5
Hispanic/Latino	89	110	28.0
Asian	17	24	5.8
Native Hawaiian or Other Pacific Islander	*	*	*
American Indian or Alaska Native	**	*	**
Two or More Races	13	**	3.1
With a Disability	28	65	13.1
Economically Disadvantaged	246	273	73.0
ELL	12	23	4.9
Migrant	**	**	1.7
Female			46.3
Male			53.7
School Enrollment Total	711		

**No data was reported indicating zero students*
*** Subpopulation less than 10*

The middle school that met the Title I designation's afterschool program showed total enrollment as 70 middle school students, and the middle school that did not meet the Title I designation was 53 (see Table 6). Thirty-eight middle school students across both middle schools provided consent to participate in the study.

Table 6: Student Enrollment in After School Programs

Group	Title I	Non-Title I
n	70	53
N= 123		

Due to attrition and student absences, 23 middle school students participated and completed all study components. Participants in the study came from one of two middle schools within the same district (see Table 7). The Participants' race/ethnicity demographics and disability status are included in Table 8. The participants' grade levels and gender are included in Table 9.

Eight participants were from the Title I school (i.e., four sixth graders, three seventh graders, and one eighth grader). Fifteen participants were from the other middle school (i.e., 10 sixth graders, four seventh graders, and one eighth grader). Eighteen students from the middle school designated as Title I returned consent forms to participate in the study. The attrition rate for the middle school that met the Title I designation was over 50%. The researcher was warned by the middle school's personnel that the general student population enrollment would likely drop as the spring semester progressed due to crop seasons and other family work-related moves that affected the student enrollment in the middle school. Three of the students had completed all the pretests and stopped attending the afterschool program for a variety of reasons. Six students returned signed consent forms to participate, but stopped attending the afterschool program before the initial pretests. The middle school that was not designated as Title I had 20 students who provided consent to participate in the study. Fifteen students completed the study. Five students did not complete the study due to attrition, and unlike the middle school that was designated as Title I, reasons for participants' attrition were due to their involvement in their school's extracurricular activities, which conflicted with the study's timeframe.

Table 7: Number of Participants from Each Middle School

Group	Title I	Non-Title I
n	8	15
N= 23		

Table 8: Participants' Race/Ethnicity and Disability Status

Group	Black	Latino/a	White	Two Races	SWD
n	7	8	7	1	1*

** SWD is included in the number of students who are black.*

Table 9: Participants' Grade Levels and Gender

Group	6th Grade	7th Grade	8th Grade	Female	Male
n	14	7	2	14	9

The distribution of participants from both middle schools varied across grade levels (see Table 9) and race/ethnicity (see Table 10). Even with variability across participants, all were enrolled in their afterschool programs due to being identified as struggling learners from low SES backgrounds who could benefit from receiving additional supports outside of the classroom setting.

Table 10: Participants' Race/Ethnicity Broken Down by Group

Group	Black	Latino/a	White	Two or More
Control	2	4	4	0
Treatment	5	5	3	1
N= 23				

Students in the afterschool program received additional educational supports in the academic areas of reading, mathematics, and science. The students' most recent state standardized reading assessment ratings were collected for the purpose of controlling for extraneous variables of reading level (see table 11). Four students did not have reading scores due to being new to the state where the study took place. Students who did not have a state standardized reading score were coded as N/A.

Table 11: Reading Level by Race/Ethnicity

Reading Level	Black	Latino/a	White	Two or More	Total
Control Group					
Mastery Level 5	0	0	0	0	0
Above Satisfactory Level 4	0	0	2	0	2
Satisfactory Level 3	2	2	0	0	4
Below Satisfactory Level 2	0	1	0	0	1
Inadequate Level 1	0	0	0	0	0
Scores Not Available N/A	0	1	2	0	3
Treatment Group					
Mastery Level 5	0	0	0	0	0
Above Satisfactory Level 4	0	2	0	0	2
Satisfactory Level 3	1	0	0	0	1
Below Satisfactory Level 2	1	1	1	0	3
Inadequate Level 1	3	2	1	1	7
Scores Not Available N/A	0	0	1	0	1

N= 23

Research Question #1 Results

To answer the first research question, a Cell Command assessment, with two sections, (i.e., 1a and 1b) was administered to measure the students' knowledge of stem cells and cell processes. Four, mid-point section assessments (i.e., 1b) were collected between the two pretests and two posttests (see Appendix F and G). The participants' reading level and grade level varied across both groups. Although all students in the study were enrolled in their schools' afterschool program, variance in students' abilities were found as participants differed across grade levels and reading levels. This variance was expected with this 21st Century, afterschool program being created for all students with deficits in skill areas. The cell diagram pretest was conducted in an attempt to control for participants' grade and reading levels, prior to being assigned to either the treatment or control groups.

Descriptive statistics were analyzed using SPSS statistical software to report for the two pretests and two posttests across the control and treatment groups.

Group Pretest Cell Command Assessment 1a Descriptive Analysis

Table 12: Descriptive statistics: pretest 1a between the treatment and control group

Dependent Variable: Pretest 1a

Group	Mean	Std. Deviation	N
Control	2.40	1.174	10
Treatment	2.43	1.342	14
Total	2.42	1.248	24

The overall mean for the correct number of multiple choice questions answered correctly, out of five, for the control group was 2.40, (*SD* = 1.17), and the treatment group mean was 2.43 (*SD* = 1.40; see Table 12). The treatment group had a higher mean score for the first pretest than the control group.

Group Posttest Cell Command Assessment 1a Descriptive Analysis

Table 13: Descriptive statistics: Posttest 1a between the treatment and control group

Dependent Variable: Posttest 1a

Group	Mean	Std. Deviation	N
Control	2.70	1.160	10
Treatment	3.15	1.405	13
Total	2.96	1.296	23

The treatment group had a higher overall mean (*M* = 3.15, *SD* = 1.40) than the control group (*M* = 2.70, *SD* = 1.70; see Table 13). The targeted population for the research was students with learning disabilities, but only one student with a learning disability consented and participated in the study. Therefore, the scores of this one participant's results were included in the treatment group's analysis, but then further examined individually to note any variance based upon being identified with a disability. The SWD's pretest 1a and pretest 1b scores both were at zero correct out of the number of questions represented in both assessments. The SWD's posttest score for 1a increased from 0 out of 5 to 4 out of 5, but remained the same between the pretest 1b and posttest 1b on cell diagram (i.e., 0 out of 12). Further examination of the SWD's cell diagram performance was measured four different times during the midpoint assessments and is described later.

Group Pretest Cell Command Assessment 1b Descriptive Analysis

Pretest Cell Command assessment 1b pretest and 1b posttest were analyzed separately, using descriptive statistics to compare across each group's performance with each assessment.

Table 14: Descriptive statistics: pretest 1b between the treatment and control group

Dependent Variable: Pretest 1b

Group	Mean	Std. Deviation	N
Control	1.20	1.398	10
Treatment	.86	1.292	14
Total	1.00	1.319	24

The control group mean for correctly labeling 12 parts in the cell diagram was higher (*M* = 1.20, *SD* = 1.40), than the treatment group (*M* = 0.86, *SD* = 1.30; see Table 14). The results for the posttest assessment 1b (i.e., fill in 12 blank labels on the cell diagram) should be viewed with caution. More than 98% of the participants informed the researcher they did not know what terms or vocabulary words to use to fill in the labels to identify parts within the cell. The Cell Command video game provided a cell diagram guide that included 12 terms and the corresponding definitions without providing hints or answers to where they go in the diagram activity (see Appendix H). For baseline purposes, the researcher withheld the cell diagram guide for pretest assessment 1b to measure participants' knowledge of the parts of a cell prior to the study. The researcher analyzed all participants' preliminary results after they completed pretest assessment 1b and decided to provide the word guide for all future assessments, midpoint and pretest, for both the experimental and control group.

Group Posttest Cell Command Assessment 1b Descriptive Analysis

In the posttest assessment 1b, descriptive statistics for the control group suggested a higher mean score (*M* = 6.70, *SD* = 3.10) than the treatment group (*M* = 3.59, *SD* = 3.15; see Table 15).

Table 15: Descriptive statistics: posttest section 1b between the treatment and control group

Dependent Variable: Posttest 1b

Group	Mean	Std. Deviation	N
Control	6.70	3.093	10
Treatment	3.69	2.594	13
Total	5.00	3.148	23

Group Pretest/Posttest Assessments 1a and 1b

Table 16: Descriptive Statistics: Pretest/Posttests Assessment 1a & 1b

	Group	Mean	Std. Deviation	N
Pre#1	Control	2.40	1.174	10
	Treatment	2.38	1.387	13
	Total	2.39	1.270	23
Post#1	Control	2.70	1.160	10
	Treatment	3.15	1.405	13
	Total	2.96	1.296	23
Pre#2	Control	1.20	1.398	10
	Treatment	.69	1.182	13
	Total	.91	1.276	23
Post#2	Control	6.70	3.093	10
	Treatment	3.69	2.594	13
	Total	5.00	3.148	23

The control group had a higher mean posttest score posttest (*M* = 6.70, *SD* = 3.10) than the treatment group (*M* = 3.69, *SD* = 2.60: see table 16).

Group Cell Command Mid-Point Assessment 1b Analysis

The four mid-point assessments were the same diagram activity as the pretest/posttest assessment 1b. After pretest assessment 1b, all students across both groups during the cell diagram activities were provided the cell structure diagram guide (see appendix H). Descriptive statistics were analyzed in SPSS on the four, mid-point assessment's 1b.

Group Assessment 1b Mid-Point Assessment Descriptive Analysis

Table 17: Descriptive Statistics: Mid-Point Assessment's 1b between control and treatment groups

	Group	Mean	Std. Deviation	N
R1	Control	5.50	3.136	10
	Treatment	3.79	2.225	14*
	Total	4.50	2.719	24
R2	Control	6.10	3.247	10
	Treatment	4.07	2.731	14*
	Total	4.92	3.063	24
R3	Control	5.80	2.936	10
	Treatment	5.57	4.201	14*
	Total	5.67	3.655	24
R4	Control	7.70	3.889	10
	Treatment	7.36	4.413	14*
	Total	7.50	4.118	24

** There were 14 participants in treatment condition during mid-point assessments.*

Both the control and treatment groups' means increased with each ensuing mid-point assessment (see Table 17), but the control group had higher mean scores across each mid-point assessment (see Table 18).

Table 18: Cell Diagram Midpoint Assessments 1b Means Across groups

Group	Midpoint 1	Midpoint 2	Midpoint 3	Midpoint 4	Mean
Control	5.5	6.1	5.8	7.7	6.2
Treatment	3.8	4.1	5.6	7.4	5.2

Note. All participants were provided cell diagram guide during all four midpoints.

For the one SWD midpoint assessments 1b; midpoint 1 and 2 were 1 out of 12, midpoint 3 score was 3 out of 12, and midpoint 4 was 2 out of 12.

Research Question #2 STEM-CIS Results Descriptive Statistics

For the second research question, descriptive statistics were used to report the findings. The question posed was: What effects does a virtual avatar, playing the role of a STEM-related professional, have on increasing middle school students', who are CLD, including a student with learning disabilities, interests in STEM careers, as measured by the STEM-Career Interests Survey?

In the STEM-CIS there are four sections, each representing a letter in the STEM acronym (i.e., Science, Technology, Engineering, and Mathematics). For each section there were 11 Likert scale questions, ranging from one to five (see appendix A). Participants had the option to respond with a N/A (i.e., Not Applicable) across all four sections. The N/A response received no score.

The highest overall STEM-CIS sum possible was 220 if participants responded with the five rating of strongly agreed to all questions within the four STEM sections. The lowest possible score across all sections was zero. The higher scaled score ratings represented students that either agreed or strongly agreed they would have positive outcomes in regards to the set of 11 questions asked, according to each acronym letter represented in STEM. The STEM-CIS pretest sum mean across all groups was 140.60 (*SD* = 24.83), and the overall STEM-CIS posttest sum mean was 133.00 (*SD* = 30.88). The control group's STEM-CIS pretest sum mean was 134.80 (*SD* = 26.16), and the control group posttest sum mean was 137.60 (*SD* = 29.00). The treatment group's overall STEM-CIS pretest sum mean was 145.07 (*SD* = 24.00), and the posttest sum mean was 129.50 (*SD* = 33.00; see Table 19 for STEM-CIS sum means).

Table 19: STEM-CIS Sum Means Descriptive Statistics

	Group	Mean	Std. Deviation	N
Pre_STEM_Sum	Control	134.8000	26.16104	10
	Treatment	145.0769	23.81338	13
	Total	140.6087	24.82803	23
Post_STEM_Sum	Control	137.6000	28.94132	10
	Treatment	129.4615	32.98893	13
	Total	133.0000	30.87512	23

The STEM-CIS sum means were analyzed through the variable "race/ethnicity," using descriptive statistics on SPSS. The study targeted participants in middle schools from rural communities who were enrolled in an afterschool program, specifically, but not limited to, SWD who are CLD (i.e., Latino/a). All students enrolled in the afterschool program that provided consent to participate were included in the study. Participants and their identified race were included in the descriptive analyses due to the researcher's attempt to provide further empirical research for SWD who are CLD (see Table 20).

Table 20: STEM-CIS Sum Mean Scores across Race

Race	Pre STEM-CIS Sum Mean		Post STEM-CIS Sum Mean	
	Control	Treatment	Control	Treatment
Black	132.50	142.75	133.50	127.00
Latino/a	120.00	148.20	136.25	134.60
White	150.00	146.00	141.00	118.00
Two Races	*	136.00	*	118.00

* No participant identified in the respective race category

Participants' Individual Pre/Posttest 1a and 1b Assessments and STEM-CIS Results

Table 21: Students Pretest and Posttest Performances

Students	**Race/ Ethnicity**	**Pretest 1a**	**Posttest 1a**	**Pretest 1b**	**Posttest 1b**	**Pre STEM-CIS**	**Post STEM-CIS**
Non-Title I Control Group							
Sixth Grade Female	L	2/5	1/5	0/12	3/12	141	136
Sixth Grade Female	B	3/5	2/5	2/12	7/12	137	176
Sixth Grade Female	L	2/5	3/5	1/12	9/12	124	133
Sixth Grade Female	W	2/5	4/5	3/12	10/12	112	107
Sixth Grade Female	W	4/5	3/5	0/12	2/12	83	112
Sixth Grade Male	W	4/5	4/5	3/12	12/12	177	130
Seventh Grade Female	W	2/5	1/5	3/12	7/12	163	173
Seventh Grade Male	L	2/5	2/5	0/12	5/12	148	154
Non-Title I Treatment Group							
Sixth Grade Female	B	3/5	0/5	1/12	2/12	159	145
Sixth Grade Female	L	2/5	4/5	3/12	7/12	157	151
Sixth Grade Male	W	5/5	5/5	3/12	8/12	133	136
Sixth Grade	L	3/5	4/5	2/12	4/12	178	183

Students	Race/ Ethnicity	Pretest 1a	Posttest 1a	Pretest 1b	Posttest 1b	Pre STEM-CIS	Post STEM-CIS
Male							
Seventh Grade Female	B	2/5	4/5	0/12	7/12	100	85
Seventh Grade Male	L	1/5	3/5	0/12	3/12	116	63
Eighth Grade Female	L	1/5	4/5	0/12	4/12	117	107
Title I Control Group							
Sixth Grade Female	B	3/5	3/5	0/12	5/12	128	91
Seventh Grade Female	L	0/5	4/5	0/12	7/12	135	164
Title I Treatment Group							
Sixth Grade Female	B	1/5	3/5	0/12	5/12	161	123
Sixth Grade Female	W	3/5	1/5	0/12	3/12	140	131
Sixth Grade Female	L	4/5	4/5	0/12	0/12	173	169
*Seventh Grade Male	B	0/5	4/5	0/12	0/12	151	155
Seventh Grade Male	W	3/5	3/5	0/12	1/12	165	117
Eighth Grade Male	TW	3/5	2/5	0/12	4/12	136	118

Note. B-Black, L-Latino, W-White, and TW-Two or more races
Pretest and Posttest 1a scored by number correct out of 5
Pretest and Posttest 1b scored by number correct out of 12
STEM-CIS score range 0-220
* Student with a learning disability

The participants' individual scores are provided to show their performances in the section 1a and 2b, and STEM-CIS pretest/posttest results, in table 21. Seven of the participants scored lower in their section 1a posttest from their pretest results. Two students did not increase their scores from the section 1b pretest to the 1b posttest in the Title I treatment group. One of the students that did not increase from the 1b pretest to the 1b posttest was the student with a LD, and a female student who is Latina in the sixth grade.

Participants' Individual Mid-Point Assessment Results

Table 22: Students' Mid-point Assessment Results

Students	Race/ Ethnicity	Mid-Point 1	Mid-Point 2	Mid-Point 3	Mid-Point 4
Non-Title I Control Group					
Sixth Grade Female	L	3/12	2/12	3/12	**
Sixth Grade Female	B	5/12	4/12	4/12	**
Sixth Grade Female	L	8/12	9/12	7/12	9/12
Sixth Grade Female	W	10/12	8/12	9/12	8/12
Sixth Grade Female	L	4/12	7/12	3/12	3/12
Sixth Grade Male	W	10/12	12/12	12/12	10/12
Seventh Grade Female	W	1/12	2/12	6/12	1/12
Seventh Grade Male	L	6/12	4/12	3/12	6/12
Non-Title I Treatment Group					
Sixth Grade Female	B	3/12	1/12	**	**
Sixth Grade Female	L	2/12	2/12	**	**
Sixth Grade Male	W	8/12	8/12	8/12	8/12
Sixth Grade Male	L	6/12	7/12	10/12	**
Seventh Grade Female	B	6/12	7/12	6/12	8/12
Seventh Grade Male	L	2/12	5/12	2/12	5/12
Eighth Grade Female	L	1/12	1/12	2/12	**
Title I Control Group					
Sixth Grade Female	B	2/12	5/12	5/12	6/12
Seventh Grade Female	L	6/12	8/12	6/12	8/12
Title I Treatment Group					
Sixth Grade Female	B	2/12	4/12	3/12	4/12
Sixth Grade Female	W	4/12	5/12	1/12	3/12
Sixth Grade Female	L	5/12	8/12	8/12	10/12
*Seventh Grade Male	B	1/12	1/12	3/12	2/12
Seventh Grade Male	W	2/12	1/12	1/12	1/12
Eighth Grade Male	TW	5/12	2/12	3/12	4/12

Note. B-Black, L-Latino, W-White, and TW-Two or more races
Mid-point 1b scored by number correct out of 12
* Student with a disability
** No data

Participants' mid-point assessments were provided to show how they performed between their pretest and posttest section 1b assessments. See table 22. All students were able to at least identify two or more cell parts in the cell diagram compared to their groups' mean scores in the section 1b pretest.

Science Content through a Video Game

The students were eager to start the study, and after the first time students in both groups played the video game, many had requested if they could continue playing the game at home or during school. The researcher informed the students that for the purpose of the study, participants' individual login username and password were only available at the time of the study and only the researcher could log them into the game. Each individual data collection session was conducted on separate days for each participant; this was due to the sporadic attendance. During the Cell Command video gameplay students would rarely speak to each other unless it was related to the video game. After school personnel had commented to each other how they were impressed by the students' interest in the game and how it kept them from being disruptive. Few students asked questions to the researcher while they were playing the game on how to maneuver or manipulate items in the game. With ongoing data collection, students progressed in the video game stages and would ask the researcher for help on the directions of the game and not about the purpose or content of the game (e.g., "I keep clicking it and it won't move"). Students who had already played a stage that other students were asking questions about would either ask if those students if they could show them what they needed to do, or they would direct, out loud, what the student should do to pass the stage. Across both groups, students asked the researcher if they could replay stages they passed but wanted to score better on.

The students enrolled in the middle school designated as Title I had played the videogame on an individual, tabletop computer connected to the internet through an internet cable and already equipped with headphones. Students were able to log in to the computers with their own school log in accounts. At times, some of the computers would freeze or take more than five minutes to log in. When this took place, students would move to the next computer and log on. The one student with a LD in the study was enrolled in the middle school designated as Title I and in the treatment group. The student with a LD would, each day of data collection, ask the researcher if he would be able to play the video game and if he could ask the avatar different questions.

Students enrolled in the non-Title I school each used the school's Google Chromebooks (i.e., laptop computer). Students were allowed to bring in their own headphones and some preferred to not to use headphones during gameplay and instead listened through the Google Chromebook speakers. There were no connectivity issues with the Wi-Fi connection and access to the video game. Students responses were similar to the students enrolled in the middle school designated as Title I, with requests to play at home or school. During gameplay students rarely asked questions on how to maneuver or play in a new stage within the videogame.

Discussions with a Virtual Avatar

The researcher informed the participants in the treatment group their discussion sessions with the avatar were not ongoing from previous sessions. Participants were informed that each session would be the first time for the avatar to meet the students. This was in an attempt for students to revisit information and discussions with the avatar for the purpose of using background knowledge from previous sessions. Students in the treatment group, during their initial discussion with the avatar, were asking each other questions on how the avatar could see them and if it was a robot, real person, artificial intelligence, or a computer program. Students would direct those same questions to the researcher. After the initial session, students were engaged in conversation with each other in their group on how the avatar was so real and able to see them and respond to them like the avatar did. They also spoke about questions they were going to ask the avatar for the pursuing discussion session. Some students had mentioned asking the avatar if they can tell the future, how the avatar was created, and if it can really see them or if someone was typing in the avatar's responses instantly.

In the pursuing discussion sessions with the avatar, students would respond to the questions (see Appendix D) the avatar was asking by providing answers that corresponded to the questions. If students were not providing an answer or indicated that they did not know how to answer, the avatar would provide an example. After each discussion session, students responded either using responses the avatar provided as examples from previous sessions or used their own unique response. By the last discussion session, students were answering the avatar without the avatar having to provide them examples based on the questions.

The student with a LD, during the first two sessions, would respond to the avatar by indicating they did not know what to say to the questions. By the last two sessions, the student was able to provide examples and responses to the avatar's questions. The student's responses were a combination of peers' responses in their group, avatar examples, content in the video game, and personal reflection in tying in sports throughout the different questions the avatar asked.

Reliability of Scores

The assessments were all permanent products and did not require interrater reliability due to the nature of the assessments' response being either multiple choice or fill-in-the-blank. The Cell Command teacher materials included the answer key for the assessment 1a and 1b (see Appendix H). Pretest/Posttest assessment section 1a comprised of five multiple choice questions with one of the four possible responses corresponding as the correct answer. Pretest/Posttest assessment's 1b comprised of a cell diagram with 12 parts of the cell, with blank labels next to each part, to be identified by the students. If students used the same label name for different parts and one was labeled correctly, the response was not counted as correct.

Fidelity of Implementation

Fidelity of implementation was conducted to ensure the avatar's interactions were consistent for each session (see Appendix K). A research associate rated the avatar's discussions with participants in the treatment group prior to playing Cell Command. The research associate was provided a scripted checklist, consisting of a set of questions to be asked by the avatar, prior to the treatment group's game play. The avatar asked questions to groups of up to five students. The questions were scripted by the researcher and structured as open-ended questions, with the purpose of activating students' prior knowledge, before they began their science curriculum unit lesson of cell structures and process through playing the Cell Command video game. The inter-rater reliability between the research associate and researcher on the avatar's discussion checklist was at rated at 100% for approximately 18% of sessions.

Social Validity Questions

Social validity was measured at the end of the study using three questions for the students in the treatment group: (1) What were your thoughts about speaking to an avatar before playing a video game on science? (2) How would you describe playing a video game on science after speaking to an avatar?, and (3) What are your thoughts on using avatars in class? Students in the treatment groups who met the TLE avatar, Stacey, were vocal during their first interaction with her. Students would ask Stacey questions that did not pertain to the video game or STEM-related fields. Students asked the researcher numerous times during discussions with Stacey if she was real or a computer program. Students asked the researcher a variety of questions before they began their Cell Command video game play. Many of the discussions after the video game were with the teacher, peers, or questions to the researcher on what they will ask Stacey the next time they speak to her. Student social validity responses of speaking to a mixed-reality avatar and playing a video game, varied from saying it was neat to weird (see Table 23 for a summary of the student's comments).

Table 23: Participants' Social Validity Responses from the Experimental Group

Participant	What were your thoughts about speaking to an avatar before playing a video game on science?	How would you describe playing a video game on science after speaking to an avatar?	What are your thoughts on using avatars in class?
8th Grade Female	I think the lady looks like a beaver.	The video game was hard.	The avatars were creepy
7th Grade Male	It was weird.	I don't know.	It is kind of weird in so many ways
6th Grade Female	She was nice.	It was a little hard.	It would be fun.
6th Grade Female	It was cool	I don't know.	It would be easier to tell like a study buddy.
7th Grade Male	I thought it was weird because she looked so fake but sounded so real.	I thought it was cool.	I think they are helpful for realizing if people are paying attention.
6th Grade Male	I like it because it is cool and makes me want to play it.	It makes me think of what we spoke about.	I think that will be good because.
7th Grade Female	I was nervous.	I understood more, so I was less nervous.	It would be a fun experience and I think it will help kids a lot.
6th Grade Female	My thoughts were that science we kinda get to tell what we know, what the game might know about it.	After talking to the avatar, and then playing, I would say that it gave me a hint of what I was playing.	It was pretty neat.
Note. The one student with a disability did not provide responses to the questions			

Summary of Results and Analysis

The participants across both groups' mean scores, from pretest to posttest and mid-point assessments for research question one, increased. However, the difference between both groups varied between the control and treatment groups, particularly with cell diagram activity used for the pretest/posttest 1b and mid-point assessments. The control group outperformed the treatment group from the initial pretest through the mid-point assessments to the posttest. The result for the STEM-CIS did not vary either, but the control group had higher sum means for the pre-STEM–CIS and post-STEM-CIS compared to the treatment groups' results. The control group's results from the study tended to be slightly higher across almost all measures taken compared to the treatment group. This may have been a result of the variation across both groups' settings and environmental factors during sessions.

The results of the assessments may have been affected by differentiated attrition and extraneous variables. The differentiated attrition occurred between the two groups that were grouped by grade level and reading level. At the conclusion of the study the control group had more students who were rated at the state assessment rating of satisfactory and above satisfactory compared to the majority of the treatment group's level at the below satisfactory or inadequate level. Both groups were matched with equal numbers of participants, representing the different reading levels in the control and treatment groups, with few participants in both groups who did not have their reading levels available for grouping purposes.

CHAPTER 5: DISCUSSION

Students who are culturally and linguistically diverse (CLD), specifically Latino/a, lack STEM-related degrees (Lu, 2015; Simpkins, Price, & Garcia, 2015), and students with disabilities are underrepresented in STEM fields (NSF, 2014). Historically, empirical research on students with disabilities (SWD) who are CLD (i.e., Latino/a) in academic content has been minimal (Cramer, 2015; Evans, 1974; Scruggs, Mastropieri, Berkeley, & Graetz, 2010; Vasquez et al., 2011). A need for empirical research on SWD who are CLD has to take in consideration the importance of students' culture (Artiles et al., 2010).

In this chapter, a summary is provided of the challenges of recruiting an adequate number of students to participate in the research study that are CLD with a learning disability (LD) from rural communities, with large, migrant farming populations, paired with a discussion of the findings from this study. The discussion is embedded in the potential use of mixed-reality based technology to support science instruction in rural communities. The findings of the study are re-examined through a discussion of the implications of the study for students who are CLD and who have an identified LD. The limitations to the study are discussed along with the impact of the transient nature of students who are CLD in rural communities, which was found to have a direct impact in the research study. The chapter concludes with recommendations for future research to better support the science instruction of students who are CLD with a LD.

Purpose of the Study

The researcher conducted this study to identify the effects of a mixed-reality, virtual avatar to activate prior knowledge for students who are CLD with a LD, who live in rural communities. The following questions guided the researcher in the study.

(1) What effects does prior knowledge, activated by a virtual avatar, playing the role of a STEM-related professional, have on increasing the skills of middle school students with learning disabilities, from culturally and linguistically diverse backgrounds, in video game-based science assessments?

(2) What effects does a virtual avatar, playing the role of a STEM-related professional have on increasing middle school students', who are CLD with learning disabilities, STEM career interests as measured by the STEM-Career Interests Survey?

To answer the first research question, quantitative data were collected, using the students' performance scores on Cell Command's assessments and diagram activities. The scores were taken at pretest and posttest. To answer the second research question, students completed the STEM Career Interest Survey (STEM-CIS). The STEM-CIS questions were based on a Likert scale and included 11 questions per STEM acronym letter. The STEM-CIS was provided to the students as a pretest and posttest measure. A control group design was conducted to measure the differences between students who were assigned to the control group, compared to those assigned to the treatment group. The students who were assigned to the control group only played the video game and did not meet the TeachLivE, adult avatar. Students who were in the treatment group played the video game and also received the intervention of speaking to the TeachLivE avatar, which was a STEM-related professional, prior to playing the video game.

The researcher attempted to recruit over 50 participants at the initial middle school, originally selected as the one research site for the study. A G*Power analysis was ran, and the suggested adequate number of participants was N = 34. The researcher attempted to oversample the G*Power analysis of 34 participants and recruited all students enrolled in the afterschool program, during the recruitment stages of the research study. There were only eight students who completed the study and the researcher included a second middle school that only had 15 participants complete the study. G*Power analysis suggestion was not met, and the researcher did not compare the means across both groups due to the concern the statistical analysis would be compromised and inadequate to report. Descriptive statistics were provided to display the results of the groups' means and the students' individual performances on the dependent variables.

Summary of the Study

The study took place in two middle schools, located in different rural communities, under the same school district. Both middle schools had a 21st Century afterschool program in place for the purpose of serving students who needed additional academic supports (e.g., struggling leaners in reading, math, and science) from low socioeconomic communities. The middle schools both served a large SWD and Latino/a population. One middle school was designated as a Title I school. Prior to the start of the study, both middle schools indicated they had SWD, specifically LD, who were CLD and attended the afterschool program. Despite recruitment efforts for participants for the targeted population of this investigation, only one participant across both middle schools was identified as having LD. The students who were CLD and enrolled in the afterschool programs were present, but did not participate at the rate expected due to a variety of reasons to be discussed. Specifically, attaining consent from this population of students seemed elusive despite all attempts from the researcher who himself is a Latino male and provided opportunities to talk with participants in English and Spanish. Recruiting and attaining individuals who are Latino/a and from low socioeconomic communities for scientific research has been an issue due to the lack of the individuals willing or able to provide consent to participate in a study (Habibi, Sarkissian, Gomez, & Ilari, 2015). The researcher's efforts of recruiting and attaining a population of SWD, who were CLD, from a low, socioeconomic community in an afterschool program, became a limiting factor to address the proposed research questions. Yet, the importance of looking at the potential of research for this population is critical with a current lack of research on SWD who are CLD from rural communities.

A Pivot in Research Design and Analysis

This study was originally proposed to be a repeated measures multivariate analysis of covariance (MANCOVA). As the study went underway, recruitment of students to participate, combined with attrition rates, meant meeting the G*Power analysis recommendations was not attainable and did not have sufficient power to report results. The overall number of participants reported at the conclusion of the study was not generalizable nor did the number of participants who completed the study meet the assumptions for analyzing the data using a MANCOVA. The researcher, instead, used descriptive analysis to report the control and treatment groups' results, and the individual participants' results. The disaggregation of the data provided results of individual performances in the study. Although this study did not meet the recommended research criteria for generalizability, the results provide a snapshot of the participants from different racial/ethnicity, gender, grade, and group assignment.

Crop Seasons and Students' Enrollment

The enrollment of the students in this study in the middle school after school program, who were CLD from rural communities, were reported by staff to be impacted due to their parents or guardians being migrant farm workers. School personnel explained the sudden large drop in students' attendance being due to the fact of an early crop season in the North as a result of an unseasonably warm, early spring. School personnel indicated many of the students in their school that enrolled in the after school program, came from migrant farming households. Levy (2011) noted students whose families are migrant farm workers often miss or move from their schools due to their family moving to different regions following the changing, crop seasons. Levy (2011) reiterated students from migrant, farming families may lack the educational supports and needs and, at times, may be considered migrant farm workers but not migrate to find work, but remain in their community. The sudden drop in attendance and ability to gain a large population of students as intended may have been attributed to students joining their families for farm work (Azano & Stewart, 2015).

Perceptions of Virtual Learning Tools in the Afterschool Setting

This study was proposed to take place in the afterschool programs for SWD from CLD backgrounds in a rural community to offer enriching academic supports outside of the classroom. The variable of early movement and lack of attendance in school or afterschool programing was not a variable realized until the study was well underway in this district. Despite these confounding variables, an investigation of the effects of virtual learning tools in science content, through both a mixed-reality virtual avatar and an online video game, were explored with the students available to participate. The research on using video games in a school setting is not novel in the field of education or literature, but could be a novelty for students with limited or sporadic education, like students from migrant families. Levy (2011) reiterated how students who are Latino/a with migrant, farming backgrounds lack access to technology, which may be beneficial to meeting their educational needs. Even if students from rural communities have access to technology devices in or outside of their school settings, the access to online connectivity are usually weak or hard to establish in schools in rural communities (Bice-Urbach & Kratochwill, 2016). This lack of connectivity to even use a basic cell phone was an issue noted by the researcher in the rural communities where this study occurred. Despite the common use of technology cited in the literature (Zheng, Warschauer, Lin, & Chang, 2016), the lack of access was an issue observed by the researcher and noted by both teachers and students in the district.

Climate of Afterschool Program

A common concern in a rural setting is the availability of teachers and support personnel who are highly qualified or have access to state-of-the-art professional development, as well as technology access (Vasquez & Serianni, 2012). It is important to note, in the initial meeting between the afterschool staff (i.e., worked directly with the students) and the researcher, the afterschool staff were not present. The researcher met with the district and school personnel who did not facilitate the afterschool programs or work with the students in the afterschool setting at the time of the study. When the study was underway, the researcher met the staff that worked with the students in the afterschool program for the first time. The afterschool personnel were not able to provide input on the logistics of the study before the study was underway. This variable was due to the rotating afterschool staff, serving in different roles within the school district during the meetings. Like many schools in the rural setting, at times, the afterschool program was understaffed and the afterschool leaders had to serve additional roles outside of the afterschool setting. This reality of roles is often the case for staff in rural middle schools across the nation, who serve various roles within the school district (Fishman, 2015).

When initial contact was made with the respective school district personnel on conducting the study, many questions were asked about the mixed-virtual avatar, yet no questions were asked about the video game. The same reaction was observed in the students during the recruitment period. Many of the students asked questions about what the avatar could or could not do. The majority of the students who were present when the researcher spoke to the group about the study had indicated to the researcher (i.e., researcher asked students to raise hands for recruitment materials to participate) they wanted to receive the recruitment letter and consent forms to participate. During those recruitment visits, students repeatedly asked other questions on how soon they could begin the study and to ensure they could participate if they provided signed consent forms. At times the researcher spoke to the students, some of the afterschool personnel said in front of the students, “Many of the students do not follow through on commitments and will lose the materials before they get home.” The other leaders in the afterschool program did not make similar comments and even asked the researcher, in front of the students, if all of them could participate if they provided the consent. Levy (2011) noted that students who are Latino/a from rural low socioeconomic communities are too often labeled or stereotyped as deficient or inadequate to properly follow or meet school demands by school personnel. The school personnel perceptions of the SWD who are CLD, especially in low socioeconomic communities, can have a negative impact on the students' expectations and academic outcomes.

A major concern for the researcher in this study was the teachers' positive perceptions of using video games for students' learning, and the teachers' perceptions not being studied through empirical research (Marino et al., 2013). With the use of video games, one of the issues to be considered is how the afterschool personnel perceived the use of educational video games. Educational video games in school settings have gained support to deliver academic content in some capacities (Annetta et al., 2013). However, the researcher's understanding in this study was that the use of a digital, mixed-reality avatar in the after school environment was the first of its kind, especially in this rural community.

Once the study began and the TLE avatar began speaking to the students, some of the afterschool staff made comments at different times to the students or to other staff members regarding the avatar and technology, including never being able to do what a teacher does, or how they know the students will get bored soon. These comments may have set a negative tone for the participants, being that they were in the room as these comments were made. The same afterschool personnel also provided unsolicited explanations out loud on the setup of TeachLivE, to the students, during their interactions with the avatar. At times the afterschool staff would interrupt the discussions between the students and avatar and provide the answers to the students or tell them that they should have known the response to provide to the avatar. Students with disabilities and CLD are oftentimes in school settings where educators are novice at incorporating digital technology as a supplemental learning support (Musti-Rao, Cartledge, Bennett, & Council, 2015).

Innovative Technology in the Afterschool Programs

If research with innovative technology (e.g., tools, software, devices, or virtual avatar) is conducted in an educational setting, the introduction of the technology to all district and school personnel prior to the study is important. Teachers and school personnel also benefit when they are provided technology tools to enhance their own instructional practices (Erickson, Noonan, & McCall, 2012). School personnel also may need to experience the technology themselves as an introduction to what the student in the study will experience. Prior experience of the staff may have helped with recruitment and would have provided a frame of reference or perspective to how and why the technology was being used in the study to impact student learning. If teachers are provided further professional development and supports to implementing virtual environments in their practices, they may realize the benefits of using the technology as a supplemental learning tool (Ludlow, 2015). This process can especially be beneficial when the technology is cutting edge to the point of being new to the K-12 classrooms or a new experience by the educators who serve the students.

There has been concern for how teachers are provided or prepared on serving students with a UDL framework, coupled with 21st century digital technology (Benton-Borghi, 2013). Cutting edge technologies, through virtual simulation (i.e., virtual avatars), have been used regularly and updated to enhance military training (Billings, 2012). Much like the up-to-date practices used by the military of utilizing the power of virtual simulation, the field of special education and teacher preparation and professional development may need to create supports to meet the needs of providing educator's up-to-date technologies tools and supports in rural schools (Dieker, Hynes, Hughes, Hardin, & Becht, 2015). Providing SWD virtual learning tools as a means of accessing content, regardless of their disability, can enhance their interests in academic content (Wilson et al., 2011).

Attrition Differences between the Title I and Non-Title 1 Middle Schools

The study was originally proposed to take place in only one middle school (i.e., a Title I school). This middle school had a large student population of SWD, who were CLD, receiving afterschool program services. A G*Power analysis was run for a between subjects repeated measures Multivariate Analysis (MANOVA) with a suggested total of 34 participants. The number of participants who completed the study did not meet the G*Power analysis, thus the researcher pivoted to reporting data through descriptive analysis. During the initial two weeks of participant recruitment, only two students provided consent due to many students no longer attending the school or afterschool program, or the students had not secured parental consent to participate. This lack of interest was not initially presented by the students, as many were enthusiastic about participating, but then stopped attending. This lack of follow-through now, retrospectively, may have been due to their knowledge that their family would soon, once again, be moving due to an early crop season in the north, validated by school personnel comments. Securing participants who are CLD into scientific studies has been a historical and ongoing issue (Habibi, Sarkissian, Gomez, & Ilari, 2015). This research study had similar findings with recruiting issues of attaining consent from students from the middle school designated as Title I to participate in the research study. The second middle school was added after the initial recruitment at the middle school designated as Title I, yet only one student with a LD, despite multiple recruiting trips, distribution of materials, and the addition of a second middle school, participated in the research study.

A reason for multiple recruiting trips to the initial middle school was due to the lack of attendance of students who were enrolled in the afterschool program during the recruiting visits. Pursuing this middle school with multiple recruiting trips was in response to the empirical study being conducted purposely in a middle school located in a rural, low socioeconomic community with a large population of individuals who are CLD. The students who were in attendance requested to receive the recruitment materials and consent forms. During those visits, the researcher was informed by school personnel that many of the students stopped coming to the afterschool program for reasons ranging from moving away, disciplinary consequences, no longer showing up to school, or students losing interest in the afterschool program. The researcher inquired about another middle school in the school district with similar demographics as the middle school that was designated as Title I, and also had a 21st Century afterschool program, for adding more middle school students in the study.

After recruiting at the middle school that was designated as Title I, and due to afterschool attendance and attrition concerns of not meeting a priori analysis suggestion of 34 participants, the second middle school (i.e., non-Title I) was included in the recruitment efforts. At the beginning of the school year, the middle school that met the Title I designation had 70 students enrolled in the afterschool program (see Table 6). By the spring semester and at the start of the research study, the after school attendance dropped by approximately 65%. The second middle school, under the same school district, was located in another rural community less than 20 miles away from the initial middle school. This middle school served the students with the same 21st century afterschool program as the middle school that was designated as Title I. The middle school not designated as Title I had an after school program student enrollment of 53 at the beginning of the school year (see Table 6). The after school attendance fluctuated at the start of the study, but not to the degree of the middle school that met the Title I designation. In less than two weeks of recruiting students at the middle school (i.e., non-Title I) 20 students in the afterschool program provided consent to participate, but less migrant families were attending this school, despite a high level of students who were CLD. Middle schools in impoverished, rural communities have struggled with adequately meeting the students' needs through positive school structures, climates, and supports (Ulrich, 2011). Serving SWD who are CLD, especially in Title I schools, needs to be established, and proactive to providing positive and beneficial supports to the students who are living in impoverished settings.

Differences of Attrition

Attrition was significantly different between the two middle schools. Prior to the study taking place, the middle school designated as Title I had students' attendance drop during the spring semester. This drop was evident when the study began. Over 50% of students who provided consent did not show up for any portion of the study. This was a stark contrast of attrition with the second middle school that was not designated as Title I. Students who were absent or did not complete the study were less than 10% of the sample population, and were absent or did not participate due to their extracurricular activities (e.g., choir, student council, band, football, student clubs, and receiving additional tutoring services). Students from low socioeconomic communities have historically been segregated, marginalized, and ignored (Ladson-Billings, 2013). The school with a Title I designation was not ignored, but presented a new issue not clearly cited in the literature or the transient nature of needed education, even with regards to afterschool programming. Considering how online tutoring might be used to support transient students, be it a game or avatar, is a future consideration.

<u>Providing Video Game, Avatar, and a Guide</u>

For assessment 1b, the cell diagram activity was used for pretest, four midpoints assessments, and posttest. This assessment was also paper and pencil-based and scored by ratio measures (i.e. number of items labeled correctly out of 12 total items). Section 1b of the assessment required participants to fill in 12 fill-in-the-the-blank labels associated to different parts of the cell. The results for assessment 1b from pretest to posttest should be taken with caution. The Cell Command diagram activity (i.e., assessment section B) included two parts: (a) cell diagram with 12 fill-in-the-the-blank parts of the cell, and (b) the cell diagram guide with the terms and definitions included, but without labels identifying the parts of the cell diagram. The 1b pretest was given to the participants without the cell diagram guide. Withholding the cell diagram guide served as a baseline measure of participants' knowledge of identifying parts of a cell before playing the video game or meeting the TLE avatar. During baseline measures, all of the participants informed the researcher they did not know what the parts were or what terms or definitions to put on the blank labels. Students either left labels blank or put "IDK" (i.e., I don't know). For the duration of the study both groups received the cell diagram guide during cell diagram activity midpoints and posttest. Across groups, students were not provided their cell diagram performance outcomes during the study.

Results after Introducing a Guide

The results for section 1b of the assessment, from pretest to posttest, were significant across both groups. The control group increased their means at pretest (M = 1.20) compared to posttest (M = 6.70). The treatment group also increased their pretest mean (M = 0.86) compared to posttest (M = 3.69). Prior to the video game play and virtual avatar interactions, the overall participants' mean of correctly labeling items out of 12 blank labels was 1.00, and their overall posttest mean increased to 5.00. Although pretest did not include the cell diagram guide for both groups, all participants across both groups received the guide after the pretest. It is important to reiterate that the guide did not indicate where labels went on the fill-in-the-blank portions of the cell structure diagram. This guide may have attributed for the variance between the control and treatment groups' reading levels.

By the end of the study, the groups were not matched according to participants' grade and reading levels. This variance in scores may have been due to the attrition of participants in both groups, affecting the variance of the equal distribution of participants according to reading levels. The control group had a higher reading level mean than the treatment group by almost one reading level. The participants who did not have reading level data available for grouping purposes may have had higher reading levels than their counterparts in the treatment group without reading level data. Those participants without reading level data available were included in the study due to their enrollment in the afterschool program and due to difficulty in recruiting participants who were CLD, shown to be a critical issue when recruiting individuals who are Latino/a (Habibi, Sarkissian, Gomez, & Ilari, 2015). Inclusion of these students was based on the schools' staff indicating all students enrolled in the afterschool program were identified as struggling with academic content. The researcher felt that all students, regardless of race/ethnicity or disability, could benefit from receiving an alternative delivery of science content through a video game and mixed-reality virtual avatar.

Implications

An abysmal amount of research is currently available for a population of students that critically need changes in their academic outcomes (Vasquez et al., 2011), with only 6.2% of empirical research on middle school students identified as Latino/a (Scruggs, Mastropieri, Berkeley, & Graetz, 2010). To add to the disparity of identifying students who are Latino/a as indicated by Scruggs, Mastropieri, Berkeley, and Graetz (2010), culturally relevant practices were already established as a viable instructional practice by Gay (2002), 10 years before the Scruggs et al. (2010) meta-analysis. A call for a paradigm shift in research on SWD who are CLD is needed (Artiles, 2015). For the SWD who are CLD, the field of educational research has shown minimal efforts to conduct research for such a vulnerable and underserved population (Arzubiaga, Artiles, King, & Harris-Murri, 2008). Yet, students with or without a disability, who come from low socioeconomic communities with large migrant farming populations, who are CLD, are continually ignored (Núñez-Mchiri, 2009). A recommendation by Trent et al. (2014) was made for researchers and editors of peer-reviewed scholarly journals to take action and resolve the issues of disparity in CLD research and become the solution by conducting empirical research that deliberately examines students who are CLD. This research study attempted to add further empirical research on SWD, who are CLD, from low socioeconomic communities. Despite limited data on SWD, findings for students who are CLD and the struggles of research in afterschool programs in rural communities was further realized as a challenge and adds to further discussion in the literature.

Providing Enriching Activities

The implications from the study provided empirical, intervention research on students who were struggling learners and their performance outcomes in science content. This study provided further intervention research needed in the field of education by investigating rural middle schools that served students from diverse populations. Vasquez et al. (2015) put out a challenge in the field of education to further conduct studies taking place in rural schools. The need for further empirical studies is limited on CLD populations (e.g., Latino/a), especially students in rural communities. A caveat to the study, and adding to the literature, was the inclusion of emerging research on mixed-reality simulation (i.e., TeachLivE) during an afterschool program. Many afterschool programs serve students who are identified as struggling learners. Students who interacted with TLE, mixed-reality avatars had enriched learning experiences that piqued their interests and knowledge in STEM (Dieker, Grillo, & Ramlakhan, 2012). Students enrolled in afterschool programs were often provided access to enriching learning supports (e.g., tutoring, hand-on learning activities, or additional academic remediation). Enriching afterschool programs and the efforts that are being taken to ensure students who are enrolled in the programs receive enriching activities is in need for further investigation. The findings in this study left more questions than answers, but did show some level of success in the use of technology-based tools in science instruction for the control group.

This study provided students an opportunity to interact with science content through an education video game and by using cutting-edge technology, through the use of a mixed-reality avatar. This study may provide further implications on how video games are used in the classroom for increasing students' knowledge in academic content areas and measuring students' academic performances with content within a video game rather than a paper and pencil assessment. We know from research that students already struggle with the traditional or business-as-usual science texts provided to them (Knight, Wood, Spooner, Browder, & O'Brien, 2015). Yet, SWD are still subjected to learn science content without accessible features (Seifert & Espin, 2012), and worst yet, are measured by assessments that do not harness accessible features for measuring their comprehension. Cell Command gameplay performance measures within the video game did not include any multiple-choice questions. The video game's science content on cell structures and processes was delivered through interactive gameplay. The video game content was presented though multimedia formats (e.g., embedded voice and visual prompts, cues, and directions to help guide game players). The embedded voice guided and informed players how to navigate throughout the game. Players had the gameplay options of receiving hints or labels with items that appeared on the screen, tutorials that allowed practice, and opportunity to replay stages. Participants had to perform at proficiency criteria during the interactive gameplay in order to enter and play, or progress to different video game stages, as opposed to filling out paper and pencil or digital assessments within the video game.

Participants' advancements were through the gameplay and their performance in the gameplay was used for entering new stages automatically built into the video game design. This researcher recommends that, as future research and development on education video games continues to build and grow, researchers should explore the potential of directly using built-in assessments during students' game play to represent the students' efforts in the virtual environment. Creating alternative assessments in video games with UDL principles may be beneficial for all learners (Dalton, Proctor, Uccelli, Mo, & Snow, 2011), including those SWD, CLD from rural low socioeconomic communities.

Students were provided an opportunity to speak to a STEM-related professional who was not part of their school or district. Ample documentation exists that SWD who are CLD are disproportionally enrolled or do not attain STEM-related degrees (Lu, 2015; NSF, 2014). This disparity is further magnified for all students, with or without a disability, who attend schools in rural communities (Mullen, & Kealy, 2013).

Empirical research and exposing students to innovative technology during afterschool hours was at the core of this study. Students increased their knowledge with science content when they were provided access to technology-based learning tools (Aydeniz et al., 2012). Different digital technology formats for enhancing students' comprehension of science content has shown value in increasing their knowledge (Rappolt-Schlichtmann et al., 2013). Students were provided access to the Cell Command video game that was created and developed by using multiple, national science standards for students who were in the sixth, seventh, and eighth grades. A recommendation is that afterschool programs do an inventory on their current practices and curriculum, using technology when serving their student populations. Afterschool programs, much like those in this study, were created to serve students who need the most support in their schools. If schools are going to extend a student's day through afterschool programs, then the district leaders and staff need to pay close attention to the practice and enrichment taking place for these students who need rich, targeted and outcome-based interventions.

Clearly, afterschool program staff needs the support and training for the students they will serve. The afterschool personnel are key role players for utilizing the time and resources they have to enrich the students' experiences and participation in activities. The use of technology for afterschool teacher professional development trainings can introduce or increase evidence-based practices (e.g., Positive Behavioral Intervention Supports [PBIS]).

Using innovative technology, meeting UDL principles during afterschool programs, needs to be further investigated. Additionally, academic content in the form of video games needs to be further investigated on using the gameplay performance outcomes as an alternative assessment or grade in reporting academic performance. Introducing students from rural communities to cutting-edge technology in the afterschool program, as learning tools, can create an environment where the students are at the forefront of up-to-date technology rather than in an isolated community with outdated technology and limited online access.

Limitations

This research study had several limitations in the attempt to answer the research questions, and are identified as: a) target population, b) attrition, c) setting, d) instrumentation, f) assessment section A and e) pretest. The target population for the study was students who were

CLD (i.e., Latino/a) served with an Individualized Education Program (IEP) for a LD. The researcher selected a rural school district that served a large Latino/a population in an attempt to recruit students who met the study's target population. The research was conducted between two middle schools that had a combined potential to have over 50 students who met the target population criteria for the study, yet only one student with LD enrolled.

During the initial time of seeking permission to conduct the study in the school district and the recruitment process of the targeted population of students, once consent forms were distributed, students were no longer enrolled or attending the school or afterschool program on a regular basis. In one of the schools, the decreasing number of students' attendance was due to many of the families in the community migrating to other regions or states due to the changing of crops seasons. Students who miss school due to crop seasons was not unusual in this rural community where crops are the leading industry, and in 2014-2015, 12% of the middle schools' students were identified as migrant. The reasons for students not attending school was similar to what Azano and Stewart (2015) reported during an interview with a teacher explaining reasons on why students in the rural community miss school.

At the beginning of the study, 38 students provided consent to participate. Due to attrition (e.g., absences, moved out of school district, or no longer enrolled), only 23 students completed the study. Due to participants not completing the study or never starting it, the researcher did not meet the a priori power analysis guidelines found in large group design for generalizable findings.

The settings of the study took place in two middle schools' afterschool programs. Students were expected, but not required, to attend the afterschool program. The research was purposely conducted in the afterschool setting for the purposes of investigating the effects of video games and incorporating a virtual avatar on science content. It was expected student attendance would be a limitation based on the students and parents or guardians flexibility of the afterschool schedule. The students did not have to attend on a daily basis and may be signed out early.

Another limitation was the schools' locations were in rural communities and online connectivity was a concern for implementing the TLE avatar. A large component of the research included Wi-Fi connectivity. The researcher attained permission to use the district's Wi-Fi under a guest access account. The researcher took further measures by bringing in his own Wi-Fi hotspot device. Both Wi-Fi connections had issues with weak connectivity and no signal for approximately 50% of the study. The researcher would have to prop his phone on the top of the window seals in the rooms where the research study took place in both middle schools.

The Cell Command video game was created by a team of game developers and a leading educational research expert on middle school students with LD, access to science content through virtual environments, supports towards STEM postsecondary outcomes, and the Universal Design for Learning (UDL) framework. The instruments used in the study from the Cell Command video game assessment included the game's curriculum. The assessment used from Cell Command had two sections used for the pretest and posttest measures and were two printable paper and pencil assessments: section 1a multiple choice questions, and section 1b fill in the blank diagram activity. At the time of this study, the Cell Command assessment did not have psychometric properties to report. However, the assessment was used as the instrument was taken directly from the video game and met content validity. Furthermore, Cell Command's content, materials, and science standards were aligned for the middle school grades of sixth through eighth, using the Next Generation Science Standards (NGSS), Common Core, and Benchmarks for Science Literacy. It is important to reiterate that Cell Command was created by the guidance of an education researcher whose research is specialized in the areas of providing digital supports to students with LD, accessibility to science content through virtual environments, and UDL.

Assessment section 1a pretest/posttest had only five multiple-choice questions. Being that the assessment 1a was multiple-choice questions, students could have guessed their recorded answers. Interestingly, the pre-test/posttests 1a performances between both groups did not vary.

For pretest baseline measures, students completed the section 1b assessment (i.e., cell diagram activity) without the cell diagram guide that had the names and definitions found on the cell diagram. This cell diagram guide did not have indicators of where the words matched within the diagram activity. The guide only provided the names and definitions to be used to fill in the diagram. The guide was not provided during the 1b pretest to the control for the students' existing knowledge of the cell structures. All students in the control and treatment groups did not meet the threshold of answering in the 1b assessment, 7 out of 12, diagram items correctly. The control group baseline average was 1.20 correct out of 12, and the treatment group baseline was 0.86 correct out of 12. To further ensure the threshold of correct responses was controlled for with the students' existing knowledge of the cell diagram activity (i.e., 1b assessment), an ensuing data sample was taken, but all students were provided the diagram guide (i.e., names and definitions to be written in the blank lines, indicating where the they belonged within the cell diagram) while completing the diagram activity. All of the students were below the threshold of 7 out of 12 items filled in correctly.

Extraneous Variables

Extraneous variables may have affected the treatment group due to the novelty of having an avatar who was able to see and speak back to the students with the afterschool personnel making remarks or comments during the interaction. A factor to consider may have been the students in the treatment group interacted with the avatar in groups rather than individually. The discussion took place alongside peers as opposed to a one-on-one setting. A further contribution to extraneous variables may have been afterschool personnel acceptance or perceptions of mixed-reality simulation in the afterschool setting and making comments or interrupting during the treatment groups' discussions with the avatar. Another possible extraneous variable was the duality of technology introduced to the treatment group: (a) Cell Command video game, and (b) TLE mixed-reality environment. Participants had not experienced the TLE, mixed-reality environment or played Cell Command prior to the study.

Future Research

Universal design for learning (UDL) has been recognized in the National Education Technology Plan (NETP, 2016), and the Every Student Succeeds Act (2015) as an instructional planning guide in lesson plans, assessments, curriculum, materials, and access to content for all students. Although UDL has been included in the federal policy for recommendations on serving all students, especially SWD and those who are CLD (i.e., English Learners), the research and literature on SWD who are CLD is limited. The lack of intervention-based practices and research for SWD who are CLD is concerning (Cramer, 2015). Further, concerns have been directed towards whether digital technology is beneficial in the classrooms for student learning. A caveat to the concerns of students' learning is teachers' acceptance and use of digital technology as supplemental tools in their classrooms. Despite past literature on technology in the classroom as being either ineffective or not needed, when good teachers are present, up-to-date digital technology was found to be beneficial for students. A meta-analysis conducted by Zheng, Warschauer, Lin, and Chang (2016) found that technology (i.e., laptops) was effective when used for students in a one-on-one setting.

Future research should examine SWD who are CLD and their interactions in the on-going development of personalized education tools and supports, innovative technology, and afterschool programs. Research on digital technology for SWD who are CLD will need to be conducted and reported at a pace that is conducive to the on-going development of technology. In this investigation, the TLE, mixed-reality avatar's discussions with the participants were designed with inquiry-based questions. Future research that investigates the effects of a virtual, mixed-reality avatar speaking to students with the purpose of activating prior knowledge is needed. This research should compare between three groups' (i.e., inquiry-based questions, explicit discussions pertaining to the content, and business as usual delivery of content) outcomes. Also, additional sessions of TLE or individual sessions might have a stronger impact.

Teachers and staff from rural, low socioeconomic communities are serving a student population, mostly living in impoverished and poverty stricken communities (Mattingly, Johnson, & Schaefer, 2011). Afterschool programs serve an important role towards providing students additional support that might be provided in the class or at home. Teachers and staff in rural communities serve roles outside of their title, including afterschool program leaders and aides. Clearly these educators serving more than their role are doing so to meet the needs and build on students' strengths. Continuing and building on the research for all students, especially SWD and CLD, in rural communities will need to look towards practices and instructional strategies that provide equity and increased academic outcomes. The resources and research, or lack thereof, for teachers serving all students in rural communities continues to be appalling. The population of the U.S. is diverse, and the 21st century digital technology tools are no longer a novelty or gimmick in the educational setting. Many SWD have been underserved in education and will continue to be underserved for every new and evolving technology that was empirically researched without SWD and CLD populations. Empirical research on SWD from rural communities and digital technologically is already at a disadvantage, with the issue of affordable online connectivity and bandwidth connectivity in rural communities. This is important to consider, knowing that most residents live in poverty and probably cannot afford efficient, online bandwidth. The school staff takes on roles and duties that were probably not part of their original assignment or title. School staff in rural communities often serves above and beyond the already mounting responsibilities educators face. Educators play an important role, encouraging students in rural communities by their belief that the student is college material (Sherman & Sage, 2011). SWD and CLD from rural communities' disadvantages are magnified with the barriers they already face in gaining access to an equitable education and well-being.

Students with disabilities, using alternative guides, tools, and technology for learning as alternatives to textbooks, can serve the students in gaining comprehension as they work on academic tasks (Marino & Beecher, 2010). Providing SWD who are CLD with non-traditional, science supports, through technology, can increase their interests in science (LeBlanc & Larke, 2011). It has been recommended that UDL and 21st century digital technology be coupled when serving diverse SWD (Edyburn, 2010). Given that science texts are already complicated to many students in the classrooms (Curry, Cohen, & Lightbody, 2006), providing students with academic tools to guide their comprehension is crucial. Why is it important to include multiple modes or materials for all SWD to receive alternatives to learning science? More than half of students struggled using business-as-usual textbook materials for learning science (Carnine & Carnine, 2004).

Clearly SWD and CLD across the U.S., and especially in rural communities, continue to severely be underserved in the field of education, from teaching and learning to research. The SWD and CLD representation in the postsecondary education, let alone STEM-related areas, attainment of higher education degrees, and professional careers are unacceptable. Science instruction for SWD and CLD has to directly and purposely utilize the students' background knowledge and lens, while following UDL instructional method principles of accessible educational content. Teachers, like the students, science instruction and preparation through professional development delivery, equally needs to be further investigated.

APPENDIX A: STEM-CAREER INTEREST SURVEY & PERMISSION

STEM Career Interest Survey		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable
Instructions: Please circle one answer for each statement below.		**SD**	**D**	**NA/D**	**A**	**SA**	**N/A**
		⇩	⇩	⇩	⇩	⇩	⇩
START HERE **Science**							
1.	**I am able to get a good grade in my science class.**	1	2	3	4	5	N/A
2.	**I am able to complete my science homework.**	1	2	3	4	5	N/A
3.	**I plan to use science in my future career.**	1	2	3	4	5	N/A
4.	**I will work hard in my science classes.**	1	2	3	4	5	N/A
5.	**If I do well in science classes, it will help me in my future career.**	1	2	3	4	5	N/A

6.	**My parents would like it if I choose a science career.**	1	2	3	4	5	N/A
7.	**I am interested in careers that use science.**	1	2	3	4	5	N/A
8.	**I like my science class.**	1	2	3	4	5	N/A
9.	**I have a role model in a science career.**	1	2	3	4	5	N/A
10.	**I would feel comfortable talking to people who work in science careers.**	1	2	3	4	5	N/A
11.	**I know of someone in my family who uses science in their career.**	1	2	3	4	5	N/A

Math

1.	**I am able to get a good grade in my math class.**	1	2	3	4	5	N/A
2.	**I am able to complete my math homework.**	1	2	3	4	5	N/A
3.	**I plan to use math in my future career.**	1	2	3	4	5	N/A
4.	**I will work hard in my math classes.**	1	2	3	4	5	N/A
5.	**If I do well in math classes, it will help me in my future career.**	1	2	3	4	5	N/A
6.	**My parents would like it if I choose a math career.**	1	2	3	4	5	N/A
7.	**I am interested in careers that use math.**	1	2	3	4	5	N/A
8.	**I like my math class.**	1	2	3	4	5	N/A
9.	**I have a role model in a math career.**	1	2	3	4	5	N/A
10.	**I would feel comfortable talking to people who work in math careers.**	1	2	3	4	5	N/A

11.	**I know someone in my family who uses math in their career.**	1	2	3	4	5	N/A

Please Continue to Next Page

STEM Career Interest Survey		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable
Instructions: Please circle one answer for each statement below.		**SD**	**D**	**NA/D**	**A**	**SA**	**N/A**
		⇩	⇩	⇩	⇩	⇩	⇩

<u>Technology</u>

1.	**I am able to do well in activities that involve technology.**	1	2	3	4	5	N/A
2.	**I am able to learn new technologies.**	1	2	3	4	5	N/A
3.	**I plan to use technology in my future career.**	1	2	3	4	5	N/A
4.	**I will learn about new technologies that will help me with school.**	1	2	3	4	5	N/A

5.	**If I learn a lot about technology, I will be able to do lots of different types of careers.**	1	2	3	4	5	N/A
6.	**My parents would like it if I choose a technology career.**	1	2	3	4	5	N/A
7.	**I like to use technology for class work.**	1	2	3	4	5	N/A
8.	**I am interested in careers that use technology.**	1	2	3	4	5	N/A
9.	**I have a role model who uses technology in their career.**	1	2	3	4	5	N/A
10.	**I would feel comfortable talking to people who work in technology careers.**	1	2	3	4	5	N/A
11.	**I know of someone in my family who uses technology in their career.**	1	2	3	4	5	N/A

Engineering

1.	**I am able to do well in activities that involve engineering.**	1	2	3	4	5	N/A
2.	**I am able to complete activities that involve engineering.**	1	2	3	4	5	N/A
3.	**I plan to use engineering in my future career.**	1	2	3	4	5	N/A
4.	**I will work hard on activities at school that involve engineering.**	1	2	3	4	5	N/A
5.	**If I learn a lot about engineering, I will be able to do lots of different types of careers.**	1	2	3	4	5	N/A
6.	**My parents would like it if I choose an engineering career.**	1	2	3	4	5	N/A

7.	**I am interested in careers that involve engineering.**	1	2	3	4	5	N/A
8.	**I like activities that involve engineering.**	1	2	3	4	5	N/A
9.	**I have a role model in an engineering career.**	1	2	3	4	5	N/A
10.	**I would feel comfortable talking to people who are engineers.**	1	2	3	4	5	N/A
11.	**I know of someone in my family who is an engineer.**	1	2	3	4	5	N/A

Please Continue to Next Page

**** Thank you for your time in completing this questionnaire. ****

Please share any additional comments you have in the box provided below.

Permission to Use STEM-CIS

Margaret Blanchard <Meg_Blanchard@ncsu.edu>
1/4/2016

Dear Benjamin,

Meredith and I are delighted that you would like to use the STEM-CIS! Please do so. We wish you the best with your work!

Meg

APPENDIX B: CONSENT FORM

The Role of Virtual Avatars in Supporting Middle School Students with Learning Disabilities from Culturally and Linguistically Diverse Backgrounds in Science

Principal Investigator: Benjamin Gallegos, M.Ed., Doctoral Student

Faculty Advisor: Lisa Dieker, PhD

Investigational Site(s): TeachLivE™ at the University of Central Florida
Designated School
University of Central Florida, Department Education and Human Performance

How to Return this Consent Form: You as the guardian will be given two consent forms. One will have to be signed by you and your child in order for your child to be in the study. Once both you and your child sign the consent form return it to their science teacher. You or your child may return the signed consent form to the science teacher. The other consent copy is yours to keep for record.

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being asked to allow your child to take part in a research study which will include about 62 students. Your child is being invited to take part in this research study because he or she is a middle school student and taking science classes.

The person doing this research is Benjamin Gallegos of the University of Central Florida Department of Education College of Education and Human Performance.

Because the researcher is a doctoral student he is being guided by Dr. Lisa Dieker, a UCF faculty advisor in the Department of Education's College of Education and Human Performance.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should allow your child to take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you or your child.

- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of this study is to see how students can get better at learning science lessons by increasing their interests in the subject with the help of a cartoon like character that appears to them on a computer screen (virtual avatar) before they play a science video game.

What your child will be asked to do in the study: For about 12 weeks your child will be given science support. First your child will do a science career survey before they get to use the technology. The survey will let the researcher know how the students' feel about science. After the survey for the next 11 weeks your child will get to practice science learning by playing a science video game for about 30 minutes for two days a week. All students will play the science video game, and some will get to meet and interact with the cartoon like character (virtual avatar) on the computer screen who's character is an expert in science and will talk to the students about what their learning in science. At the end of the 12 weeks your child will take the survey again about their interests in science.

Your child does not have to answer every question or complete every task. You or your child will not lose any benefits if your child skips questions or tasks.

Location: Your child will do their computer learning science activities in their school.

Time required: We expect that your child will be in this research study for about 12 weeks. For the first week the student will complete a survey, then, begin their learning activities by playing a science video game.

Risks: The risks associated to this study may be issues with participants' anonymous, non-identifiable participation to the study. The researcher will take measures on using numerical codes to represent participant identification.

Benefits:

We cannot promise any benefits to you, your child, or others from your child taking part in this research. However, possible benefits include extra time doing science activities outside of the classroom. Your child's activity in this study will not affect their grades in school. Your child will not benefit directly for taking part in this research, besides learning more about how research is conducted.

Compensation or payment:

There is no compensation, payment or extra credit for your child's part in this study

Confidentiality: We will limit your personal data collected in this study. Efforts will be made to limit your child's personal information to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of UCF.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt your child talk to Benjamin Gallegos, Doctoral Student, Exceptional Education Program, College of Education and Human Performance, (915) 269-3393 or Dr. Lisa Dieker, Faculty Supervisor, Department of Education and Human Performance by email at Lisa.Dieker@ucf.edu.

IRB contact about you and your child's rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

Withdrawing from the study:

You may decide not to have your child continue in the research study at any time without it being held against you or your child. If you decide to have your child leave the research.

If you decide to have your child leave the study, contact the investigator so that the investigator can remove your child from the study.

The person in charge of the research study can remove your child from the research study without your approval. Possible reasons for removal include your child being absent too many times, destroying research materials, or informing the researcher that they do not want to participate anymore.

Results of the research:

If you would like information or results to the study please ask the researcher for information.

DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW

____

Name of child participant

____

Signature of parent or guardian*

_________________________ ______________

Printed name of parent or guardian* Date

Assent __ Obtained verbally

* Note on permission by guardians: An individual may provide permission for a child only if that individual can provide a written document indicating that he or she is legally authorized to consent to the child's general medical care. Attach the documentation to the signed document.

APPENDIX C: RECRUITMENT LETTER

Dear Parents/Guardians and Student,

Hello my name is Benjamin Gallegos and I am a research associate at the University of Central Florida's innovative TeachLivE^{TM} mixed reality lab. Your school district has given approval for me to conduct my research study in your school and I would like to ask you to participate in my study.

I will provide interactive science learning opportunities through science learning content using a state of the art cartoon like virtual avatar that will serve as a science expert guide on a computer screen. The cartoon like virtual avatar will serve as a science expert that can help and guide students while they are engaging, exploring, and learning science content playing a science video game. This will take place daily during afterschool tutoring. If you choose to participate, the information gathered from the study will serve as a powerful tool for the TeachLivE research and development team. Your contributions to the study are valuable on knowing how middle school students interact with science activities using innovative technology through a science expert virtual avatar guide while playing science video games. Keep in mind that your information is confidential. Remember, this study is completely voluntarily on your behalf. If you choose not to participate in this study there are no consequences for not participating.

If you choose to participate, please let the assigned science teacher know and they will contact me so that I can give you a permission form to participate. The permission form will require both the parents'/guardians' and students' permission.

For questions or concerns, please do not hesitate to contact me at 915-269-3393, or email me at bgallegos2@knights.ucf.edu.

Thank you for your time and consideration to participating in my research project.

Sincerely,

Benjamin Gallegos
TeachLivE Research Associate

APPENDIX D: VIRTUAL AVATAR DISCUSSION PROTOCOL

Science Professional Facilitating Science Video Game

- TeachLivE avatars will be serving the role of a science professional who has earned their doctorate's degree in a science content related field (according to the content of the nine week science unit) at the University of Central Florida and will be talking with students before they play a video game.
- Students will play Cell Command and take the quizzes independently.

Stacey will ask these questions before students play the video game Cell Command

Avatars will spend 10 minutes per group of 5 middle school students facilitating students with a pre-video gameplay discussion on the Cell Command video game. The avatar's role is to activate students' prior knowledge by asking students questions based on the content and vocabulary they will be exposed to playing Cell Command:

1. What comes to your mind with this video game?
2. What do cells have to do within your life?
3. What kind of scientists or what should someone be a professional in that look at cells?
4. Which colleges do you know of that look at cells?
5. What degrees do you know of at universities that would involve studying or knowing cells?
6. After student's response, Stacey provides one cell related profession (microbiology) and one name of a university that has a program that pertains to the topic of cells the student did not mention (e.g., University of Texas, Florida, FAU, FIU, USC, UCLA etc.).
7. Stacey tells the student how excited she is that the student will get to play Cell Command to play and learn about cell structures and cell processes.

Stacey may add to the questions for the purpose of facilitating prior knowledge with students (e.g., I'm not sure myself, but if you had to guess…. or I know these types of scientists/ sciences that look at cells to investigate their processes for a million different reasons, so which scientists/ sciences do you think may look into this?).

Framework for Facilitating Prior Knowledge

A virtual avatar representing a science professional will facilitate science video gameplay by discussing prior knowledge and 'big ideas' before the students play Cell Command. The operational definition for the facilitating of science video game play in this study will be based on the UDL Version 2.0 Means of Representation options for comprehension items (a) 3.1 activate or supply background knowledge, (b) 3.2 Highlight patterns, critical features, big ideas, and relationships, (c) 3.3 Guide information processing, visualization, and manipulation, and (d) 3.4 maximize transfer and generalization (CAST, 2011).

APPENDIX E: PERMISSION TO USE CELL COMMAND MATERIALS

Filament Service Desk (Filament Service)

May 17, 1:02 PM

Hi Benjamin,

Thank you for reaching out to us! Feel free to use screen shots and materials from our website and let me know if you need anything else. We'd love to see your dissertation when it's done!

Best of luck,

Name removed for confidentiality

Filament Service Desk

APPENDIX F: CELL COMMAND PRE AND POSTEST SECTION 1a

Assessment 1

Name _______________________________ Date_____________ Class_______________

Directions: Read the questions below. Circle the letter next to the correct answer.

1 According to the cell theory, where do cells come from?

A. cork

B. living cells

C. water

D. energy

2 What happens when a cell undergoes mitosis?

A. two cells become one cell with 23 chromosomes

B. two cells become one cell with 46 chromosomes

C. two daughter cells are produced with different DNA

D. two daughter cells are produced with identical DNA

3 Which structure is considered a cell's control center?

A. nucleus

B. ribosome

C. mitochondrion

D. endoplasmic reticulum

4 Which structure functions most like skin on the human body?

A. nucleus

B. vacuole

C. cell membrane

D. Golgi body

5 Which is the primary energy source in cells?

A. ATP

B. RNA

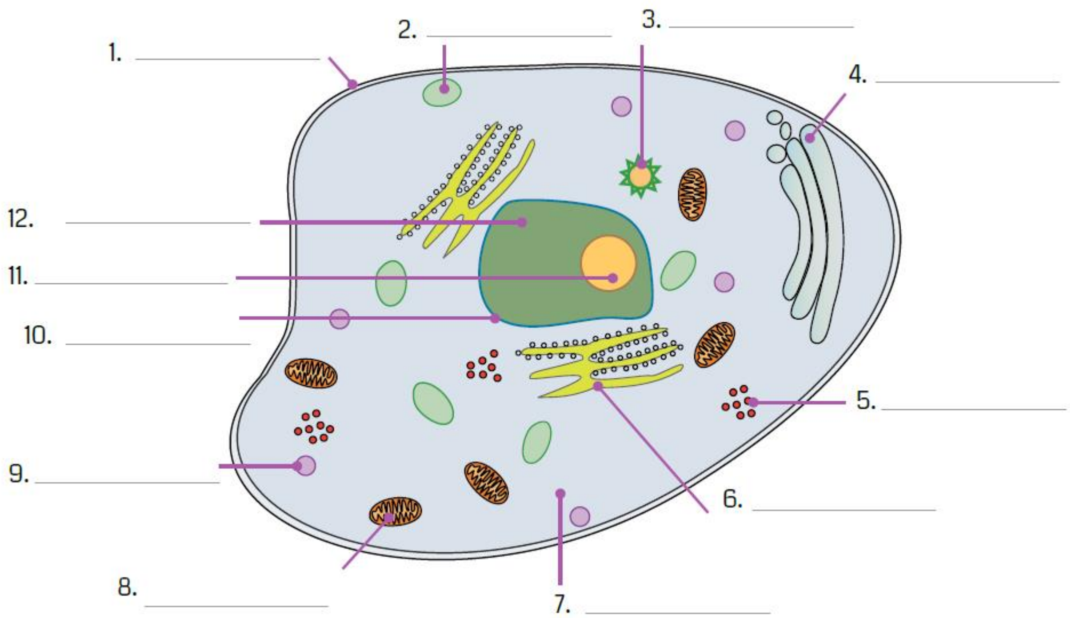
C. DNA

D. H2O

APPENDIX G: CELL COMMAND PRE AND POSTEST SECTION 1b

Assessment 1

Directions: List each organelle below the diagram and describe its function. If needed, you may use an extra sheet of paper.



Organelle Functions:

1. ______________________ 7. ______________________

2. ______________________ 8. ______________________

3. ______________________ 9. ______________________

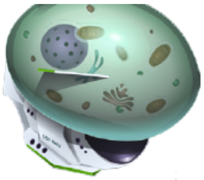
4. ______________________ 10. ______________________

5. ______________________ 11. ______________________

6. ______________________ 12. ______________________

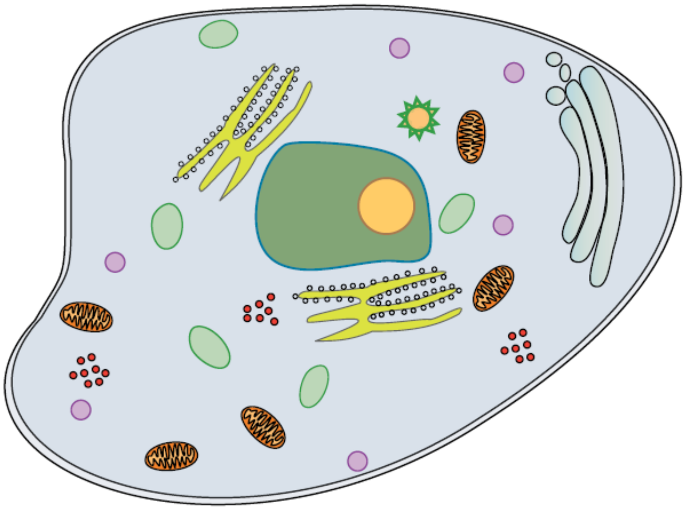
APPENDIX H: CELL COMMAND DIAGRAM GUIDE

Printable Student Sheet/
Whiteboard Projection



Pre-Assessment

Part 1: Group Diagram



Cell membrane	a thin layer that surrounds a cell; this layer separates and protects the inside of the cell from harmful agents around the cell and controls what moves in and out of the cell.
Lysosome	breaks down waste materials in an animal cell.
Nucleus	the information center of a cell that controls the chemical reactions that happen in cytoplasm; also stores DNA.
Nucleolus	a round structure that is inside the nucleus of a cell; this structure makes ribosomes.
Nuclear membrane	separates the nucleus from the rest of the cell; regulates substances that move in and out of the nucleus.
Vacuole	stores food, water, and wastes.
Mitochondrion	converts food into usable energy.
Golgi body	processes, packs, and transports proteins to be sent outside a cell.
Ribosomes	make proteins for a cell.
Endoplasmic reticulum	processes and transports proteins from place to place inside a cell.
Cytoplasm	a jellylike substance that fills up the inside of a cell.
Centrosome	the region of a cell that is located next to the nucleus and contains the centrioles.

APPENDIX I: CELL COMMAND ASSESSMENT ANSWER KEY

Assessment 1

Answer Key

1 B

2 D

3 A

4 C

5 A

Cell Diagram

1 Cell membrane: a thin layer that surrounds a cell; this layer separates and protects the inside of the cell from harmful agents around the cell and controls what moves in and out of the cell.

2 Vacuole: stores food, water, and wastes.

3 Centrosome: the region of a cell that is located next to the nucleus and contains the centrioles.

4 Golgi body: processes, packs, and transports proteins to be sent outside a cell.

5 Ribosomes: make proteins for a cell.

6 Endoplasmic reticulum: processes and transports proteins from place to place inside a cell.

7 Cytoplasm: a jellylike substance that fills up the inside of a cell.

8 Mitochondrion: converts food into usable energy.

9 Lysosome: breaks down waste materials in an animal cell.

10 Nuclear membrane: separates the nucleus from the rest of the cell; regulates substances that move in and out of the nucleus.

11 Nucleolus: a round structure inside the nucleus of a cell that makes ribosomes.

12 Nucleus: the information center of a cell that controls the chemical reactions that happen in cytoplasm; also stores DNA.

APPENDIX J: IRB

University of Central Florida Institutional Review Board

Office of Research & Commercialization

12201 Research Parkway, Suite 501

Orlando, Florida 32826-3246

Telephone: 407-823-2901 or 407-882-2276

www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Benjamin Gallegos**

Date: **March 08, 2016**

Dear Researcher:

On 03/08/2016, the IRB approved the following minor modifications to human participant research until 01/14/2017 inclusive:

Type of Review:	IRB Addendum and Modification Request Form
Modification Type: School District:	New research locations in removed for confidentiality Removed for confidentiality Middle School and removed for confidentiality Middle School have been added. New versions of the Informed Consent have been approved for use.
Project Title:	The Role of Virtual Avatars in Supporting Middle School Students with Learning Disabilities from Culturally and Linguistically Diverse Backgrounds in Science
Investigator:	Benjamin Gallegos
IRB Number:	SBE-16-11952
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining

IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 01/14/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 03/08/2016 12:54:02 PM EST

IRB Manager

APPENDIX K: FIDELITY OF IMPLEMENTAION

Avatar Fidelity of Implementation Checklist

Tasks	**Circle Yes or No**	
Stacey introduces herself to the group of students	YES	NO
Stacey asks the student **"I hear you all are going to play Cell Command, I want each one of you to tell me what you think the video game will be about?"** Go to each student for their response	YES	NO
After each students respond, Stacey asks all of them **"What do cells have to do within your life/personal experiences?"** Go to each student for their response	YES	NO
After each students respond, Stacey asks each all of them **"What kind of scientists look at cells?"** Go to each student for their response	YES	NO
After students respond, Stacey asks **"Which colleges do you know of where you can study cells?"** Go to each student for their response	YES	NO
After students respond, Stacey asks **"What degrees do you know of at universities that would involve studying or knowing cells?"** Go to each student for their response	YES	NO
After student's response, Stacey provides one cell related profession (microbiology) and one name of a university that has a program that	YES	NO

Tasks	**Circle Yes or No**
pertains to the topic of cells the student did not mention (e.g., University of Texas, Florida, FAU, FIU, USC, UCLA etc.).	
Stacey tells the student how excited she is that the student will get to play Cell Command to play and learn about cell structures and cell processes.	YES NO

REFERENCES

Annetta, L. A., Frazier, W. M., Folta, E., Holmes, S., Lamb, R., & Cheng, M. T. (2013). Science teacher efficacy and extrinsic factors toward professional development using video games in a design-based research model: The next generation of STEM learning. *Journal of Science Education and Technology, 22*(1), 47-61. doi:10.1007/s10956-012-9375-y

Artiles, A. J. (2011). Toward an interdisciplinary understanding of educational equity and difference the case of the racialization of ability. *Educational Researcher, 40*(9), 431-445.

Artiles, A. J. (2015). Beyond responsiveness to identity badges: Future research on culture in disability and implications for Response to Intervention. *Educational Review*, *67*(1), 1-22.

Artiles, A. J., Kozleski, E. B., Trent, S. C., Osher, D., & Ortiz, A. (2010). Justifying and explaining disproportionality, 1968–2008: A critique of underlying views of culture. *Exceptional Children*, *76*(3), 279-299.

Arzubiaga, A. E., Artiles, A. J., King, K. A., & Harris-Murri, N. (2008). Beyond research on cultural minorities: Challenges and implications of research as situated cultural practice. *Exceptional Children*, *74*(3), 309-327.

Aydeniz, M., Cihak, D. F., Graham, S. C., & Retinger, L. (2012). Using inquiry-based instruction for teaching science to students with learning disabilities. *International Journal of Special Education, 27*(2), 189–206.

Azano, A. P., & Stewart, T. T. (2015). Exploring place and practicing justice: Preparing pre-service teachers for success in rural schools. *Journal of Research in Rural Education, 30*(9), 1-12.

Bakken, J. P., Mastropieri, M. A., & Scruggs, T. E. (1997). Reading comprehension of expository science material and students with learning disabilities: A comparison of strategies. *The Journal of Special Education, 31*(3), 300–324. Retrieved from http://doi.org/10.1177/002246699703100302

Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through Universal Design for Learning. *TEACHING Exceptional Children*, *45*(4), 8–15.

Basham, J. D., Meyer, H., & Perry, E. (2010). The design and application of the digital backpack. *Journal of Research on Technology in Education*, *42*(4), 339-359.

Benton-Borghi, B. H. (2013). A universally designed for learning (UDL) infused technological pedagogical content knowledge (TPACK) practitioners' model essential for teacher preparation in the 21st Century. *Journal of educational computing research*, *48*(2), 245-265.

Berkeley, S., Mastropieri, M. A., & Scruggs, T. E. (2011). Reading comprehension strategy instruction and attribution retraining for secondary students with learning and other mild disabilities. *Journal of Learning Disabilities, 44*(1), 18–32. Retrieved from http://doi.org/10.1177/0022219410371677

Bice-Urbach, B. J., & Kratochwill, T. R. (2016). Teleconsultation: The use of technology to improve evidence-based practices in rural communities. *Journal of School Psychology, 56,* 27-43. doi:10.1016/j.jsp.2016.02.001

Billings, D. R. (2012). Efficacy of adaptive feedback strategies in simulation-based training. *Military Psychology, 24*(2), 114-133.

Blank, R. K. (2013). Science instructional time is declining in elementary schools: What are the implications for student achievement and closing the gap? *Science Education, 97*(6), 830–847. Retrieved from http://doi.org/10.1002/sce.21078

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 717–726. Retrieved from http://doi.org/10.1016/S0022-5371(72)80006-9

Brigham, F. J., Scruggs, T. E., & Mastropieri, M. A. (2011). Science education and students with learning disabilities. *Learning Disabilities Research & Practice, 26*(4), 223–232. Retrieved from http://doi.org/10.1111/j.1540-5826.2011.00343.x

Brownell, M. T., Bishop, A. M., & Sindelar, P. T. (2005). NCLB and the demand for highly qualified teachers: Challenges and solutions for rural schools. *Rural Special Education Quarterly, 24*(1), 9-15.

Bruhn, A. L., & Hasselbring, T. S. (2013). Increasing student access to content area textbooks. *Intervention in School and Clinic, 49*(1), 30–38. Retrieved from http://doi.org/10.1177/1053451213480030

Bulgren, J. A., Graner, P. S., & Deshler, D. D. (2013). Literacy challenges and opportunities for students with learning disabilities in social studies and history. *Learning Disabilities Research & Practice, 28*(1), 17–27.

Byun, S. Y., Irvin, M. J., & Meece, J. L. (2012). Predictors of bachelor's degree completion among rural students at four-year institutions. *The Review of Higher Education, 35*(3), 463-484.

Camacho, M. M., & Lord, S. M. (2011). Quebrando fronteras: Trends among Latino and Latina undergraduate engineers. *Journal of Hispanic Higher Education, 10*(2), 134-146.

Carnine, L., & Carnine, D. (2004). The interaction of reading skills and science content knowledge when teaching struggling secondary students. *Reading & Writing Quarterly, 20*(2), 203–218. Retrieved from http://doi.org/10.1080/10573560490264134

CAST (2011). *Universal Design for Learning Guidelines version 2.0.* Wakefield, MA: Author.

Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119*(2), 217-230.

Chang, H. Y., Quintana, C., & Krajcik, J. S. (2010). The impact of designing and evaluating molecular animations on how well middle school students understand the particulate nature of matter. *Science Education, 94*(1), 73–94.

Chen, J. M., Chen, M. C., & Sun, Y. S. (2014). A tag based learning approach to knowledge acquisition for constructing prior knowledge and enhancing student reading comprehension. *Computers & Education, 70*, 256–268. Retrieved from http://doi.org/10.1016/j.compedu.2013.09.002

Christen, W. L., & Murphy, T. J. (1991). *Increasing comprehension by activating prior knowledge* (ERIC Digest 61). Bloomington, IN: ERIC Clearinghouse on Reading, English, and Communication. Retrieved from http://eric.ed.gov/?id=ED328885

Clough, M. P., Berg, C. A., & Olson, J. K. (2009). Promoting effective science teacher education and science teaching: A framework for teacher decision-making. *International Journal of Science and Mathematics Education, 7*(4), 821–847.

Coiro, J. (2011). Predicting reading comprehension on the internet: Contributions of offline reading skills, online reading skills, and prior knowledge. *Journal of Literacy Research, 43*(4), 352-392. Retrieved from http://doi.org/10.1177/1086296X11421979

Costley, K. C., & West, H. G. (2012). Teaching practice: A perspective on inter-text and prior knowledge. *SRATE Journal, 21*(2), 21-25.

Cramer, L. (2015). Inequities of intervention among culturally and linguistically diverse students. *Perspectives on Urban Education, 12*(1), 1-9.

Cummins, J. (1991). *Empowering culturally and linguistically diverse students with learning problems*. Reston, VA: Council for Exceptional Children. Retrieved from http://eric.ed.gov/?id=ED333622

Curry, C., Cohen, L., & Lightbody, N. (2006). Universal design in science learning. *The Science Teacher, 73*(3), 32–37.

Dalton, B., Morocco, C. C., Tivnan, T., & Mead, P. L. R. (1997). Supported inquiry science: Teaching for conceptual change in urban and suburban science classrooms. *Journal of Learning Disabilities, 30*(6), 670–684.

Dalton, B., Proctor, C. P., Uccelli, P., Mo, E., & Snow, C. E. (2011). Designing for diversity the role of reading strategies and interactive vocabulary in a digital reading environment for fifth-grade monolingual English and bilingual students. *Journal of Literacy Research, 43*(1), 68–100. Retrieved from http://doi.org/10.1177/1086296X10397872

Dalton, E. M., & Brand, S. T. (2012). The assessment of young children through the lens of universal design for learning (UDL). *Forum on Public Policy Online, 2012*(1), 1-18.

Darling-Hammond, L. (2012). Redlining our schools: Why is congress writing off poor children? Linda Darling-Hammond. *The Nation, 294*(5), 11-15.

Davis, E. A. (2015). *Scaffolding learning*. In R. Gunstone (Ed.), Encyclopedia of Science Education (pp. 845–847). Springer Netherlands. Retrieved from http://link.springer.com/referenceworkentry/10.1007/978-94-007-2150-0_206

Davis, M. H., & Guthrie, J. T. (2015). Measuring reading comprehension of content area texts using an assessment of knowledge organization. *The Journal of Educational Research, 108*(2), 148–164. Retrieved from http://doi.org/10.1080/00220671.2013.863749

Deshler, D. D. (2015). Moving in the right direction but at what speed, and how smoothly? *Remedial and Special Education, 36*(2), 72-76.

Deshler, D. D., Schumaker, J. B., Lenz, B. K., Bulgren, J. A., Hock, M. F., Knight, J., & Ehren, B. J. (2001). Ensuring content-area learning by secondary students with learning disabilities. *Learning Disabilities Research & Practice, 16*(2), 96–108. Retrieved from http://doi.org/10.1111/0938-8982.00011

Dieker, L. A., Hynes, M. C., Hughes, C. E., Hardin, S., & Becht, K. (2015). TLE TeachLivE™: Using technology to provide quality professional development in rural schools. *Rural Special Education Quarterly, 34*(3), 11-16.

Dieker, D. L., Hynes, M., Stapleton, C., & Hughes, D. C. (2007). Virtual classrooms: STAR simulator building virtual environments for teacher training in effective classroom management. *New Learning Technology SALT, 4,* 1-22.

Dieker, L., Grillo, K., & Ramlakhan, N. (2012). The use of virtual and simulated teaching and learning environments: Inviting gifted students into science, technology, engineering, and mathematics careers (STEM) through summer partnerships. *Gifted Education International, 28*(1), 96–106. Retrieved from http://doi.org/10.1177/0261429411427647

Dieker, L., Rodriguez, J. A., Lignugaris/Kraft, B., Hynes, M. C., & Hughes, C. E. (2014). The potential of simulated environments in teacher education: Current and future possibilities. *Teacher Education and Special Education, 37*(1), 21–33.

Dogan, E., Ogut, B., & Kim, Y. Y. (2015). Early childhood reading skills and proficiency in NAEP eighth-grade reading assessment. *Applied Measurement in Education, 28*(3), 187–201. Retrieved from http://doi.org/10.1080/08957347.2015.1042157

Dunn, C., Rabren, K. S., Taylor, S. L., & Dotson, C. K. (2012). Assisting students with high-incidence disabilities to pursue careers in science, technology, engineering, and mathematics. *Intervention in School and Clinic*, *48*(1), 47–54.

Dye, M. W., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. *Neuropsychologia, 47*(8), 1780-1789.

Edyburn, D. L. (2010). Would you recognize universal design for learning if you saw it? Ten propositions for new directions for the second decade of UDL. *Learning Disability Quarterly*, *33*(1), 33-41.

Eslinger, E., White, B., Frederiksen, J., & Brobst, J. (2008). Supporting inquiry processes with an interactive learning environment: Inquiry Island. *Journal of Science Education and Technology, 17*(6), 610–617.

Erickson, A. S. G., Noonan, P. M., & McCall, Z. (2012). Effectiveness of online professional development for rural special educators. *Rural Special Education Quarterly, 31*(1), 22-32.

Evans, C., Williams, J. B., King, L., & Metcalf, D. (2010). Modeling, guided instruction, and application of UDL in a rural special education teacher preparation program. *Rural Special Education Quarterly, 29*(4), 41–48.

Every Student Succeeds Act of 2015, S. 1117, 114th Cong. (2015).

Fishman, D. (2015). School Reform for Rural America. *Education Next, 15*(3), 8-15.

Fogleman, J., McNeill, K. L., & Krajcik, J. (2011). Examining the effect of teachers' adaptations of a middle school science inquiry-oriented curriculum unit on student learning. *Journal of Research in Science Teaching, 48*(2), 149–169.

Fox, S. B., & McDermott, C. L. (2015). The role of 21st century skills in two rural regional areas of public education. *Journal for Leadership and Instruction, 14*(2), 26-30.

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education, 53*(2), 106–116.

G*Power 3 (2013). Software. Heinrich Heine University. Retrieved from http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction*. Boston : Pearson/Allyn & Bacon, c2007.

Habibi, A., Sarkissian, A. D., Gomez, M., & Ilari, B. (2015). Developmental brain research with participants from underprivileged communities: Strategies for recruitment, participation, and retention. *Mind, Brain, and Education, 9*(3), 179-186.

Hall, T. E., Cohen, N., Vue, G., & Ganley, P. (2015). Addressing learning disabilities with UDL and technology: Strategic reader. *Learning Disability Quarterly, 38*(2), 72–83.

Hall, T., Vue, G., Strangman, N., & Meyer, A. (2004). *Differentiated Instruction and Implications for UDL Implementation.* Wakefield, MA: National Center on Accessing the General Curriculum. (Links updated 2014). Retrieved from http://aem.cast.org/about/publications/2003/ncac-differentiated-instruction-udl.html

Helman, A. L., Calhoon, M. B., & Kern, L. (2015). Improving science vocabulary of high school English language learners with reading disabilities. *Learning Disability Quarterly, 38*(1), 40–52.

Hernandez, D. J. (2011). Double Jeopardy: How Third-Grade Reading Skills and Poverty Influence High School Graduation. *Annie E. Casey Foundation*. Retrieved from http://eric.ed.gov/?id=ED518818

Holmes, B. C. (1983). The effect of prior knowledge on the question answering of good and poor readers. *Journal of Literacy Research, 15*(4), 1–18. Retrieved from http://doi.org/10.1080/10862968309547493

Howley, C. (2001). The rural school bus ride in five states: *A Report to the Rural School and Community Trust*. Retrieved from http://files.eric.ed.gov/fulltext/ED456013.pdf

Hughes, C., Page, A., & Ford, D. Y. (2011). Cultural dynamics in an economically challenged, multiethnic middle school: Student perceptions. *Journal of At-Risk Issues, 16*(1), 9-16.

Hughes, C. E., Stapleton, C. B., Hughes, D. E., & Smith, E. M. (2005). Mixed reality in education, entertainment, and training. *IEEE Computer Graphics and Applications, 25*(6), 24–30. Retrieved from http://doi.org/10.1109/MCG.2005.139

Israel, M., Maynard, K., & Williamson, P. (2013). Promoting literacy-embedded, authentic STEM instruction for students with disabilities and other struggling learners. *TEACHING Exceptional Children, 45*(4), 18–25.

Izzo, M. V. (2012). Universal design for learning: Enhancing achievement of students with disabilities. *Procedia Computer Science, 14*, 343-350.

Jimenez, T. C., Graf, V. L., & Rose, E. (2007). Gaining access to general education: The promise of universal design for learning. *Issues in Teacher Education, 16*(2), 41–54.

Johnson, C. C., & Fargo, J. D. (2014). A study of the impact of transformative professional development on Hispanic student performance on state mandated assessments of science in elementary school. *Journal of Science Teacher Education, 25*(7), 845–859. Retrieved from http://doi.org/10.1007/s10972-014-9396-x

Johnston, P. (1984). Prior knowledge and reading comprehension test bias. *Reading Research Quarterly, 19*(2), 219–239. Retrieved from http://doi.org/10.2307/747364

Judge, S., Bobzien, J., Maydosz, A., Gear, S., & Katsioloudis, P. (2013). The use of visual-based simulated environments in teacher preparation. *Journal of Education and Training Studies, 1*(1), 88-97.

Katz, J. (2013). The three block model of Universal design for learning (UDL): Engaging students in inclusive education. *Canadian Journal of Education, 36*(1), 153-194.

Kennedy, M. J., Deshler, D. D., & Lloyd, J. W. (2015). Effects of multimedia vocabulary instruction on adolescents with learning disabilities. *Journal of Learning Disabilities, 48*(1), 22–38. Retrieved from http://doi.org/10.1177/0022219413487406

Kennedy, M. J., Thomas, C. N., Meyer, J. P., Alves, K. D., & Lloyd, J. W. (2014). Using evidence-based multimedia to improve vocabulary performance of adolescents with LD: A udl approach. *Learning Disability Quarterly, 37*(2), 71-86.

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM Career Interest Survey (STEM-CIS). *Research in Science Education, 44*(3), 461-481.

King, K. A., Kozleski, E. B., & Lansdowne, K. (2009). Where are all the students of color in gifted education? *Principal, 88*(5), 16–20.

Kirchgasler, K. L, & Feinstein, N. W. (2015). Sustainability in science education? How the Next Generation Science Standards approach sustainability, and why it matters. *Science Education*, *99*(1), 121–144. Retrieved from http://doi.org/10.1002/sce.21137

Knight, V. F., Wood, C. L., Spooner, F., Browder, D. M., & O’Brien, C. P. (2015). An exploratory study using science eTexts with students with autism spectrum disorder. *Focus on Autism & Other Developmental Disabilities, 30*(2), 86–99. Retrieved from http://doi.org/10.1177/1088357614559214

Kozleski, E. B. (2010). Culturally Responsive Teaching Matters. Online Submission. Retrieved from http://eric.ed.gov/?id=ED520957

Kozleski, E. B., & Waitoller, F. R. (2010). Teacher learning for inclusive education: Understanding teaching as a cultural and political practice. *International Journal of Inclusive Education, 14*(7), 655–666.

Krajcik, J., & Merritt, J. (2012). Engaging students in scientific practices: What does constructing and revising models look like in the science classroom? *Science Teacher, 79*(3), 38–41.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The Elementary School Journal, 94*(5), 483–497.

LeBlanc, J., & Larke, P. J. (2011). Culturally responsive teaching in science. *National Forum of Multicultural Issues Journal, 8*(1), 40-51.

Lerner, J. W., & Schuyler, J. A. (1973). Computer applications in the field of learning disabilities. Final Report. Retrieved from http://eric.ed.gov/?id=ED096974

Levy, M. S. (2011). Migrant laptops: Extending the academic day for the children of farm workers and their credit recovery via laptops. *Computers in the Schools, 28*(2), 140-157.

Lipson, M. Y. (1984). Some unexpected issues in prior knowledge and comprehension. *The Reading Teacher, 37*(8), 760–764.

Lomax, R. G., & Hahs-Vaughn, D. L. (2012). *An introduction to statistical concepts* (3rd ed.). New York, NY: Routledge/Taylor & Francis Group.

Lu, C. (2015). Finding los científicos within: Latino male science identity development in the first college semester. *Journal of College Student Development, 56*(7), 740-745.

Ludlow, B. L. (2015). Virtual reality: Emerging applications and future directions. *Rural Special Education Quarterly, 34*(3), 3-10.

Magnusson, S. J., & Palincsar, A. S. (1995). The learning environment as a site of science education reform. *Theory into Practice, 34*(1), 43–50.

Magnusson, S., & Krajcik, J. S. (1993). Teacher knowledge and representation of content in instruction about heat energy and temperature. Retrieved from http://eric.ed.gov/?id=ED387313

Marino, M. T., & Beecher, C. C. (2010). Conceptualizing RTI in 21st-century secondary science classrooms: Video games' potential to provide tiered support and progress monitoring for students with learning disabilities. *Learning Disability Quarterly, 33*(4), 299–311.

Marino, M. T., Coyne, M., & Dunn, M. (2010). The effect of technology-based altered readability levels on struggling readers' science comprehension. *Journal of Computers in Mathematics and Science Teaching, 29*(1), 31-49.

Marino, M. T., Tsurusaki, B. K., & Basham, J. D. (2011). Selecting software for students with learning and other disabilities. *Science Teacher*, *78*(3), 70–72.

Marshall, J. C. (2014). In step with the new science standards. *Educational Leadership, 72*(4), 16–22.

Mattingly, M. J., Johnson, K. M., & Schaefer, A. (2011). More poor kids in more poor places: Children increasingly live where poverty persists. Issue Brief Number 38. *Carsey Institute*. Retrieved from http://scholars.unh.edu/cgi/viewcontent.cgi?article=1149&context=carsey

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences, 15*(2), 153–191.

Meece, J. L., Hutchins, B. C., Byun, S. Y., Farmer, T. W., Irvin, M. J., & Weiss, M. (2013). Preparing for adulthood: A recent examination of the alignment of rural youth's future educational and vocational aspirations. *Journal of Educational and Developmental Psychology, 3*(2), 175-192.

Messinger-Willman, J., & Marino, M. (2010). Universal design for learning and assistive technology: Leadership considerations for promoting inclusive education in today's secondary schools. *NASSP Bulletin, 94*(1) 5–16. doi: org/10.1177/0192636510371977.

Metcalf, D., Evans, C., Flynn, H. K., & Williams, J. B. (2009). Direct instruction + UDL = access for diverse learners: How to plan and implement an effective multisensory spelling lesson. *TEACHING Exceptional Children Plus, 5*(6), 1-22.

Moll, K., Kunze, S., Neuhoff, N., Bruder, J., & Schulte-Körne, G. (2014). Specific learning disorder: Prevalence and gender differences. *PLoS ONE, 9*(7), 1–8. Retrieved from http://doi.org/10.1371/journal.pone.0103537

Mullen, C. A., & Kealy, W. A. (2013). Poverty in school communities. *Kappa Delta Pi Record, 49*(2), 70-77.

Musti-Rao, S., Cartledge, G., Bennett, J. G., & Council, M. (2015). Literacy instruction using technology with primary-age culturally and linguistically diverse learners. *Intervention in School and Clinic, 50*(4), 195-202.

Nakhleh, M. B., & Krajcik, J. S. (1991). The effect of level of information as presented by different technologies on students' understanding of acid, base, and ph concepts. Retrieved from http://eric.ed.gov/?id=ED347062

National Assessment Governing Board. (2010). *Science Framework for the 2011 National Assessment of Educational Progress.* Retrieved from https://www.nagb.org/publications/frameworks/science/2011-science-framework.html

National Assessment Governing Board. (2012). Reading Framework for the 2013 National Assessment of Educational Progress. National Assessment Governing Board.

National Assessment Governing Board. (2014). Abridged technology and engineering literacy framework for the 2014 National Assessment of Educational Progress. Washington, DC.

Neuman, S. B., Kaefer, T., & Pinkham, A. (2014). Building background knowledge. *Reading Teacher, 68*(2), 145–148. Retrieved from http://doi.org/10.1002/trtr.1314

Núñez-Mchiri, G. G. (2009). The political ecology of the colonias on the US-MEXICO border: Human-environmental challenges and community responses in southern New Mexico*. *Southern Rural Sociology, 24*(1), 67-91.

Orosco, M. J., & O'Connor, R. (2014). Culturally responsive instruction for English language learners with learning disabilities. *Journal of Learning Disabilities, 47*(6), 515-531.

Olinghouse, N. G., & Colwell, R. P. (2013). Preparing students with learning disabilities for large-scale writing assessments. *Intervention in School and Clinic, 49*(2), 67–76.

Palincsar, A. S., & Collins, K. M. (2000). Investigating the engagement and learning of students with learning disabilities in guided inquiry science teaching. *Language, Speech & Hearing Services in Schools, 31*(3), 240–252.

Palincsar, A. S., & Klenk, L. (1992). Fostering literacy learning in supportive contexts. *Journal of Learning Disabilities, 25*(4), 211-225.

Palincsar, A. S., Parecki, A. D., & McPhail, J. C. (1995). Friendship and literacy through literature. *Journal of Learning Disabilities, 28*(8), 503-510.

Peterson, B., Bornemann, G., Lydon, C., & West, K. (2015). Rural students in Washington State: STEM as a strategy for building rigor, postsecondary aspirations, and relevant career opportunities. *Peabody Journal of Education, 90*(2), 280-293.

Priebe, S. J., Keenan, J. M., & Miller, A. C. (2010). How prior knowledge affects word identification and comprehension. *Reading and Writing, 25*(1), 131–149. Retrieved from http://doi.org/10.1007/s11145-010-9260-0

Provasnik, S., Kastberg, D., Ferraro, D., Lemanski, N., Roey, S., & Jenkins, F. (2012). Highlights from TIMSS 2011: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context. NCES 2013-009. National Center for Education Statistics. Retrieved from http://eric.ed.gov/?id=ED537756

Puttick, G., & Mutch-Jones, K. (2015). Supporting science access for all students. *Science Scope, 38*(9), 31–37.

Rappolt-Schlichtmann, G., Daley, S. G., Lim, S., Lapinski, S., Robinson, K. H., & Johnson, M. (2013). Universal design for learning and elementary school science: Exploring the efficacy, use, and perceptions of a web-based science notebook. *Journal of Educational Psychology, 105*(4), 1210–1225. Retrieved from http://doi.org/10.1037/a0033217

Rivet, A. E., & Krajcik, J. S. (2008). Contextualizing instruction: Leveraging students' prior knowledge and experiences to foster understanding of middle school science. Journal of *Research in Science Teaching, 45*(1), 79–100.

Rose, D. H., Harbour, W. S., Johnston, C. S., Daley, S. G., & Abarbanell, L. (2006). Universal design for learning in postsecondary education: Reflections on principles and their application. *Journal of Postsecondary Education and Disability, 19*(2), 135–151.

Rose, D., & Meyer, A. (2000). Universal design for learning. *Journal of Special Education Technology*, *15*(1), 67–70.

Santiago, D.A., Galdeano, E.C., & Taylor, M. (2015). The condition of Latinos in Education: 2015 factbook. Excelencia in Education. Retrieved from http://www.edexcelencia.org/research/2015-factbook

Schumaker, J. B., & Deshler, D. D. (1992). *Validation of learning strategy interventions for students with learning disabilities: Results of a programmatic research effort*. In Contemporary intervention research in learning disabilities (pp. 22-46). Springer New York.

Scruggs, T. E., Brigham, F. J., & Mastropieri, M. A. (2013). Common Core Science Standards: Implications for students with learning disabilities. *Learning Disabilities Research & Practice, 28*(1), 49–57.

Scruggs, T. E., Mastropieri, M. A., Berkeley, S., & Graetz, J. E. (2010). Do special education interventions improve learning of secondary content? A meta-analysis. *Remedial and Special Education, 31*(6), 437–449.

Scruggs, T. E., Mastropieri, M. A., & Boon, R. (1998). Science education for students with disabilities: A review of recent research. *Studies in Science Education*, *32*(1), 21–44.

Scruggs, T. E., Mastropieri, M. A., Levin, J. R., & Gaffney, J. S. (1985). Facilitating the acquisition of science facts in learning disabled students. *American Educational Research Journal, 22*(4), 575–586. Retrieved from http://doi.org/10.2307/1163141

Seifert, K., & Espin, C. (2012). Improving reading of science text for secondary students with learning disabilities: Effects of text reading, vocabulary learning, and combined approaches to instruction. *Learning Disability Quarterly, 35*(4), 236–247.

Sherman. J. & Sage, R. (2011). Sending off all your good treasures: Rural schools, brain-drain, and community survival in the wake of economic collapse. *Journal of Research in Rural Education, 26*(11), 1-13. Retrieved from http://jrre.psu.edu/articles/26-11.pdf.

Simpkins, P. M., Mastropieri, M. A., & Scruggs, T. E. (2009). Differentiated curriculum enhancements in inclusive fifth-grade science classes. *Remedial and Special Education, 30*(5), 300–308.

Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among Latino and Caucasian boys and girls. *Journal of Research in Science Teaching*, *52*(10), 1386-1407.

Sinha, S., Rogat, T. K., Adams-Wiggins, K. R., & Hmelo-Silver, C. E. (2015). Collaborative group engagement in a computer-supported inquiry learning environment. *International Journal of Computer-Supported Collaborative Learning*, *10*(3), 273–307. Retrieved from http://doi.org/10.1007/s11412-015-9218-y

Stokes, P. J., Levine, R., & Flessa, K. W. (2015). Choosing the geoscience major: Important factors, race/ethnicity, and gender. *Journal of Geoscience Education, 63*(3), 250-263.

Strangman, N., Hall, T., & Meyer, A. (2004). *Background knowledge instruction and the implications for UDL implementation.* Wakefield, MA: National Center on Accessing the

General Curriculum. (Links updated 2009). Retrieved from http://aem.cast.org/about/publications/2004/ncac-background-knowledge-udl.html

Street, C. D., Koff, R., Fields, H., Kuehne, L., Handlin, L., Getty, M., & Parker, D. R. (2012). Expanding access to stem for at-risk learners: A new application of universal design for instruction. *Journal of Postsecondary Education and Disability, 25*(4), 363–375.

Sullivan, A. L., & Artiles, A. J. (2011). Theorizing racial inequity in special education: Applying structural theory to disproportionality. *Urban Education, 46*, 1526–1552. http://dx.doi.org/10.1177/0042085911416014

Sullivan, G. S., Mastropieri, A. M., & Scruggs, E. T. (1995). Reasoning and remembering: Coaching students with learning disabilities to think. *Journal of Special Education*, 29, 310–322. Retrieved from http://doi.org/10.1177/002246699502900304

Tarchi, C. (2010). Reading comprehension of informative texts in secondary school: A Focus on direct and indirect effects of reader's prior knowledge. *Learning and Individual Differences, 20*(5), 415–420.

Tarchi, C. (2015). Fostering reading comprehension of expository texts through the activation of readers' prior knowledge and inference-making skills. *International Journal of Educational Research*, 72, 80–88. Retrieved from http://doi.org/10.1016/j.ijer.2015.04.013

Tighe, E. L., Wagner, R. K., & Schatschneider, C. (2014). Applying a multiple group causal indicator modeling framework to the reading comprehension skills of third, seventh, and tenth grade students. *Reading and Writing, 28*(4), 439–466. Retrieved from http://doi.org/10.1007/s11145-014-9532-1

Trent, S. C., Driver, M. K., Rodriguez, D., Oh, K., Stewart, S., Kea, C., ... & Hull, M. (2014). Beyond Brown: Empirical research on diverse learners with or at-risk for specific learning disabilities from 1994-2012. *Multiple Voices for Ethnically Diverse Exceptional Learners*, *14*(2), 12-29. Retrieved from

Turing, A. M. (1950). Computing machinery and intelligence. *Mind, 59*(236), 433–460.

Ulrich, J. D. (2011). Education in chronically poor rural areas lags across generations. Issue Brief Number 24. *Carsey Institute*. Retrieved from http://scholars.unh.edu/cgi/viewcontent.cgi?article=1131&context=carsey

Vasquez III, E., Lopez, A., Straub, C., Powell, S., McKinney, T., Walker, Z., ... & Bedesem, P. L. (2011). Empirical research on ethnic minority students: 1995–2009. *Learning Disabilities Research & Practice*, *26*(2), 84-93.

Vasquez, E., Nagendran, A., Welch, G. F., Marino, M. T., Hughes, D. E., Koch, A., & Delisio, L. (2015). Virtual learning environments for students with disabilities: A review and analysis of the empirical literature and two case studies. *Rural Special Education Quarterly, 34*(3), 26-32.

Vasquez, E., & Serianni, B. A. (2012). Research and practice in distance education for K-12 students with disabilities. *Rural Special Education Quarterly*, *31*(4), 33.

Vasquez-Salgado, Y., & Chavira, G. (2014). The transition from middle school to high school as a developmental process among Latino youth. *Hispanic Journal of Behavioral Sciences*, *36*(1), 79-94.

Vaughn, S., & Fletcher, J. M. (2012). Response to intervention with secondary school students with reading difficulties. *Journal of Learning Disabilities*, *45*(3), 244–256. Retrieved from http://doi.org/10.1177/0022219412442157

Vaughn, S., Swanson, E. A., Roberts, G., Wanzek, J., Stillman-Spisak, S. J., Solis, M., & Simmons, D. (2013). Improving reading comprehension and social studies knowledge in middle school. *Reading Research Quarterly*, *48*(1), 77–93.

Verdugo, R. (2006). A report on the status of Hispanics in education: Overcoming a history of neglect. Washington, DC: National Education Association of the United States. Human and Civil Rights. Retrieved from http://199.223.128.57/assets/docs/HE/mf_hispaniced.pdf

Wanzek, J., & Vaughn, S. (2009). Students demonstrating persistent low response to reading intervention: Three case studies. Learning Disabilities Research & Practice, 24(3), 151–163. Retrieved from http://doi.org/10.1111/j.1540-5826.2009.00289.x

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, *16*(1), 3–118.

Won, M., Yoon, H., & Treagust, D. F. (2014). Students' learning strategies with multiple representations: Explanations of the human breathing mechanism. *Science Education*, *98*(5), 840–866. Retrieved from http://doi.org/10.1002/sce.21128

Young, M. F., & Kulikowich, J. M. (1992). Anchored instruction and anchored assessment: An ecological approach to measuring situated learning. Retrieved from http://eric.ed.gov/?id=ED354269

Zars, B. (1998). Long rides, tough hides: Enduring long school bus rides. *Rural School and Community Trust Policy Program*. Retrieved from http://www.eric.ed.gov/contentdelivery/servlet/ERICServlet?accno=ED432419

Zheng, B., Warschauer, M., Lin, C. H., & Chang, C. (2016). Learning in one-to-one laptop environments: A meta-analysis and research synthesis. *Journal of Educational Computing Research*. February, 5, 2016, 1-33. doi:10.3102/0034654316628645

Zhu, J., Moshell, J. M., Ontañón, S., Erbiceanu, E., & Hughes, C. E. (2011). *Why can't a virtual character be more like a human: A mixed-initiative approach to believable agents*. In R. Shumaker (Ed.), Virtual and Mixed Reality - Systems and Applications (pp. 289–296). Springer Berlin Heidelberg. Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-22024-1_32

Zirzow, N. K. (2015). Signing avatars: Using virtual reality to support students with hearing loss. *Rural Special Education Quarterly, 34*(3), 33-36.