AUGMENTED AND VIRTUAL REALITIES IN SPECIAL EDUCATION CONTEXTS: A META-ANALYSIS

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by

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ABSTRACT

The augmented and virtual reality applications literature base spans more than 30 years with one of the first studies conducted by Meredith Bricken in 1991. With the advances in technology, researchers are increasingly examining the use of augmented reality (AR) and virtual reality (VR) within educational contexts, more specifically special education contexts. VR is one of the fastest growing technologies (Nuguri, Calyam, Oruche, Gulhane, Valluripally, Stichter, & He, 2021) and AR is growing rapidly showing advances in interaction, navigation, and tracking within education, entertainment, business, medicine, and other settings (Ablyaev, Abliakimova, & Seidametova, 2020). Despite AR and VR demonstrating documented success with enriching learning opportunities and task performances (Billingsley, Smith, Smith, & Meritt, 2019; Bricken, 1991; Nuguri et al., 2021), there is limited research on applying these programs directly within a school setting for students with disabilities. To understand the effectiveness of AR and VR, a meta-analysis of six studies was conducted using hierarchical linear modeling focusing on functional, transitional, and social skills. Participants included 18 students ages 6-15-years-old all with a special education diagnosis (i.e., Intellectual Disability or Autism). Results suggest that these interventions are effective in developing functional, transitional, and social skills with students with disabilities. Most notably, participants aged 14-15 years old showed the greatest effect estimates. There were no differences for sex. Limitations and potential future directions in supporting students with disabilities are discussed.

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CHAPTER 1: INTRODUCTION

In response to the global COVID-19 pandemic, Governor Tom Wolf closed Pennsylvania's public schools for in-person learning beginning March 16, 2020 for two weeks, which eventually lasted through the remainder of the 2019-2020 school year. The Pennsylvania Department of Education (PDE) required school districts to create a Continuity of Education Plan and a Health and Safety Plan for approval. These plans sufficed in completing the 2019-2020 school term but failed to account for a true provision of a Free and Appropriate Public Education (FAPE) under the Individuals with Disabilities Education Act (IDEA, 2004). For students receiving special education services through their Individualized Education Programs (IEPs), many of their supports and services were unimplemented or, at least, negatively impacted by the global situation. More specifically, students with low-incidence disabilities, such as Autism, Intellectual Disability (ID), or Multiple Disabilities (MD), require supports and services to develop functional and transitional skills. At times, these skills occur via Community-based Instruction (CBI), as this model lends itself to natural practice of these functional and transitional skills (e.g., ordering from a menu, buying groceries, accessing public transportation, depositing or withdrawing money from the bank, and so forth). Unfortunately, these instructional experiences ceased March 16, 2020 and, in some instances, have yet to resume at particular school districts.

However, both augmented reality (AR) and virtual reality (VR) programs, which already exist, could have—should have—been utilized to continue a proper provision of a FAPE for these students. It is from this perspective that the current study investigated the effectiveness of augmented and/or virtual realities across various moderators as an instructional tool for students with low-incidence disabilities to receive functional and transitional skills training (at times, through CBI).

Overview

The IDEA (2004) requires local educational agencies (LEA) to service the specific needs of students with disabilities at school, to include academic instruction, related services, community experiences, and so forth. Services are based around the student's individual strengths and needs. The needs of students are met through an IEP which is a legally binding agreement between the IEP team which minimally includes parent, student (if 14 years of age or older in Pennsylvania), LEA representative, regular education teacher, and special education teacher. Other members could include related services (e.g., occupational therapist (OT), physical therapist (PT), speech therapist), school counselor, school psychologist, special education consultant, and/or specialist teachers. Within an IEP, a student must have targeted goals to meet the individual needs of the student. Often students with low-incidence disabilities require skill development in the areas of adaptive (functional) skills, transitional skills, and social skills, which are offered through the IEP by way of CBI. Particularly, individuals with physical, mental, cognitive, or sensory impairments face significant barriers that negatively affect their inclusion and participation in typical community activities (Baragash, Al-Samarraie, Alzahrani, & Alfarraj, 2020).

Virtual programs, originally developed for training task performance in the military (Furness, 1978), have undergone sophisticated upgrades to now offer students opportunities to see, hear, and touch virtual objects in real-life contexts without real-life limitations in order to acquire the necessary skills within IEP's. The innovation of technology applications can provide enhanced educational experiences. More specifically, the potential of AR and VR programs minimizes many obstacles students with disabilities face while maximizing their educational experience. As technology continues to advance and online learning environments continue, AR and VR can change the course of 21st Century learning and redefine how students with disabilities receive their education.

Significance of Study

Prior research conducted on AR provides evidence that it is effective for students to make academic gains (Baragash et al., 2020). The current study will research deeper into special education needs and provide evidence that AR and VR can help with the specialized teaching required to facilitate learning for specialized populations. Students with low-incidence disabilities face unique challenges that require the LEA to not only provide structured, consistent, and least restrictive environments but also naturalistic, creative, authentic, challenging, and enriching learning environments that overcomes communicative, cognitive, behavioral, physical, and developmental deficits. Special education populations require more assistance in meeting their learning goals.

Definition of Terms

1**. Augmented Reality (AR):** AR is a form of virtual technology "interconnecting virtual objects and integrating them into the real world" (p. 186, Gybas, Kostolányová, Klubal, 2019). Users see and interact with virtual objects through visual overlay and audio speakers (Sahin, Keshav, Salisbury, and Vahabzadeh, 2018). Furthermore, users look at a screen to experience the virtual environment (Cumming, 2007; Smedley & Higgins, 2005).

2. **Community-based Instruction (CBI): "**CBI is the [direct] instruction of functional skills in the place where they naturally occur" (p. 314, Rowe, Cease-Cook, & Test, 2011, as cited in Barczak).

3. **Least Restrictive Environment (LRE):** LRE is "the most integrated setting appropriate" (p.

523, Stone, 2018). As defined by IDEA (2004), LRE is when children with disabilities are educated with non-disabled peers to the maximum extent appropriate and the removal from the regular educational environment occurs only when the severity of the disability cannot be met in regular classes with supplementary aids and services. Failure to implement LRE is a violation of providing a free appropriate public education (FAPE).

4. **Virtual Reality (VR):** VR is an online three-dimensional environment where "generated objects are displayed on an imaging device" (p. 186, Gybas, Kostolányová, Klubal, 2019). Users are placed entirely in the virtual world (Sahin, Keshav, Salisbury, and Vahabzadeh, 2018). A user wears specialized equipment (i.e., headset, gloves, headphones) to be transported/fully immersed in the virtual environment and interacts through an avatar. The environment is seen by the user through the equipment (Cumming, 2007). Some or all of the senses are used within the environment (Eden & Bezer, 2011).

CHAPTER 2: LITERATURE REVIEW

The IDEA (2004) is a federal legislation that mandates LEAs to provide a FAPE to students with disabilities by meeting their individualized needs in the areas of academic instruction, related services, community experiences, transition services, and so forth. This study will focus on students with low-incidence disabilities, as defined by IDEA, 2004, including visual and/or hearing impairment, significant cognitive impairment, or any impairment that requires personnel with highly specialized skills to provide early intervention (EI) or FAPE. More specifically, this study will highlight the educational disability categories of Intellectual Disability (ID), Autism, and Multiple Disabilities (MD) and the need for academic instruction, community experience, and transitional services for functional skill development.

Educational Disabilities

Under the IDEA (2004), students qualify for special education services under one of thirteen disability categories (i.e., Autism, Deaf-Blindness, Deafness, Emotional Disturbance, Hearing Impairment, Intellectual Disability, Multiple Disabilities, Orthopedic Impairment, Other Health Impairment, Specific Learning Disability, Speech or Language Impairment, Traumatic Brain Injury, Visual Impairment Including Blindness). For this study, the low-incidence disabilities are the focus (i.e., ID, Autism, Multiple Disabilities), with the following definitions from IDEA (2004):

- Intellectual Disability (mental retardation) “means significantly subaverage general intellectual functioning, existing concurrently with deficits in adaptive behavior and manifested during the developmental period, that adversely affects a child’s educational performance” (§300.8 (8));
- “Autism means a developmental disability significantly affecting verbal and non-verbal

communication and social interaction, generally evident before age three, that adversely affects a child's educational performance. Other characteristics often associated with Autism are engagement in repetitive activities and stereotyped movements, resistance to environmental change or change in daily routines, and unusual responses to sensory experiences" (§300.8 (1)(i));

- Multiple Disabilities means concomitant impairments (such as [ID]-blindness or [ID]-orthopedic impairment), the combination of which causes such severe educational needs that they cannot be accommodated in special education programs solely for one of the impairments. Multiple disabilities does not include deaf blindness" (§300.8 (7)).

According to the Penndata Special Education Data Report School Year 2020-2021, 6.2% (19,070), 12.1 % (37,218), and 1.0% (3,075) of students are identified as having ID, Autism, and MD, respectively.

Intellectual Disability

The American Association on Intellectual and Developmental Disabilities (AAIDD) asserts that students with ID require a FAPE that includes fair evaluation, challenging goals and objectives, and the right to progress by receiving individualized supports, quality instruction, and access to the general education curriculum in inclusive settings (Thompson, Walker, Snodgrass, Nelson, Carpenter, Hagiwara, & Shogren, 2020). ID is a diverse disability that affects individuals differently; however, it is commonly characterized by problems in adaptive skills (Eden & Bezer, 2011; McNicholas, Floyd, Woods, Singh, Manguno, & Maki, 2018; Pan, Totsika, Nicholls, & Paris, 2018; Smogorzewska, Szumski, & Grygiel, 2018). Adaptive skills, which are comprised of conceptual skills, social skills, and practical skills (de Oliveira Malaquias, Malaquias, Lamounier Jr., & Cardoso, 2013), are essential for daily living functioning, interacting with others, and working. More specifically, adaptive behavior includes social functioning defined as deficits in understanding emotions, reduced communication skills, speech and language difficulties, lack of reciprocal communication which can lead to further difficulties in the educational environment and postsecondary transitioning (Smogorzewska et al., 2018). Chang, Kang, and Huang (2013) cite that those individuals with cognitive impairments are systematically excluded from working, as they are regarded as unemployable, which reinforcers the notion that this population requires training in functional skills.

Due to the need for developing essential daily living skills, students with ID can benefit from direct instruction and practice with independent and functional living skills. Online environments appear to demonstrate a way for individuals to learn and transfer these required skills in real-life situations. Computer-based technology and games are enjoyable for people with disabilities and provide an option to promote skill development within mainstream education settings (Standen, Brown, & Cromby, 2001).

Rubenstein, Daniels, Schieve, Christensen, Van Naarden Braun, Rice, and colleagues (2017), as cited in Howard, Copeland, Gifford, Lawson, Bai, Heilbron, and Maslow (2021), indicate that a decrease in prevalence of ID over time is linked to the increase of prevalence of Autism, which leads to focusing on the growing needs of students with autism.

Autism

Prevalence rates of Autism has increased, thus requiring schools to provide appropriate education services and raising the standards of a FAPE. *Endrew F. v. Douglas County School District* ruled that a child with Autism must have an IEP that appropriately challenges the student. Therefore, although goals may differ, each student will be given the chance to meet challenging objectives (Wangsgard & Cardon, 2020). More specifically, students with Autism require training in skill development for daily life in the community, which is grouped into five areas that include self-care, recreation, employment, and community participation (Clark, Field, Patton, Brolin, & Sitlington, 1994, as cited in Chiang, Ni, & Lee, 2017).

Autism is a multifaceted disability that has varying degrees of symptoms, deficits, impacts, and outcomes that influence the need for life skills training. One of the most common symptoms are social communication and social interaction deficits in individuals with Autism (American Psychiatric Association, 2013; Chen, Lee, & Lin, 2015; Ghanouni, Jarus, Zwicker, Lucyshyn, Mow, & Ledingham, 2018; Hu & Han, 2019; Jeffs, 2009; Self, Scudder, Weheba, & Crumrine, 2007). Social interaction can be defined as reciprocal communication where individuals initiate and respond to social stimuli with others (Merrell & Gimpel, 1988; Shores, 1987, as cited in Wang, Laffey, Xing, Galyen, & Stichter, 2017). Individuals with autism lack the ability to read verbal and nonverbal social cues (i.e., gestures, body movement, eye contact, facial expressions, and perspective-taking), which can result in exhibiting socially inappropriate behavior (Wang et al., 2017) and lead to fewer peer relationships, social networks, and engagement in activities (Ghanouni et al., 2018). Additionally, social skill deficits can lead to further difficulties in academic and occupational outcomes (Ke & Im, 2013).

When comparing students without disabilities and students with Autism, the latter have poorer postsecondary outcomes. In other words, less than half pursue postsecondary education and only about half find a paid job (Chiang, Cheung, Hickson, Xian, & Tsai, 2012; Chiang, Cheung, Li, & Tsai, 2013, as cited in Chiang et al., 2017). Evidence-based practices (i.e., peer reviewed educational interventions that are consistent and reliable) are most effective when working with students with Autism (Garland, Vasquez III, & Pearl, 2012). Now regarded as an evidence-based practice, life skills training can improve secondary transition for those with

Autism. Life skills training should be implemented within both classroom and community settings in order for students to develop and apply learned skills in daily living environments (Chiang et al., 2017).

Sahin, Keshav, Salisbury, and Vahabzadeh (2018) propose that technology-based interventions can be particularly suited for individuals with Autism due to a propensity to use digital tools with an expressed interest in electronic media, preference for predictable interactions, enjoyment in game-like tasks, and preference to computer-generated speech. Hu and Han (2019) support the use of technology and electronics to provide a natural, predictable, and less aversive environment for students with Autism. Moreover, Chia and Li (2012) suggest technology is portable and flexible, thus allowing for various advantages for children with difficulties. Self and colleagues (2007) propose virtual environments assist in generalization of skills, specifically communication skills for children with Autism. Therefore, AR and VR interventions may be particularly effective for students with Autism that require functional life skill development.

Multiple Disabilities

Students with MD often require the most extensive supports compared to all the disability categories under IDEA, exhibiting deficits in motor skills, cognitive skills, social skills, and self-care (DÜZKANTAR, ATLIN, ÖĞÜLMÜŞ, & GÖRGÜN, 2020), with documented difficulties achieving employment, postsecondary education, and independent community living outcomes (Shattuck, Wagner, Narendorf, Sterzing, & Hensley, 2011; Shogren & Plotner, 2012, as cited in Qian, Johnson, Wu, LaVelle, Thurlow, & Davenport, 2020). Consequently, their IEPs focus on functional life skills that help students to be more independent across various settings (e.g., school, home, community).

State legislation requires students with MD to progress in the general education curriculum in addition to receiving a modified functional life skills curriculum (Bobzien, 2014). Specifically, students with a concurrent visual impairment or blindness require skills to build orientation skills, navigation of the environment, and community literacy skills. Students with a concurrent orthopedic impairment require development in community literacy and navigation, mobility, social skills, and safety skills. As seen in these examples, the combination of multiple disabilities can manifest in complex needs and, consequently, necessitate creative or unique supports. There are multiple challenges to providing opportunities for students with MD to practice and acquire such skills in typical educational settings; however, the advantages to online learning environments, in particular, include repetition of skills in a safe, interactive, and engaging environment guided by an educator (Jeffs, 2009).

The unique challenges that students with disabilities (i.e., ID, Autism, and MD) face require special educational programming to meet their individual needs. Often times, those needs cannot be meet with typical general education curriculum or strictly within the structure of a classroom setting; therefore, instruction must be adapted to provide an environment to acquire and practice new skills. Community-based instruction provides students an opportunity to develop real world skills.

Community-based instruction

Community-based instruction (CBI) is an integral part of educational programming for students who have difficulties developing and applying daily living and other functional and/or transitional skills in real-life contexts. CBI supports students with disabilities by preparing them to transition into postsecondary life in a safe and natural setting. These students often struggle to generalize the skills learned in the structured environment of a classroom into other settings (e.g., community) since it does not emulate the real-world environment that is variable and unpredictable (Barczak, 2019; Cromby, Standen, & Brown, 1996; Hopkins & Dymond, 2020). For example, CBI provides instruction for students with ID, Autism, or MD the opportunity to learn specific skills (e.g., use money, communicate needs, social interactions, and so forth) in order to go grocery shopping, eat in a restaurant, go to a movie, and ride public transportation, all of which enhances their acquisition of independency.

CBI allows adults, by way of the special education teacher and paraprofessionals, to provide guidance and reinforcement of skills, which is important for learning of children with disabilities (Ke & Im, 2013). CBI, combined with direct classroom instruction, has been found to be more effective and allows students to acquire the necessary skills in less time than classroom instruction alone (Bates, Cuvo, Miner, & Korabek, 2001; Branham, Collins, Schuster, & Kleniert, 1999; Cihak, Alberto, Kessler, & Taber, 2004, as cited in Hopkins & Dymond, 2020). Instruction provided in the community decreases the need for repetitive instruction across various settings and allows for focused instruction of the targeted skill within the applicable environment, which decreases the need for students to generalize (Barczak, 2019). Other benefits of CBI include providing students with disabilities opportunities to familiarize themselves with the community organizations and build positive relationships with community members, which can positively affect postsecondary opportunities for these students (Barczak, 2019).

Research on successful methods for teaching these skills has been declining even though there is evidence supporting CBI as an evidence-based strategy to prepare students with low-incidence disabilities transitioning into adulthood (Hopkins & Dymond, 2020). Historically, some students have been precluded from CBI, which has most notably been exacerbated during and after the COVID-19 pandemic. School districts are limited in providing CBI due to transportation, funding, staffing, and administrative support, and it also reduces time in the classroom. To that end, the advances in educational technology, such as AR and VR, must be explored to enhance CBI instruction to promote the acquisition of functional, transitional, and social skills.

Functional Skills

Functional skills as defined as daily living skills that can positively or negatively affect the overall quality of life (Bobzien, 2014). In daily living, individuals with disabilities encounter difficulties in acquiring the skills to develop self-determination, self-help, and happiness (e.g., personal well-being, pleasure, and satisfaction) which can often be overlooked within educational contexts (Bobzien, 2014). Examples of functional skills important for students with disabilities to develop include the practical skills of cooking, cleaning, sewing, time management, and so on. Also included in functional skills development is physical skills, or activities that allow an individual with a disability to physically navigate tasks (e.g., navigation within a store or restaurant) and interactions which can reduce social isolation and promote relationships (McMahon, Cihak, & Wright, 2015, as cited in Baragash et al., 2020). Simulated learning environments provide an opportunity for students with disabilities to practice mobility, navigation, and advocacy skills within real-life contexts (Jeffs, 2009). VR can enhance functional performance in a flexible and ecologically valid way to improve specific skills in real-life simulations that are safe, interactive, and motivating for individuals with physical deficits (Kirshner, Weiss, & Tirosh, 2011).

Transitional Skills

Transitional skills are defined as overall skills to transition to be more independent moving from school age to adulthood across settings (e.g., home, community, work). These skills include community literacy (e.g., reading labels, maps, menus, bus schedules, and so forth), financial skills (e.g., purchasing skills, buying groceries, ordering from a menu, using the bank, and so forth.), occupational/vocational skills (e.g., applying for a job, time management, and so forth), and safety skills (e.g., reading traffic signs, crossing a cross walk, and so forth; Jeffs, 2009). Simulated environments allow individuals to explore, navigate, and manipulate the environment in order to utilize the necessary skills to succeed in the real world. For example, virtual environments were found to be new and effective ways for teaching skills for independent living for individuals with ID (Standen, Brown, & Cromby, 2001).

Social Skills

Improving social skills, as defined as verbal and nonverbal communication, social interaction (e.g., reciprocal conversation, taking another's perspective, asking for assistance, and so forth) and understanding and expressing emotions (e.g., speech, gestures, eye contact and body posture; Ke & Im, 2013), is a common goal within an IEP for students with low-incidence disabilities. Social skills training can facilitate understanding of social contexts that students with social deficits find difficult to interpret (Ghanouni et al., 2018). Therefore, providing them instruction and practice via innovative tools can improve their skills and promote positive behavior (Baragash et al., 2020). Communication skills are essential for daily life, which can impact an individual's social, emotional, and learning foundation (Lan, Hsiao, & Shih, 2018). Consequently, it is imperative to improve social communication skills, thereby improving a student with a disability's daily functioning.

Research suggests that using virtual environments demonstrates potential for teaching social skills for individuals with social deficits, including disabilities such as ID, Autism, and

MD (Cobb, 2007; Dieker, Hynes, Hughes, & Smith, 2008; Mitchell, Parsons, & Leonard, 2007). More specifically, virtual environments provide students with Autism an innovative way to challenge their typically rigid and inflexible language, behavior, and mental concepts (Jeffs, 2009).

Providing CBI to facilitate the development of functional, transitional, and social skills is critical to positively impacting student achievement and success. Although many factors inhibit school districts from providing CBI (i.e., staffing, budget, safety, and transportation), a major impact on CBI occurred globally during the COVID-19 pandemic resulting in mass school closures and prolonged online distance learning.

COVID-19 Closure & Online Distance Learning

During the 2020 global COVID-19 pandemic, mass school closures resulted in students receiving educational instruction by way of online distance learning (ODL) defined as virtual or remote learning, not face to face, via the internet (Eldokhny & Drwish, 2021). For example, school districts used internet applications such as Zoom and Google Classroom. During the 2019-2020 school year, all schools in Pennsylvania were closed for about 13 weeks. Although districts operated under state approved Continuity of Education Plans for the remainder of the year, a FAPE could not be fully provided to students with disabilities. Despite educators' utilization of ODL in new ways in attempts to be effective, CBI was significantly impacted and essentially eliminated during this time. Consequently, COVID-19 Compensatory Services (CCS) was offered to meet special education services missed due to the closures. A service to be considered as part of special education programming for CCS is CBI.

As schools prepared for reopening for the 2020-2021 school year all districts had to develop and implement a School Health and Safety Plan that followed all state policies and recommended state health and safety guidelines. Many school districts opted to remain closed, thereby continuing ODL, while others provided hybrid models, and fewer yet opened completely. Due to social distancing, mask mandates, and other health and mitigations efforts, the provisions continued to inhibit CBI and districts did not creatively adapt to address this problem. Specifically, one consideration overlooked by schools was the use of AR and VR to provide CBI, especially for students with low-incidence disabilities.

Due to comorbidity issues, these students can, at times, be regarded as medically fragile and, with this designation, many parents/guardians opted for their students to remain ODL longer than the state or school district required. Although a vaccination was developed and approved for adults and most teenagers, children elementary-aged cannot yet receive the vaccination and other parents may opt not to have their child receive the vaccination regardless of the child's age, which could lead to continued ODL for the 2021-2022 school year. Therefore, CBI through AR and VR continues to be a relevant topic of research and discussion. Some studies have shown that incorporating AR with ODL stimulates learning (Lytridis, Tsinakos, & Kazanidis, 2018, as cited in Eldokhny & Drwish, 2021). While virtual environment technology emerged in the 1970s with the latest advances in technology, there has been a dramatic rise in utilization continuing to grow since the early 2010s (Howard, 2018 and Plunkett, 2014, as cited in Howard & Gutworth, 2020).

Augmented Reality

An accepted definition of AR is defined as the "integration of three dimensional (3D) virtual objects into a 3D real environment in real time" (Azuma, 1997, as cited in Gybas, Kostolányová, Klubal, 2019, p. 185), and further understood as a simpler way to complete a task in the real world by combining virtual and real environments ((Dubois, Nigay & Troccaz, 2001, as cited in Gybas, Kostolányová, & Klubal, 2019; Eldokhyn & Drwish, 2021). Not only is AR a form of virtual technology, but specific features enable an individual to see information at the right time and place by linking realistic goals with 3D images and graphics that present facts, time, and spatial obstacles more effectively (Eldokhny & Drwish, 2021). AR technology takes virtual objects and audio guidance by way of a visual overlay and audio speakers allowing users to see and interact with the virtual world around them (Sahin et al., 2018). From an educational standpoint, AR is displaying text, video, and images (i.e., any computer-generated materials) through technology into a real-world environment (Yuen, Yaoyuneyong, & Johnson, 2011, as cited in Gybas, Kostolányová, & Klubal, 2019).

AR technology provides a realistic opportunity that enriches student engagement, motivation, and performance by allowing students to repetitively practice skills that are more difficult to repeat in reality. Moreover, AR equips educators to provide a learning environment individualized to meet students' creativity, imagination, learning style, and cognitive ability all while providing an environment suitable for collaborative, cooperative, and effective learning (Eldokhyn & Drwish, 2021). AR can also be commonly referred to as simulations or computer displayed virtual worlds (Cumming, 2007). In a simulation, a student assumes a role and makes choices while maneuvering through the environment (Smedley & Higgins, 2005).

Chen, Law, sand Chen (2018) as cited in Wang (2020) elaborate that AR, the combination of visual information with physical objects, helps present and explain educational content, more specifically abstract content. For example, Cheng and Tsai's (2013) research suggests that image-based AR benefits students' learning of practical skills and conceptual understanding. Research evidence not only supports the use of AR for educational learning but suggests benefits of AR for students with disabilities (Baragash et al., 2020; Cobb, 2007; Gybas et al., 2019; Jeffs, 2009; Lan et al., 2018; Wang, 2020). AR applications have been widely used to facilitate skill acquisition for individuals with learning, communication, behavior, and developmental disorders (Baragash et al., 2020). Sahin and colleagues (2018) highlight that technology-based interventions can support improvement in social-emotional skills, communication ability, academics, employment skills, and behavior for individuals with Autism. Chen and colleagues (2015) found evidence in their research that an AR program can be used to teach facial emotional expressions recognition and response. Skills acquired through AR programs help individuals with disabilities access their community and leisure activities (Chang, Chen, & Huang, 2011, as cited in Lin & Chang, 2015).

AR provides students with Autism a visual and auditory experience that promotes generalization, decreases rigidity, and is well-suited to meet their needs to learn social-emotional skills. AR applications on smartphones and tablets have shown improvement in identifying and understanding social cues, emotions, and facial expressions in book characters (Sahin et al., 2018). In terms of safety and sensory challenges, Sahin and collegues (2018) found in their study that individuals with Autism were able to use AR technology (e.g., AR smart glasses) without reporting any major negative effects (e.g., headache, eye strain, dizziness, and other sensory and motor discomfort).

AR simulations are more affordable and available compared to full-immersion VR programs (Cumming, 2007) making them more accessible within educational contexts. AR fills in the gaps to complete educational learning (Eldokhny & Drwish, 2021) and, therefore, is not considered to be a replacement but in addition to direct classroom instruction. Examples of AR programs or applications include Aurasma application, *Let's go banking!*, Augmented reality role-playing game (AR-RPG), Augmented reality concept map (ARCM), Kinect Skeletal

Tracking (KST) system, Meal-Maker, and Heads Up Navigator. Until the beginning of the 21st century, the terms AR and VR had similar definitions and were used interchangeably. However, the introduction of mobile technology helped delineate the difference between the two terms (Gybas et al., 2019).

Virtual Reality

In contrast to AR, VR can be defined as a representation of computer-generated, 3D, real life environments (Cobb, 2007; Chia & Li, 2012; Cromby et al., 1996; Fitzgerald, Yap, Ashton, Moore, Furlonger, Anderson, Kickbush, Donald, Busacca, & English, 2018; Howard & Gutworth, 2020; Hu & Han, 2019; Ke & Im, 2013; Muscott & Gifford, 1994; Self et al., 2007; Standen et al., 2001) that a user autonomously navigates with an avatar (i.e., graphical representations) (Ke & Im, 2013). Wang, Laffey, Xing, Galyen, and Stichter (2017) define VR as an online simulated environment where users have an opportunity to interact with others locally or globally using avatars, also considered a collaborative virtual environment (CVE). Zhang, Weitlauf, Amat, Swanson, Warren, & Sarkar (2020) define a CVE as a computer-based, online space where multiple users collectively interact including across various distances.

VR environments typically require a user to wear a head mounted stereoscopic display (e.g., Leap Motion, HTC Vive, Oculus Rift, Samsung Gear VR, and Google Cardboard) with headphones that allow a user to transmit and receive data, thus creating a total immersive experience (Cumming, 2007; Muscott et al., 1994; Newbutt, Bradley, Conley, 2020; Smedley & Higgins, 2005; Standen et al., 2001). Movements by the user are fed into the computer which generates a graphic display in real time based on the user's activity (Cromby et al., 1996). In contrast to AR, VR headsets allow the user to place themselves and their senses completely within the virtual world, thus removing them from seeing and hearing in the real world (Cobb, 2007; Radianti, Majchrzak, Fromm, & Wohlgenannt; 2020; Sahin et al., 2018), which can create a Cave Automatic Virtual Environment (CAVE). A CAVE uses surround vision projection where two or more people can experience the environment simultaneously while others observe (Cumming, 2007; Howard & Gutworth, 2020; Powers & Darrow, 1994; Smedley & Higgins, 2005). The CAVE environment can specifically benefit individuals with severe physical disabilities (Powers & Darrow, 1994).

VR can be a useful tool for individuals with disabilities because it offers a safe, structured, and controlled learning environment to acquire and practice the necessary competencies (Fitzgerald et al., 2018; Howard & Gutworth, 2020; Kirshner et al., 2011; Ke & Im, 2013; Self et al., 2007) to improve functional, transitional, and social skills. Collaborative virtual learning environments (CVLE) deliver a distinct likeness to real-life social scenarios (Bailenson, Yee, Merget, & Schroeder, 2006; Yee, Bailenson, Urbanek, Chang, & Merget, 2007, as cited in Wang et al., 2017). Additional advantages to VR for individuals with disabilities include creating a real-life practice environment where mistakes can be made without fear of danger or embarrassment, individuals with mobility issues can more easily navigate situations, and the experiences are not limited by caregivers who hinder the individual doing things on their own. Lastly, but particularly important for individuals with disabilities, virtual environments can be manipulated in ways the real world cannot. For example, scaffolding tasks so the user can start with simple skills and move to more complex skills at their individualized pace (Cromby et al., 1996; Standen et al., 2001).

Virtual learning environments (VLE) allow students to engage in interactive learning, but also provide the learner control over the learning process (Jeffs, 2009). VR can be a useful tool for individuals with disabilities because it supports generalization of social interactions into the real world (Beaumont & Sofronoff, 2008; Parsons & Cobb, 2011; Parsons & Mitchell, 2002; Schmidt & Schmidt, 2008; Strickland, McAllister, Coles, & Osborne, 2007, as cited in Ke & Im, 2013; Zhang et al., 2020) by providing role-play through flexible scenarios which helps develop cognitive flexibility. More specifically, individuals with Autism can practice a variety of responses to simulated but real-life scenarios with reduced anxiety yet increased cognitive flexibility (Parsons & Mitchell, 2002, as cited in Ke & Im, 2013). Standen and colleagues (2001) cite Sims (1994) who suggests individuals with ID, who typically display passive behavior, can benefit from interactive online learning environments where learning is controlled by the student, thus providing an environment that is self-paced with decreased peer irritation and increased attention to task.

VR programs such as Second Life, iSocial, Virtual Café, and virtual reality job interview training (VR-JIT) are examples of programs that can be infused into special education classrooms to develop daily living skills (i.e., functional, transitional, and social) and have a major impact on students with low-incidence disabilities by improving their overall ability to navigate in society.

Brain Impact

Pugnetti, Mendozzi, Barberi, Rose and Attree (1996) state in numerous research papers that VR profoundly affected the brain psychologically, neurophysiological, and emotionally. More specifically, VR affects the brain in terms of learning, cognition, perception, affect, and motivation. Pugnetti and colleagues (1996) examined brain functioning using electroencephalography (EEG) and event-related potential (ERP) during VR sessions. Maps of the brain showed distinct multi-channel changes in the brain before VR sessions compared to during VR sessions. The authors' findings suggest neurophysiological correlations. The specific areas of the brain affected were the anterior regions and frontal lobes (Pugnetti et al., 1996).

Furthering the research on the brain and VR, Rodriguez Ortega, Rey, Clemente Bellido, Wrzesien, and Alacañiz Raya (2015) found brain activation in the frontal lobe, limbic lobe, and temporal lobe during a VR simulation which is associated with emotional processes (e.g., sadness and happiness). Specific areas of the brain activated included the limbic lobe (e.g., emotional regulation), occipital lobe (e.g., cognitive reappraisal), parietal lobe (e.g., spatial processing and mental rotation tasks), and the temporal lobe and parietal lobe (e.g., sense of self-awareness, self-consciousness, presence, and navigation).

Zanier, Zoerle, Di Lernia and Riva (2018) and De Luca, Maggio, Maresca, Latella, Cannavò, Sciarrone, Lo Voi, Accorinit, Bramanti, and Calabrò (2019) state that VR requires cognitive involvement that may improve brain plasticity and regenerative processes. VR programs have been used to detect visual-vestibular deficits in adults, evaluate executive dysfunctions, and assess residual executive functions in individuals with traumatic brain injury (TBI). Other uses were to assess subclinical cognitive abnormalities in individuals that suffered a concussion but were asymptomatic. VR tools are demonstrated effective tools for neurorehabilitation. VR has the potential to address cognition, behavior, attention, memory, executive functioning, behavioral control, mood regulation, and many other areas individuals with brain deficits exhibit (Zanier et al., 2018).

Previous studies on AR and VR have yielded positive results worth future exploration. As technology continues to advance and the difficulties of students with disabilities require innovative yet evidence-based strategies to address, a meta-analysis to compile results on AR and VR programs with students with low-incidence disabilities (i.e., ID, Autism, and MD) provides further evidence for education entities to implement.

Purpose of the Study

Through an investigation of the research literature, the current study hopes to understand the effectiveness of AR and/or VR across various moderators as an instructional tool for students with low-incidence disabilities to receive functional and transitional skills training. With increasing numbers of students pursuing remote or online education settings, schools face challenges of meeting the IDEA (2004) mandates to ensure students with disabilities receive a FAPE, which is individualized to meet the students' specific needs through an IEP. More specifically, students who need CBI for development and implementation of functional and transitional skills training, the state mandates schools to develop goals, provide instruction, and monitor progress in relation to these aforementioned skills. A consequence of virtual schooling is the lack of opportunity to provide students with CBI opportunities. AR and/or VR programs offer students with disabilities receiving remote instruction opportunities to continue receiving direct instruction and implementation of functional and transitional skills.

Research Question

More specifically, the research question guiding this study is:

How effective are augmented and virtual realities across various moderators (i.e., school level, sex, and AR or VR)?

By investigating and answering this research question, the current study hopes to add to the literature on augmented and virtual realities in special education contexts and provide teachers with an evidence-based intervention to use with students with low-incidence disabilities to receive functional and transitional skills training.

Need for the Study

Although AR and VR have been shown effective in educational contexts (Baragash et al., 2020; Cobb, 2007; Cromby et al., 1996; Cumming, 2007; de Oliveira Malaquias et al., 2013; Eldokhny & Drwish, 2021; Gybas et al., 2019; Hu & Han, 2019; Jeffs, 2009; Lan et al., 2018; Muscott et al., 1994; Powers & Darrow, 1994; Sahin et al., 2018; Smedley & Higgins, 2005; Standen et al., 2001; Wang, 2020; Wu, Lee, Chang, & Liang, 2013), AR and VR utilized for a FAPE for students with low-incidence disabilities to meet CBI goals (functional, transitional, and social skills) has only recently been explored. At least six studies have investigated AR and/or VR for students with ID, Autism, and/or MD for CBI. With Bricken (1991) publishing the first known study using VR, she has influenced, and is cited in, subsequent studies on the topic. However, additional research is needed on both AR and VR as the prevalence of technology in special education classrooms, specifically with low-incidence populations, increases. After all, 70 percent of school-aged students own a device (Bedesem, 2012) and 90 percent of children in the United States between the ages of 5 and 17 use a computer daily (DeBell & Chapman, 2003, as cited in Cumming, 2007). Furthermore, increasingly schools are now implementing 1:1 device programs that can be used for AR/VR to improve functional, transitional, and social skills. For example, iPads can be used to utilize an AR program iSocial for a student with Autism to practice social skills. To that end, this study investigated the effectiveness of AR and VR across various moderators.

CHAPTER 3: METHODOLOGY

Restatement of the Purpose

The current study is a meta-analysis of six studies in order to understand the effectiveness of AR and VR as an instructional method for students with low-incidence disabilities to receive a FAPE through CBI in order to learn functional, transitional, and social skills. More specifically, this meta-analysis employed a hierarchical linear modeling as the quantitative method to answer the following research question:

> How effective are augmented and virtual realities across various moderators (i.e., school level, sex, and AR or VR)?

Procedure

Meta-analysis

The meta-analysis method was chosen to investigate the overall effect of AR and VR on transitional, functional, and social skills of students with low-incidence disabilities. This method was chosen because it combines data from multiple studies to determine the effect size estimates of multiple moderators (e.g., school level, sex, and AR or VR) on outcome variables. A smaller meta-analysis (i.e., less than 200 events) is useful for summarizing information and producing recommendations for future research (Flather, Farkough, Pogue, & Yusuf, 1997). Regardless of the breadth of the meta-analysis, combining multiple studies with smaller sample sizes into one larger sample size increases reliability and validity (Flather, Farkough, Pogue, & Yusuf, 1997; Glass, McGaw, & Smith, 1981).

A comprehensive search was conducted for studies utilizing AR and VR to analyze dependent variables of transitional, functional, and social skills. Continuing along the framework, as outlined by Glass, McGraw, and Smith (1981), the six identified studies were then reviewed and coded. Finally, the individual and overall effect size estimates for each moderator were calculated using hierarchical linear modeling, as described by Shadish (2014). Specifically, data points will be extracted from the sample study graphs using WebPlotDigitizer and coded for the total number of effect size estimates to be analyzed through hierarchical linear modeling.

Sampling of Studies

Search process. In order to complete the comprehensive search for existing data on AR and VR studies, the following chosen search terms were entered into *EBSCOhost*:

- Augment* reality or AR OR Virtual reality or VR AND Special Education,
- Augment* reality or AR AND Virtual reality or VR AND Special Education,
- Augment* reality or AR AND Virtual reality or VR AND Autism
- Augment* reality or AR AND Virtual reality or VR AND Multiple Disabilit*
- Augment* reality or AR AND Virtual reality or VR AND Intellectual Disabilit* or Mental Retardation
- Augment* reality or AR OR Virtual reality or VR AND Autism
- Augment* reality or AR OR Virtual reality or VR AND Multiple Disabilit*
- Augment* reality or AR OR Virtual reality or VR AND Intellectual Disabilit* or Mental Retardation
- Augment* reality or AR OR Virtual reality or VR AND Autism AND functional skills
- Augment* reality or AR OR Virtual reality or VR AND Multiple Disabilit* AND functional skills
- Augment* reality or AR OR Virtual reality or VR AND Intellectual Disabilit* or Mental Retardation AND functional skills
- Augment* reality or AR OR Virtual reality or VR AND Autism AND Transition* skills

- Augment* reality or AR OR Virtual reality or VR AND Multiple Disabilit* AND Transition* skills
- Augment* reality or AR OR Virtual reality or VR AND Intellectual Disabilit* or Mental Retardation AND Transition* Skills
- Augment* reality or AR OR Virtual reality or VR AND Autism AND Social skills
- Augment* reality or AR OR Virtual reality or VR AND Multiple Disabilit* AND Social skills
- Augment* reality or AR OR Virtual reality or VR AND Intellectual Disabilit* or Mental Retardation AND Social skills
- Augment* reality or AR AND Special Education,
- Augment* reality or AR AND Community Based Instruction or CBI,
- Augment* reality or AR AND functional skills,
- Augment* reality or AR AND transitional skills,
- Augment* reality or AR AND social skills,
- Virtual reality or VR AND Special Education,
- Virtual reality or VR AND Community Based Instruction or CBI,
- Virtual reality or VR AND functional skills,
- Virtual reality or VR AND transitional skills, and
- Virtual reality or VR AND social skills.

Finally, from the resulting studies from the aforementioned search terms, other studies were identified through a review of their references and searched for in *EBSCOhost*. It should be noted that the search was restricted to peer-reviewed articles with no limitations to publication date and all studies were written in English.

Criteria for selecting studies. The following inclusion criteria to qualify research studies for the current study were:

1. Study employed single-subject research design.
2. Study participants included at least one individual.
3. Study settings included at least one educational setting.
4. Study participants included at least one low-incidence disability (i.e., Autism, ID, MD).
5. Study intervention or independent variables included augmented and/or virtual realities.
6. Study dependent variables included quantitative measures of transitional, functional, and social skills.

The aforementioned search process and criteria filtering yielded six studies.

Coding of Studies

Table 1 summarizes the information from the six participating studies based on these categories: study, participant demographics, setting, type of disability, research design, independent variable, and dependent variable. Table 2 summarizes data based on these categories: study, number of participants, number of dependent variables, number of conditions, and number of effect size estimates. Specific coding information can be found in the corresponding Appendices A-D.

Table 1

Descriptive Information for Augmented and Virtual Reality Studies

Author(s), Year	Participant Characteristics	Setting	Independent Variable	Dependent Variable with Measures	Research Design
Cheng, Huang, & Yang, 2015	Three participants Male Unknown ethnicity Ages 10-13 Autism Special education eligible	Unknown school level Unknown grade	VR	Oral exam scores on social behavioral scale (SBS)	Multiple baseline across participants AB plus maintenance
Cihak, Moore, Wright, McMahon, Gibbons, & Smith, 2016	Three participants Male Unknown race/ethnicity Ages 6 & 7 Autism Special education eligible	Elementary school Grades 1 & 2	AR	Number of task-analyzed steps completed independently (out of 16) Event recording	Multiple baseline across participants AB plus maintenance
Kang & Chang, 2019	Three participants 2 Male 1 Female Unknown race/ethnicity Ages 14 & 15 Intellectual Disability Special education eligible	Junior high School Grade 9	AR	Percentage of correct task steps for cash withdrawal and money transfer	Multiple baseline across participants AB plus maintenance
Lee, Chen, Wang, &	Three participants 2 Male	Elementary School	AR	Ability to identify the correct	Multiple baseline

Chung, 2018a	1 Female Ages 8-9 Autism Special education eligible	Unknown Grade		greeting behavior	across participants AB plus maintenance
Lee, Lin, Chen, & Chung, 2018b	Three participants 2 Males 1Female Ages 7-9 Autism Special education eligible	Elementary School Unknown Grade	AR	Error rate	Multiple baseline across participants AB plus maintenance
Lee, 2021	Three participants 2 Males 1 Female Ages 7-9 Autism Special education eligible	Elementary School Unknown Grade	AR	Ability to accurately identify body gestures	Multiple baseline across participants AB plus maintenance

Note: AR = Augmented Reality; VR = Virtual Reality

Table 2

Number of Effect Sizes by Study

Author(s), Year	Number of Participants	Number of Dependent Variables	Number of Conditions	Number of Effect Sizes
Cheng, Huang, & Yang, 2015	3	1	1	3
Cihak, Moore, Wright, McMahon, Gibbons, & Smith, 2016	3	1	1	3
Kang & Chang, 2019	3	2	1	6
Lee, Chen, Wang, & Chung, 2018a	3	1	1	3
Lee, Lin, Chen, & Chung, 2018b	3	1	1	3
Lee, 2021	3	1	1	3
			Total	21

Primary Moderators

This study focused on three primary moderators which included school level, sex, and AR or VR. By determining the effect size estimates of AR or VR interventions on social, transitional, and functional skills, it allows the generalization of each study's results across school settings. Similarly, comparing the effect size estimates among boys versus girls allows the generalizability across all students. Finally, with AR being more researched than VR (Cihak, Moore, Wright, McMahon, Gibbons, & Smith, 2016; Kang and Chang, 2019; Lee, Chen, Wang, & Chung, 2018a; Lee, Lin, Chen, & Chung, 2018b; Lee, 2021), evaluating effect size estimates for AR and VR adds to the literature about VR as a viable intervention for developing social, transitional, and functional skills.

Outcome Variables

Social, transitional, and functional skills serve as the outcome variables of the current study. All six studies evaluated one or more of these as their dependent variable(s) to determine the efficacy of AR or VR as their intervention, or independent variable (Cihak, Moore, Wright, McMahon, Gibbons, & Smith, 2016; Cheng, Huang, & Yang, 2015; Kang and Chang, 2019; Lee, Chen, Wang, & Chung, 2018a; Lee, Lin, Chen, & Chung, 2018b; Lee, 2021). To that end, in order to corroborate the reliability and validity of results from each individual study included in this meta-analysis, the outcome variables of social, transitional, and functional skills is the outcome variable of the current study.

Participant Characteristics

Number. The total number of participants included within the six studies was 18 (n = 18). In all six of the studies the number of participants was three (n = 3).

Sex/Gender, age and race/ethnicity. Fourteen of participants were male (n = 14) and four of the participants were female (n = 4) in the corresponding studies. The ages of the participants ranged from 6- to 15- years old, more specifically 6 (n = 2), 7 (n = 4), 8 (n = 5), 9 (n = 1), 10 (n = 1), 11 (n = 1), 12 (n = 1), 14 (n = 1), and 15 (n = 2). The race and ethnicity of the participants was not included in any of the six studies; therefore, it is undetermined for all 18 participants.

Special education eligibility and disability labels. All the participants qualified under one of the thirteen special education disability categories. Fifteen of the eighteen participants had a special education eligibility diagnosis of Autism (n = 15), with the remaining participants qualifying for special education under ID (n = 3).

Settings. All the studies included had varying information included for the setting. Studies were conducted within a regular education classroom with the addition of a teacher's aide and occupational therapist substitute (n = 2), within a special education classroom (n = 3), and within a special education class with an Occupational Therapist (n = 1). None of the studies identified the region.

Data Analysis

Meta-analysis was created as a tool to extract pertinent information within the plethora of available research in journals and other sources (Glass, 2000, as cited in Cooper & Patall, 2009). Hauser (2007) claims meta-analysis as a valuable research tool that has impacted the field of scientific research. According to Cooper and Patall (2009) meta-analysis takes two forms as a technique to combine quantitative data from multiple different studies. Meta-analysis can be conducted in two forms, aggregated data (AD) or individual participant-level data (IPD). AD relies on summary results of studies creating a statistical synthesis of the data by collecting published and unpublished works on a specific topic, extracting effect size estimates within the reports, and combing effects to reveal an average effect size estimates (Cooper, 2009, as cited in Cooper & Patall, 2009).

IPD relies on central collection, checking, and re-analysis of each studies raw data to combine results. Similarly to AD, IPD collects data from both published and unpublished works. When outcomes across the various selected studies are measured exactly, the raw data can be re-analyzed using traditional inferential statistics (Cooper & Patall, 2009).

Kavale (1984) highlights the benefits of using meta-analysis specifically for research in special education. Due to the inconsistent and often contradictory nature of special education research, meta-analysis is warranted to find valuable information across studies. Specifically, when the literature is smaller it becomes more manageable, allowing for accumulating data that is direct. Special education research findings are highly variable, creating gaps in past and future research. However, synthesizing results creates comprehensive statistical summaries. Other advantages include (a) using quantitative methods for organization and information extraction from large databases, (b) eliminating selection bias, (c) transforming study information into equal experimental effects, (d) detecting statistical interactions, and (e) generating practical conclusions. In summary, a meta-analysis statistically accumulates data and findings from multiple separate studies into one comprehensive review summary (Kavale, 1984). A popular approach to analyze the data used in a meta-analysis is hierarchical linear modeling.

Hierarchical linear modeling (HLM) is used to analyze clustered data using regression equations to describe variations of scores within the groups being analyzed. A summary of findings of several cases are examined in a systematic and quantitative way. By aggregating the results of several cases, the power for assessing effect size estimates is increased and the results are not restricted to the specific studies cases, but instead allow for broader population inferences to be drawn. A major advantage to HLM is it can be easily adapted and is beneficial for behavioral research and particularly single-case study designs (Van den Noortgate & Onghena, 2007). There are various tools to extract data in order to apply HLM. WebPlotDigitizer is a free tool used to extract data points on an XY chart. Drevon, Fursa, and Malcolm (2017) found that WebPlotDigitizer is a reliable and valid tool for extracting data with intercoder reliability of 90% proportional agreement and over half in exact agreement.

CHAPTER 4: RESULTS

The purpose of the current investigation is to analyze existing research examining the impact of AR and VR technology on the skills of children with disabilities. This study utilizes meta-analytic techniques on a group of publicly available research studies that individually examined the effectiveness of AR or VR to support the development of functional, social, and transitional skills. The present hierarchical meta-analysis was guided by two research questions:

1. How effective are augmented reality (AR) and virtual reality (VR) technologies in supporting functional, social, and transitional skills of children with disabilities?
2. What moderators or variables are associated with effectiveness AR and VR interventions for students with disabilities?

Descriptive Analysis

A total of six studies with twenty-one effect size measures were analyzed. Outcome measures for each study was centered around functional, social, and transitional skills. Based on the individual participant data collected, the present study yielded twenty-one cases for a total sample size of n = 391 data points. The number of data points is based on the multiple outcome measures related to functional, social, and transitional skills development collected and analyzed for the investigation. Tables 3-5 provide demographic data of the study's participants, beginning with participants by gender. As indicated in Table 3, there were three times more male children diagnosed with a disability included as a part of the hierarchical meta-analysis compared to females. In Table 4, data are organized by age of participants, showing a large majority of participants' ages fell between six and 12 years. Finally, Table 5 includes demographic data organized by disability category. Autism is the identified disability for 71% of the participant data collected.

Table 3

Descriptive Data – Participants by Gender

Gender	*n*	%
Male	16	76.2
Female	5	23.8

Table 4

Descriptive Data – Participants by Age

Age (years)	*n*	%
6-12	15	71.4
14-15	6	28.6

Table 5

Descriptive Data – Participants by Disability

Disability	*n*	%
Autism	15	71.4
ID	6	28.6

In order to determine the effectiveness of AR or VR to support the development of functional, social, and transitional skills, including identified potential moderators or variables related to the intervention's efficacy, further examination of participant demographic data was warranted. A total of three models using Hierarchical Linear Modeling (HLM) were conducted. HLM was used to synthesize the available cases as a group in order to understand the degree of impacts found across different student characteristics on the skills being measured. HLM is considered to be the gold-standard approach in computing a synthesis of small sample studies because it takes into consideration the number of measures at and after baseline. Therefore, HLM accounts for any auto-correlations that may bias the data across the data collection (Boedeker, 2017).

The first model analyzed the effect of *all* identified moderator variables (i.e., gender, age, school level, study, disability, AR or VR, and skill) being measured against the outcomes across the baselines and subsequent phases. The HLM analysis used a restricted maximum likelihood (REML) estimation to reduce bias in comparison to a full maximum likelihood estimation. The decision to conduct a REML was based on the small number of groups in the present investigation (Boedeker, 2017). REML was used for each of the three models/runs. The results generated after one hundred iterations and the following levels were evaluated:

Model 1

Level-1 Model

$$OUTCOME_{ij} = \beta_{0j} + \beta_{1j}*(PHASE_{ij}) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(STUDY_j) + \gamma_{02}*(SCHOOLEVEL_j) + \gamma_{03}*(AGE_j) + \gamma_{04}*(SEX_j)$$

$$+ \gamma_{05}*(DISABILI_j) + \gamma_{06}*(AR\ OR\ VR_j) + \gamma_{07}*(SKILL) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

Mixed Model

$OUTCOME_{ij} = \gamma_{00} + \gamma_{01}*STUDY_j + \gamma_{02}*SCHOOLEVEL_j + \gamma_{03}*AGE_j$

$+ \gamma_{04}*SEX_j + \gamma_{05}*DISABILI_j + \gamma_{06}*AR\ or\ VR_j + \gamma_{07}*SKILL_j$

$+ \gamma_{10}*PHASE_{ij} + u_{0j} + r_{ij}$

The $OUTCOME_{ij}$ noted for the Level-1 Model refers to the functional, social, or transitional skills measure for participant "i" on level "j". The intercept for the Level-1 Model is β_{0j}, the slope for *PHASE*, β_{1j}, and r_{ij} accounts for the Level-1 error. In reference to Level-2, β_{0j}, refers to the results for the intercept. The intercept for the Level-2 Model is γ_{00}, the slope for *STUDY*, γ_{01}, the slope for *SCHOOL LEVEL*, γ_{02}, the slope for *AGE*, γ_{03}, the slope for *SEX*, γ_{04}, the slope for *DISABILITY*, γ_{05}, the slope for *AR or VR*, γ_{06}, the slope for *SKILL*, γ_{07}, and u_{0j} accounts for Level-2 error.

The results of this model did not converge as singularity exists between one moderator variable and the outcomes (disability by outcomes) and between two moderators (school level and age group). The model was reanalyzed after removing disability and school level, and the model was determined not to have the power to support analysis with all remaining moderator variables in a single model. Therefore, two additional models were conducted:

- Model 2 including AR vs. VR, Skill Type, and Study
- Model 3 including AR vs. VR, Age, and Gender

Model 2

Model 2 converged after 31 iterations, and is summarized:

Level-1 Model

$OUTCOME_{ij} = \beta_{0j} + \beta_{1j}*(PHASE_{ij}) + r_{ij}$

Level-2 Model

$\beta_{0j} = \gamma_{00} + \gamma_{01}*(STUDY_j) + \gamma_{02}*(AR\ OR\ VR_j) + \gamma_{03}*(SKILL_j) + u_{0j}$

$\beta_{1j} = \gamma_{10}$

Mixed Model

$OUTCOME_{ij} = \gamma_{00} + \gamma_{01}*STUDY_j + \gamma_{02}*AR\ or\ VR_j + \gamma_{03}*SKILL_j$

$+ \gamma_{10}*PHASE_{ij} + u_{0j} + r_{ij}$

The results from Model 2 are presented in Table 6.

Table 6

HLM Results for a Two-Level Model – Study, AR vs VR, and Skill

Fixed Effect	Coefficient	SE	*t*-ratio	*d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	66.716014	6.390030	10.441	17	<0.001
STUDY, γ_{01}	-5.718786	0.795974	-7.185	17	<0.001
AR OR VR, γ_{02}	-42.319585	3.888308	-10.884	17	<0.001
SKILL, γ_{03}	22.384980	1.803440	12.412	17	<0.001
For PHASE slope, β_1					
INTRCPT2, γ_{10}	2.393329	0.137499	17.406	368	<0.001

As shown in Table 6, all three potential moderators were revealed to be significant, with p-values of < 0.001. Specifically, these results indicate that there were significant differences found across the six investigations, the outcomes for AR relative to VR, and the outcomes based on the type of skill measured. Table 7 presents the average Tau-U for each study and shows the largest effect size estimates were reported in Lee (2021) and the smallest effect size estimates were found in Lee (2018). Table 8 presents the average Tau-U by AR or VR and revealed VR interventions resulted in the largest effect size estimates. Table 9 provides the average Tau-U by skill measured and the results indicate that the greatest effect for AR or VR is found in developing functional skills followed by transitional skills. Closer examination of the data reveals that the VR intervention was used with studies measuring social skills.

Table 7

Average Tau-U by Study

Study	N	Tau-U Mean	SD
1	3	0.984	0.014
2	3	0.838	0.140
3	6	0.957	0.057
4	3	-0.333	1.154
5	3	-0.999	0.000
6	3	0.999	0.000

Table 8

Average Tau-U by AR or VR

	N	Mean	SD
AR	18	0.427	0.911
VR	3	0.838	0.140

Table 9

Average Tau-U by Skill

Skill	N	Mean	SD
Functional	3	0.984	0.014
Social	12	0.126	0.997
Transitional	6	0.957	0.057

Model 3

Model 3 examined age, gender, AR, or VR, against the estimated effect size estimates. The model is summarized:

Level-1 Model

$$OUTCOME_{ij} = \beta_{0j} + \beta_{1j}*(PHASE_{ij}) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(AGE_{j}) + \gamma_{02}*(SEX_{j}) + \gamma_{03}*(AR\ or\ VR_{j}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

Mixed Model

$$OUTCOME_{ij} = \gamma_{00} + \gamma_{01}*AGE_{j} + \gamma_{02}*SEX_{j} + \gamma_{03}*AR\ or\ VR_{j}$$

$$+ \gamma_{10}*PHASE_{ij} + u_{0j} + r_{ij}$$

The results of Model 3, after seven iterations, are presented in Table 10.

Table 10

HLM Results for a Two-Level Model – Age, SEX, and AR vs VR

Fixed Effect	Coefficient	SE	*t*-ratio	*d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	30.064445	6.553158	4.588	17	<0.001
AGE, γ_{01}	34.688616	2.408926	14.400	17	<0.001
SEX, γ_{02}	0.535899	2.612815	0.205	17	0.840
AR or VR, γ_{03}	-24.937530	3.540750	-7.043	17	<0.001
For PHASE slope, β_1					
INTRCPT2, γ_{10}	2.389349	0.135209	17.672	368	<0.001

As indicated in Table 10, the outcomes did not significantly differ based on the gender of the student (p = 0.840), but significantly differed by AGE of the student and VR or AR, as indicated in the previous model. Closer examination of the data indicates that the greatest effect size estimates were found with 14–15-year-old students (Tau-U Mean = 0.957) relative to the 6–12-year-old students (Tau-U Mean = 0.298). The available data indicates that only 6-12-year-old students participated in the VR research (Tau-U Mean = 0.838), and that 14-15-year-old students had greater outcomes for the AR research (Tau-U Mean = 0.957).

Finally, the data were manually analyzed in order to assess the overall estimate of the use of AR and VR on students' development of functional, social, and transitional skills. The details of this analyses are presented in Appendix E. Overall, the use of AR and VR reveal a significantly large effect size estimate of Tau-U = 0.6364, $p < 0.001$ when examining all twenty-one students' data from baseline to subsequent phases of data collection.

Test of Bias Estimates: Egger's Test of the Intercept

Egger's Test of the Intercept suggests that bias is assessed by using precision (the inverse of the standard error) to predict the standardized effect (effect size divided by the standard error). In this equation, the size of the treatment effect is the slope of the regression line (B1) while bias is captured by the intercept (B0). This approach is advantageous in that it is a more powerful test, indicating that if an effect exists, it will more likely reveal that effect (Paige, Stern, Higgins, & Egger, 2020). For the current investigation, Egger's Test was computed in CMA®, a dedicated meta-analysis software. Results indicate that for the current investigation, the intercept (B0) is 0.04523, 95% confidence interval (-0.03749, 0.12795), with t = 1.14435, df = 19. The 1-tailed p-value is 0.13335, indicating no significant bias exists is the twenty-one effect size measures analyzed.

Summary

The current investigation utilized meta-analysis within an HLM platform to examine the impact AR or VR to support the development of functional, social, and transitional skills. The resulting analysis included three models:

1. A full model of all available moderators against the outcomes.
2. A second model examining for differences across the six studies, the skills being measured, and whether AR or VR was utilized.
3. A third model examining for differences across the age of the student, the gender of the student, and whether AR or VR was utilized.

Two moderators created singularity in the full model and were eliminated from the calculations. These variables were disability and school level. The second model revealed that there were differences in the reported effects for the six studies, as well as across the skills being measured, and whether AR or VR was being utilized in the intervention. The third model revealed that there were differences for age of the student, but no differences for sex. Further analysis revealed that 14-15-year-old students revealed the greatest effect estimates, however they were only included in the AR research studies. Overall, the use of AR and VR reveal a significantly large effect size estimate when examining all twenty-one students' data from baseline to subsequent phases of data collection.

While there is a lack of research available on AR and/or VR, the result of this investigation provides evidence that this technology can be effective in developing the functional, social, and transitional skills of students with disabilities. Chapter five will discuss these results in light of the available research and potential future directions in supporting students with disabilities through the use of these technologies.

CHAPTER 5: DISCUSSION

Inferences

The purpose of this meta-analysis was to investigate the effectiveness of AR and VR for developing functional, transitional, and social skills for students with low-incidence disabilities. The research questions guiding this study:

1. How effective are augmented reality (AR) and virtual reality (VR) technologies in supporting functional, social, and transitional skills of children with disabilities?
2. What moderators or variables are associated with effectiveness AR and VR interventions for students with disabilities?

The results of the current study suggest that AR and VR are effective to develop transitional, functional, and social skills for students with low-incidence disabilities (i.e., Autism and Intellectual Disability), supporting the prior research (Baragash et al., 2000; Cobb, 2007; Gybas et al., 2019; Jeffs, 2009; Ke & Im, 2013; Kirsher et al., 2011; Lan et al., 2018; Standen, 2001; Standen et al., 2001; Wang, 2020). When examining what moderators or variables are associated with effectiveness, AR and VR was shown effective across both age and gender. There was no significant difference across gender which is surprising due to the majority of participants being male (e.g., 76%). AR was shown specifically effective for participants ages 14-15-years-old across all three skills (i.e., transitional, functional, and social). VR was shown specifically effective for participants ages 6-12-years-old and particularly in teaching social skills. This is due to the only skill examined using VR was social skills, however, it is still statistically significant in effectiveness.

The population that had the largest effect size estimates was participants ages 6-12 and diagnosed with Autism. This may be due to the majority of participants included in the meta-analysis being between the ages of 6-12 years (e.g., 71%) old and with an Autism diagnosis (e.g., 71%). VR had the largest effect size estimates in comparison with AR, determining VR programs are more efficacious. This is noteworthy due to only one VR study was included in the meta-analysis.

Overall, the use of AR and VR was affective across phases (e.g., baseline to subsequent phases of data collection). AR or VR was found to be most effective in developing functional skills followed by transitional skills. Considering the majority of the meta-analysis examined social skills, the data suggests AR and VR are more suited to develop functional and transitional skills as compared to social skills. This somewhat contradicts the research literature that shows virtual environments are particularly suited for students to develop social skills due to their propensity for technology in relation to their disability (Cobb, 2007; Dieker et al., 2008; Jeffs, 2009; Mitchell et al., 2007).

Lee (2021) showed the largest effect size estimates compared to all six studies included in the meta-analysis. When considering the data collection method, participants were evaluated based on a 5-point Likert scale (i.e., 1- absolutely inappropriate, 2- slightly inappropriate, 3- neutral, 4- slightly appropriately, and 5- absolutely appropriate) after being asked to display the appropriate social greeting behavior for specific scenarios, leaving a margin for rater bias. Compared to the other studies which had a more methodical method for evaluation. Possible rater bias could result in over-estimation of effect size estimates.

Lee (2018a) and Lee (2018b) showed the smallest effect size estimates compared to all the studies. In both studies the data collection method was based on correct rate and error rate respectively. Participants chose a social behavior to respond to a specific scenario and it was either correct or incorrect, leaving no margin for interpretation. Therefore, the results can be considered more accurate, and illustrate a truer depiction of the participants skill development whether positive or negative in supporting the research hypothesis.

The existing research literature provided evidence that AR and/or VR was effective for developing functional (Jeffs, 2009; Kirsher et al., 2011), transitional (Jeffs, 2009; Standen et al., 2001), and social skills (Baragash et al., 2020; Sahin et al., 2018) for individuals with disabilities (Baragash et al., 2000; Cobb, 2007; Gybas et al., 2019; Jeffs, 2009; Lan et al., 2018; Wang, 2020), specifically, Autism (Ke & Im, 2013) and ID (Standen, 2001). Although, the existing research supports the results from this current meta-analysis, the current study adds further evidence for the specific population of students with disabilities receiving intervention within an educational context.

The current study included only six available studies on the topic of AR or VR as it is implemented for the development of functional, transitional, and social skills with students with low-incidence disabilities (e.g., Autism and ID) within an educational context resulting in 21 cases providing 391 extracted data points to run a HLM for examination. The majority of the population was male, ages 6-12-years-old, and diagnosed with Autism. Although significant effect size estimates resulted, the study is not without limitations which will be discussed in further detail.

Limitations

The following limitations must be taken into consideration when examining the results and conclusions. First, there is limited research literature on using AR and VR within an educational setting to instruct students with low incidence disabilities functional, transitional, and social skills, therefore yielding a small sample of studies to select to include within the meta-analysis. Specifically for VR, only one study was included as the rest were studies using AR.

All but one study was found using *EBSCOhost* excluding studies published in languages other than English and any unpublished and/or peer reviewed articles which contributes to possible sampling bias which leads to possible under- or over- estimation of the effect size estimates.

Due to the limited number of studies included, this resulted in convergence issues. More specifically for Model 1, in HLM, it was deemed not to have enough statistical power to evaluate the effectiveness across all moderators. Calculations were unable to determine efficacy across school level because of the singularity between school level and age. That is, all 14-15-year-olds were in the same school level (e.g., junior high) and 15 of 21 cases were 6-12 years old who were also coded as in elementary school. Therefore, school level and age moderators were too similar to distinguish and analyze through HLM. Likewise, 71% of participants had Autism. Singularity existed between disability and some other moderators. Increased studies would provide more accurate evidence of the effectiveness of AR and VR by alleviating the convergence issue mentioned.

Due to the nature of the topic being examined, data collection of the studies was variable. The variable nature of the collection methods used in each individual study can produce an under- or over-estimation of effect size estimates. The current study relies on the accuracy and reliability of the reporting of results for each individual study that was included in the meta-analysis. In response to these limitations, future recommendations will be discussed to further the investigation of this worthy topic.

Recommendations

In future research, the aforementioned limitations should be accounted for to produce further evidence of the effectiveness of AR and VR. During the study selection process only one other study was found examining VR but was not included due to the lack of data and data analysis.

This deemed it unusable for the current meta-analysis. The results indicate AR and VR are effective intervention tools to teach required skills to students with disabilities within educational contexts, providing educators more evidence-based strategies that are useful across various moderators (e.g., age and gender). Providing intervention directly in educational contexts provides students affordable access to effective tools. However, the small sample of the current study limited the generalizability of the results. Replication of results will increase the generalizability of findings.

As continued research develops, technology advances, and more affordable AR and VR options become available allowing for more schools to implement AR and VR within both regular and special education contexts, an updated meta-analysis can be conducted to further the research and provide more evidence of AR and VR's efficacy. In addition, with more studies, separating and examining more moderators and variables will account for singularity issues and results in further evidence of which target populations can benefit the most from AR and VR programs.

Conclusion

In conclusion, as COVID-19 continues to impact school districts and the education of students, specifically students with disabilities, options to provide FAPE, CBI, and evidence-based interventions to address IEP goals, transition goals, and necessary life skills, AR and VR programs were found effective across various moderators for the development of all three functional, transitional, and social skills. Although the current research is limited, future research can address the limitations of the current study to increase generalizability of results. In the meantime, there are affordable and accessible AR and VR options for educators to use in their classrooms to adhere to FAPE and LRE for students with disabilities requiring CBI per their IEPs. AR and VR provide a safe, controlled, naturalistic setting for students to learn and, with the evidence the current meta-analysis discovered, AR and VR are shown to be effective options.

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APPENDIX A

Data

Study	Study	Participant ID	Author	Year	Source
Chiak (2016)	1	101	5,12,15,11,6,13	2	1
Chiak (2016)	1	102	5,12,15,11,6,13	2	1
Chiak (2016)	1	103	5,12,15,11,6,13	2	1
Cheng (2015)	2	201	3,7,16	1	1
Cheng (2015)	2	202	3,7,16	1	1
Cheng (2015)	2	203	3,7,16	1	1
Kang (2019)	3	301	8, 1	4	1
Kang (2019)	3	302	8, 1	4	1
Kang (2019)	3	303	8, 1	4	1
Kang (2019)	3	304	8, 1	4	1
Kang (2019)	3	305	8, 1	4	1
Kang (2019)	3	306	8, 1	4	1
Lee (2018a)	4	401	9, 2, 14, 4	3	1
Lee (2018a)	4	402	9, 2, 14, 4	3	1
Lee (2018a)	4	403	9, 2, 14, 4	3	1
Lee (2018b)	5	501	9, 10, 2, 4	3	1
Lee (2018b)	5	502	9, 10, 2, 4	3	1
Lee (2018b)	5	503	9, 10, 2, 4	3	1
Lee (2021)	6	601	9	5	1
Lee (2021)	6	602	9	5	1
Lee (2021)	6	603	9	5	1

School Level	Age Range	Sex/Gender	Disability/Category	AR or VR	Type of Skill
1	1	1	1	1	1
1	1	1	1	1	1
1	1	1	1	1	1
3	1	1	1	2	2
3	1	1	1	2	2
3	1	1	1	2	2
2	2	1	2	1	3
2	2	1	2	1	3
2	2	1	2	1	3
2	2	1	2	1	3
2	2	2	2	1	3
2	2	2	2	1	3
1	1	1	1	1	2
1	1	1	1	1	2
1	1	2	1	1	2
1	1	1	1	1	2
1	1	1	1	1	2
1	1	2	1	1	2
1	1	1	1	1	2
1	1	1	1	1	2
1	1	2	1	1	2

APPENDIX B

Coding Key

Author(s)		**Year**		**Source**		**School Level**		**Age Range**	
Chang	1	2015	1	journal article	1	elementary	1	6-12	1
Chen	2	2016	2			junior high	2	14-15	2
Cheng	3	2018	3			unknown	3		
Chung	4	2019	4						
Cihak	5	2021	5						
Gibbons	6								
Huang	7								
Kang	8								
Lee	9								
Lin	10								
McMahon	11								
Moore	12								
Smith	13								
Wang	14								
Wright	15								
Yang	16								

Sex/Gender		**Disability/Category**		**AR or VR**		**Type of Skill**	
male	1	Autism	1	AR	1	Functional	1
female	2	ID	2	VR	2	Social	2
		MD	3			Transitional	3

APPENDIX C

Phases

Participant ID	Study	Phase	Session	Outcome
101	1	0	0.929296161	18.47215
101	1	0	1.970107862	18.47748312
101	1	0	3.016057135	12.55949762
101	1	0	4.008213005	18.6621424
101	1	0	5.005808657	18.49303806
101	1	1	6.008541881	12.40061509
101	1	1	6.995106862	24.94922425
101	1	1	7.981671844	37.49783342
101	1	1	9.033212005	25.13388353
101	1	1	9.99303139	18.51859259
101	1	1	10.97385438	37.68738139
101	1	1	11.9495398	62.77948882
101	1	1	12.90346608	62.95859277
101	1	1	13.96074824	93.97446324
101	1	1	14.92011431	87.88181806
101	1	1	15.96092601	87.88715118
101	1	1	16.96909901	75.52297908
101	1	1	17.99933336	87.72337995
101	1	1	18.94781986	94.17423303
101	1	1	19.93997573	100.2768778
101	1	1	20.98078744	100.2822109
101	1	1	21.93471372	100.4613149
101	1	2	67.95255301	94.59954935
102	1	0	1.0391198	37.7224199
102	1	0	2.03667482	31.6725979
102	1	0	2.95110024	37.9003559
102	1	0	3.99022005	31.4946619
102	1	0	4.94621027	25.2669039
102	1	0	7.9804401	25.2669039
102	1	0	11.0562347	37.7224199
102	1	0	13.9657702	43.772242
102	1	0	16.9584352	37.544484
102	1	0	19.9511002	37.544484
102	1	0	22.9437653	37.7224199

102	1	1	24.0244499	50.1779359
102	1	1	25.0635697	43.772242
102	1	1	25.9779951	56.405694
102	1	1	26.9755501	50.1779359
102	1	1	28.0146699	62.633452
102	1	1	29.0537897	62.633452
102	1	1	30.00978	50
102	1	1	31.0904645	56.227758
102	1	1	31.9633252	56.405694
102	1	1	32.9608802	68.683274
102	1	1	33.9584352	81.316726
102	1	1	35.0391198	93.9501779
102	1	1	36.0366748	100.355872
102	1	1	37.0342298	100.355872
102	1	1	37.9486553	100.355872
102	1	2	68.0831296	100.177936
103	1	0	0.89688249	24.8120301
103	1	0	1.95683453	24.8120301
103	1	0	3.01678657	25
103	1	0	3.91366906	24.8120301
103	1	0	8.03117506	24.6240602
103	1	0	11.0071942	18.7969925
103	1	0	13.942446	24.8120301
103	1	0	16.9592326	6.01503759
103	1	0	19.9760192	18.4210526
103	1	0	22.9928058	24.8120301
103	1	0	26.0095923	24.8120301
103	1	0	28.9448441	24.8120301
103	1	0	31.9616307	24.8120301
103	1	0	34.9784173	18.4210526
103	1	0	37.9952038	18.4210526
103	1	1	38.9736211	31.2030075
103	1	1	39.911271	37.2180451
103	1	1	40.971223	43.6090226
103	1	1	41.9088729	56.0150376
103	1	1	42.9688249	56.0150376
103	1	1	43.9472422	50
103	1	1	44.8848921	50
103	1	1	45.9448441	62.406015

103	1	1	46.9640288	43.6090226
103	1	1	47.942446	56.0150376
103	1	1	49.0023981	68.4210526
103	1	1	49.940048	62.593985
103	1	1	50.9592326	74.8120301
103	1	1	51.9376499	75.1879699
103	1	1	52.9160671	68.7969925
103	1	1	53.9760192	62.406015
103	1	1	54.9544365	68.4210526
103	1	1	55.9328537	62.406015
103	1	1	56.9520384	62.2180451
103	1	1	57.971223	81.2030075
103	1	1	58.9904077	87.593985
103	1	1	59.9280576	93.2330827
103	1	1	60.9064748	87.593985
103	1	1	61.9664269	93.2330827
103	1	1	62.9448441	100
103	1	1	63.9232614	93.2330827
103	1	1	64.9832134	100
103	1	1	65.9616307	100
103	1	1	66.940048	100
103	1	2	67.9184652	100
201	2	0	0.45844504	7.94646013
201	2	0	1.50268097	11.9891173
201	2	0	2.49597855	9.98669447
201	2	1	3.48927614	17.9398272
201	2	1	4.48257373	19.9670341
201	2	1	5.47587131	22.942389
201	2	1	6.4691689	24.9695959
201	2	1	7.48793566	24.0341575
201	2	2	9.47453083	25.9552378
201	2	2	13.4731903	28.138457
201	2	2	16.4530831	28.175633
202	2	0	0.49850075	11.0871369
202	2	0	3.50374813	12.0829876
202	2	0	4.50074963	10.0248963
202	2	0	5.49775112	14.0746888
202	2	1	6.46626687	22.1742739
202	2	1	7.49175412	24.1659751

202	2	1	8.48875562	20.1161826
202	2	1	9.47151424	24.1659751
202	2	1	10.4827586	26.1576763
202	2	1	11.494003	25.0954357
202	2	2	13.4737631	25.0954357
202	2	2	15.4962519	26.0912863
202	2	2	17.476012	27.0871369
203	2	0	0.50390016	11.9631375
203	2	0	3.49765991	2.99943709
203	2	0	4.47581903	8.03885681
203	2	0	5.49843994	10.0271161
203	2	0	6.46177847	10.1179536
203	2	0	7.49921997	8.97232095
203	2	1	9.48517941	18.2266755
203	2	1	10.4929797	14.9364556
203	2	1	11.50078	20.2235553
203	2	1	12.4641186	22.2113
203	2	1	13.4867395	24.1995593
203	2	2	14.4945398	24.2083085
203	2	2	15.4875195	25.289094
203	2	2	17.4586583	26.213423
301	3	0	0.86363636	27.176781
301	3	0	1.72727273	27.176781
301	3	0	2.59090909	27.176781
301	3	1	4.31818182	100
301	3	1	5.13636364	100
301	3	1	6	99.8680739
301	3	1	6.86363636	100
301	3	1	7.72727273	100
301	3	1	8.59090909	100
301	3	1	9.45454545	100
301	3	1	11.1818182	99.7361478
301	3	1	12	100
301	3	1	12.8636364	99.7361478
301	3	1	14.5909091	99.7361478
301	3	1	15.4545455	99.7361478
301	3	1	16.3181818	99.7361478
301	3	2	18	100
301	3	2	18.8636364	100

302	3	0	0.86363636	27.176781
302	3	0	1.72727273	27.176781
302	3	0	2.59090909	27.176781
302	3	1	4.31818182	100
302	3	1	5.13636364	100
302	3	1	6	99.8680739
302	3	1	6.86363636	100
302	3	1	7.72727273	100
302	3	1	8.59090909	100
302	3	1	9.45454545	100
302	3	1	11.1818182	99.7361478
302	3	1	12	100
302	3	1	12.8636364	99.7361478
302	3	1	14.5909091	99.7361478
302	3	1	15.4545455	99.7361478
302	3	1	16.3181818	99.7361478
302	3	2	18	100
302	3	2	18.8636364	100
303	3	0	0.88888889	22.997416
303	3	0	1.73333333	22.997416
303	3	0	2.57777778	50.129199
303	3	0	3.46666667	50.129199
303	3	0	4.31111111	50.129199
303	3	1	6.02222222	100.129199
303	3	1	6.88888889	100.258398
303	3	1	8.57777778	100.258398
303	3	1	9.44444444	100.129199
303	3	1	10.3111111	100
303	3	1	11.1555556	100.258398
303	3	1	12.0444444	100.258398
303	3	1	12.8888889	100
303	3	1	14.5777778	100.258398
303	3	1	15.4666667	100.258398
303	3	1	16.3111111	100
303	3	2	18.0444444	100
303	3	2	18.8888889	100
304	3	0	0.88888889	19.6382429
304	3	0	1.75555556	39.5348837
304	3	0	2.57777778	39.5348837

304	3	0	3.42222222	39.5348837
304	3	0	4.33333333	49.6124031
304	3	1	6.02222222	100.129199
304	3	1	6.88888889	100.258398
304	3	1	8.57777778	100.258398
304	3	1	9.44444444	100.129199
304	3	1	10.3111111	100
304	3	1	11.1555556	100.258398
304	3	1	12.0444444	100.258398
304	3	1	12.8888889	100
304	3	1	14.5777778	100.258398
304	3	1	15.4666667	100.258398
304	3	1	16.3111111	100
304	3	2	18.0444444	100
304	3	2	18.8888889	100
305	3	0	0.99547511	50.1312336
305	3	0	1.99095023	50.2624672
305	3	0	2.98642534	50.1312336
305	3	0	3.98190045	50.1312336
305	3	0	6.96832579	50.1312336
305	3	0	7.9638009	50.1312336
305	3	0	8.95927602	50.3937008
305	3	1	10.9954751	100
305	3	1	12.9864253	100
305	3	1	13.9819005	100
305	3	1	15	100.131234
305	3	1	15.9728507	100
305	3	1	16.9909502	100
305	3	1	17.9638009	100
305	3	1	19.0045249	100
305	3	2	20.9954751	100
305	3	2	21.9909502	100
306	3	0	0.99547511	29.9212598
306	3	0	1.99095023	39.6325459
306	3	0	2.98642534	39.6325459
306	3	0	3.95927602	39.7637795
306	3	0	6.96832579	39.6325459
306	3	0	7.98642534	99.7375328
306	3	0	8.95927602	39.6325459

306	3	1	10.9954751	100
306	3	1	12.9864253	100
306	3	1	13.9819005	100
306	3	1	15	100.131234
306	3	1	15.9728507	100
306	3	1	16.9909502	100
306	3	1	17.9638009	100
306	3	1	19.0045249	100
306	3	2	20.9954751	100
306	3	2	21.9909502	100
401	4	0	0.49797023	29.3103448
401	4	0	1.61840325	16.091954
401	4	0	2.67658999	29.3103448
401	4	0	3.64140731	14.9425287
401	4	0	4.69959405	21.2643678
401	4	0	5.72665765	25.862069
401	4	1	6.72259811	45.9770115
401	4	1	7.78078484	54.5977011
401	4	1	8.80784844	59.1954023
401	4	1	9.91271989	45.4022989
401	4	1	10.8930988	59.7701149
401	4	1	11.9512855	55.1724138
401	4	1	12.947226	65.5172414
401	4	1	13.9431664	49.7126437
401	4	1	15.0013532	60.3448276
401	4	1	15.9972936	68.9655172
401	4	2	17.0554804	45.4022989
401	4	2	18.0514208	60.3448276
401	4	2	19.1096076	54.5977011
401	4	2	20.1366712	65.5172414
401	4	2	21.2259811	59.7701149
401	4	2	22.1596752	55.1724138
402	4	0	0.49132176	19.8992596
402	4	0	1.59679573	20.4947506
402	4	0	2.64085447	15.975088
402	4	0	3.623498	25.0902719
402	4	0	4.69826435	30.2304588
402	4	0	5.71161549	14.9145831
402	4	0	6.70961282	30.2801463

402	4	0	7.76902537	25.1926812
402	4	1	8.81308411	40.5593822
402	4	1	9.88785047	53.6541146
402	4	1	10.9012016	75.554148
402	4	1	11.9452603	65.0685763
402	4	1	12.9586115	70.207246
402	4	1	13.941255	75.3451572
402	4	1	14.9853138	81.6209491
402	4	1	15.9986649	75.9641643
402	4	1	17.0427236	65.1945018
402	4	1	18.0560748	76.0149897
402	4	2	19.1308411	45.3597221
402	4	2	20.1134846	55.6112696
402	4	2	21.2496662	51.0938828
402	4	2	22.1708945	55.0939131
403	4	0	0.50291545	24.8447205
403	4	0	1.60932945	14.2857143
403	4	0	2.68221574	24.8447205
403	4	0	3.65451895	19.8757764
403	4	1	4.69387755	35.4037267
403	4	1	5.73323615	39.7515528
403	4	1	6.70553936	44.7204969
403	4	1	7.77842566	60.2484472
403	4	1	8.81778426	54.6583851
403	4	1	9.89067055	59.0062112
403	4	1	10.8965015	64.5962733
403	4	1	11.9693878	69.5652174
403	4	1	12.9752187	65.2173913
403	4	1	13.9475219	59.6273292
403	4	2	15.0204082	54.6583851
403	4	2	15.9927114	60.2484472
403	4	2	17.03207	45.3416149
403	4	2	18.0379009	55.2795031
403	4	2	19.1107872	54.6583851
403	4	2	20.1166181	59.6273292
403	4	2	21.2565598	64.5962733
403	4	2	22.1618076	45.3416149
501	5	0	0.49713056	75.3058856
501	5	0	1.62697274	69.7483597

501	5	0	2.65136298	65.0278884
501	5	0	3.61549498	70.4165525
501	5	1	4.67001435	59.7988168
501	5	1	5.69440459	45.8086825
501	5	1	6.70373027	30.9750455
501	5	1	7.74318508	26.2553802
501	5	1	8.76757532	26.3101897
501	5	1	9.82209469	15.692454
501	5	1	10.8163558	20.2400335
501	5	1	11.8708752	15.8020731
501	5	2	12.8651363	36.0799897
501	5	2	13.8292683	31.0753954
501	5	2	14.8837877	24.9520417
501	5	2	15.8780488	25.0052391
501	5	2	16.9325681	20.005481
501	5	2	17.9268293	26.2384537
501	5	2	18.9813486	20.1151
501	5	2	19.9756098	25.786275
502	5	0	0.51289009	70.212766
502	5	0	1.62415197	64.893617
502	5	0	2.64993216	59.0425532
502	5	0	3.61872456	68.6170213
502	5	0	4.67299864	73.9361702
502	5	0	5.69877883	68.6170213
502	5	1	6.69606513	55.8510638
502	5	1	7.75033921	45.7446809
502	5	1	8.74762551	25.5319149
502	5	1	9.83039349	26.0638298
502	5	1	10.8276798	20.7446809
502	5	1	11.85346	16.4893617
502	5	1	12.8507463	20.7446809
502	5	1	13.8480326	10.106383
502	5	2	14.8738128	25.2659574
502	5	2	15.8710991	21.2765957
502	5	2	16.8968792	21.2765957
502	5	2	17.8941655	25.5319149
502	5	2	18.9769335	17.0212766
502	5	2	19.9742198	16.4893617
503	5	0	0.5193068	69.2004238

503	5	0	1.60675803	64.5793676
503	5	0	2.66146995	54.7248469
503	5	0	3.62899767	64.6353543
503	5	0	4.6882316	69.3158425
503	5	0	5.71635415	73.9954694
503	5	0	6.70902419	64.7206264
503	5	0	7.768439	69.9825149
503	5	1	8.75622529	45.0098623
503	5	1	9.82649291	35.1557722
503	5	1	10.8361657	30.5325627
503	5	1	11.8614846	26.2004841
503	5	1	12.8596715	34.6583519
503	5	1	13.8505327	19.5695053
503	5	1	14.8759421	15.5281269
503	5	1	15.8715062	15.5556895
503	5	2	16.9320063	24.3059802
503	5	2	17.9263043	20.2637404
503	5	2	18.9826441	15.6418229
503	5	2	19.9780274	15.0879853
601	6	0	0.47644231	15.2173913
601	6	0	1.60977564	8.69565217
601	6	0	2.65649038	8.42391304
601	6	0	3.63301282	20.1086957
601	6	0	4.69455128	20.1086957
601	6	1	5.73108974	35.326087
601	6	1	6.73525641	40.7608696
601	6	1	7.81434295	50.2717391
601	6	1	8.83285256	54.3478261
601	6	1	9.92820513	69.0217391
601	6	1	10.930609	68.4782609
601	6	1	11.9613782	64.1304348
601	6	1	12.9961538	73.3695652
601	6	2	13.9666667	64.673913
601	6	2	15.0294872	69.0217391
601	6	2	16.0291667	59.2391304
601	6	2	17.0629808	65.2173913
601	6	2	18.0653846	64.673913
601	6	2	19.1564103	64.673913
601	6	2	20.1559295	54.3478261

602	6	0	0.5117801	24.6851367
602	6	0	1.62565445	20.7155323
602	6	0	2.67931937	14.8058464
602	6	0	3.64267016	19.7360384
602	6	0	4.69633508	19.6596859
602	6	0	5.75	14.5833333
602	6	0	6.7434555	18.9557882
602	6	0	7.79712042	24.9905468
602	6	1	8.82068063	29.9163758
602	6	1	9.90445026	43.7267307
602	6	1	10.9280105	54.2081152
602	6	1	11.9816754	58.8539849
602	6	1	12.9751309	68.5042176
602	6	1	13.9685864	73.9877836
602	6	1	15.0222513	68.6336533
602	6	1	16.0157068	48.8394415
602	6	2	17.0693717	68.763089
602	6	2	18.0628272	68.1355439
602	6	2	19.1465969	63.3347877
602	6	2	20.1400524	68.2627981
603	6	0	0.49263722	19.8985335
603	6	0	1.60107095	25.607734
603	6	0	2.64792503	19.9517768
603	6	0	3.63319946	25.6579348
603	6	1	4.71084337	25.4004655
603	6	1	5.72690763	35.3687477
603	6	1	6.71218206	39.938542
603	6	1	7.78982597	50.1924364
603	6	1	8.83668005	51.0705702
603	6	1	9.91432396	70.6994645
603	6	1	10.8995984	65.0419861
603	6	1	11.9464525	70.7496653
603	6	2	12.9625167	65.6611294
603	6	2	13.9477912	60.003651
603	6	2	14.9330656	70.2552635
603	6	2	16.0107095	70.2818851
603	6	2	17.0267738	60.9319855
603	6	2	18.0890228	60.6741359
603	6	2	19.0589023	60.6980954

603	6	2	20.1365462	56.1792625

APPENDIX D

Moderators

Participant ID	**School Level**	**Age Range**	**Sex/Gender**	**Disability/Category**	**AR or VR**	**Type of Skill**
101	1	1	1	1	1	1
102	1	1	1	1	1	1
103	1	1	1	1	1	1
201	3	1	1	1	2	2
202	3	1	1	1	2	2
203	3	1	1	1	2	2
301	2	2	1	2	1	3
302	2	2	1	2	1	3
303	2	2	1	2	1	3
304	2	2	1	2	1	3
305	2	2	2	2	1	3
306	2	2	2	2	1	3
401	1	1	1	1	1	2
402	1	1	1	1	1	2
403	1	1	2	1	1	2
501	1	1	1	1	1	2
502	1	1	1	1	1	2
503	1	1	2	1	1	2
601	1	1	1	1	1	2
602	1	1	1	1	1	2
603	1	1	2	1	1	2

APPENDIX E

Tau Output

Identification	S	PAIRS	TAU	TAU	VARIANCE	SD	SD Tau	Z	P Value	CI 90%
101	100	102	0.98	0.98	816.00	28.57	0.28	3.50	0.00	0.520<>1
102	174	180	0.97	0.97	1680.00	40.99	0.23	4.25	0.00	0.592<>1
103	360	360	1.00	1.00	4800.00	69.28	0.19	5.20	0.00	0.683<>1
201	68	80	0.85	0.85	666.67	25.82	0.32	2.63	0.01	0.319<>1
202	68	70	0.97	0.97	420.00	20.49	0.29	3.32	0.00	0.490<>1
203	36	56	0.64	0.69	354.67	18.83	0.34	1.91	0.06	0.090<>1
301	65	65	1.00	1.00	411.67	20.29	0.31	3.20	0.00	0.487<>1
302	61	72	0.85	0.85	456.00	21.35	0.30	2.86	0.00	0.359<>1
303	70	70	1.00	1.00	420.00	20.49	0.29	3.42	0.00	0.518<>1
304	64	72	0.89	0.94	432.00	20.78	0.29	3.08	0.00	0.414<>1
305	73	77	0.95	0.95	487.67	22.08	0.29	3.31	0.00	0.476<>1
306	99	99	1.00	1.00	693.00	26.32	0.27	3.76	0.00	0.563<>1
401	55	55	1.00	1.00	311.67	17.65	0.32	3.12	0.00	0.472<>1
402	-50	50	-1.00	-1.00	266.67	16.33	0.33	-3.06	0.00	-1<>-0.463
403	-63	63	-1.00	-1.00	357.00	18.89	0.30	-3.33	0.00	-1<>-0.507
501	-50	50	-1.00	-1.00	266.67	16.33	0.33	-3.06	0.00	-1<>-0.463
502	-63	63	-1.00	-1.00	357.00	18.89	0.30	-3.33	0.00	-1<>-0.507

503	-81	81	-1.00	-1.00	513.00	22.65	0.28	-3.58	0.00	-1<>-0.540
601	60	60	1.00	1.00	340.00	18.44	0.31	3.25	0.00	0.494<>1
602	81	81	1.00	1.00	513.00	22.65	0.28	3.58	0.00	0.540<>1
603	45	45	1.00	1.00	225.00	15.00	0.33	3.00	0.00	0.452<>1

APPENDIX F

IRB Approval

SlipperyRock University of Pennsylvania

TO: Dr. Matthew Erickson
Special Education

FROM: ________________________________
Michael Holmstrup, Ph.D., Chairperson
Institutional Review Board (IRB)

DATE: September 17, 2021

RE: Protocol Title: Augemented and Virtual Realities in Special Education Contexts: A Meta-Analysis

Your protocol submission has been reviewed and determined to not be research as defined by the Federal Regulations that govern human research (45 CFR part 46). Therefore, it does not require the review/approval of the IRB.

We appreciate you submitting the protocol for clarification, and hope that you will continue to consult with the IRB in the future.

If you have any questions, please contact the IRB Office by phone at (724)738-4846 or via e-mail at irb@sru.edu.