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The Effects of a Video-Enhanced Intervention Package on the Science Practices of Students with Neurodevelopmental Disorders

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Abstract

Students with intellectual disabilities (ID) and neurodevelopmental disorders (NDD) often experience barriers to accessing science, technology, engineering, and mathematics (STEM) instruction in the general classroom. The current research guiding equitable STEM education for this population lacks scope, primarily targeting vocabulary or content knowledge instead of the cross-curricular application of science practice skills in STEM. Using single-case research designs, the current paper examined the efficacy of an intervention package used to teach science practices in STEM education to students with ID and NDD. A multiple probe across participant design revealed that the intervention package was effective in teaching two students with NDD science practice skills. Further, a single case study comprised of a treatment and baseline phase showed positive preliminary evidence in using the intervention package for a student with ID although more high-quality research is needed. The results of these studies inform practice implications and future research directions.

Keywords

Science, Technology, Engineering, and Mathematics (STEM)

Accessible Education

Systematic Instruction

Neurodevelopmental Disorders

Intellectual Disabilities

Summary for Lay Audience

The importance of promoting students' science, technology, engineering, and mathematics (STEM) literacy has been at the forefront of educational and political interest across North America. Yet, most educational programs and instructional approaches related to STEM learning are designed for neurotypical students. Traditional methods of STEM education often present barriers to the general curriculum for diverse learners, including students with intellectual disabilities (ID) and students with neurodevelopmental disorders (NDD). Students with ID and NDD often require differentiated instruction and support to access STEM learning alongside their peers; however, research guiding equitable access to STEM education for this population is lacking. Most of the current literature focuses on teaching science vocabulary or content knowledge instead of science practice skills (e.g., asking questions, analyzing findings, interpreting results) in the context of STEM as an interdisciplinary subject. As a result, traditional STEM instruction is often beyond reach for students with ID and NDD. The current paper presents two studies using single-case research designs to investigate the efficacy of an intervention package on the science practices of students in grades three to four with ID and NDD. It was found that two students with NDD acquired science practices after receiving the intervention package, indicating it was effective at teaching target skills. Further, positive preliminary results revealed that one student with ID learned science practice skills when introduced to the intervention package although additional high-quality research is needed. Social validity data from both studies revealed that the use of the intervention package in teaching science practices was considered socially important to participants and caregivers. The findings suggest that the intervention package has the potential to eliminate barriers to STEM education for students with ID and NDD. Future research directions and practice implications related to research supporting a range of students in STEM education are discussed.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

1.1 Introduction

Accessible science, technology, engineering, and mathematics (STEM) education serves as a fundamental human right for all students (Education Act, 1990) and sets a precedent for personal autonomy and participation as an informed citizen (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2018). To achieve this goal, STEM education must extend beyond the basic understanding of scientific content to equip students with a foundational set of science practice skills (Next Generation of Science Standards [NGSS], 2013). Science practices draw on the behaviours and habits commonly used to design solutions within the field of engineering (NGSS, 2013). This includes asking questions, planning and conducting experiments, analyzing findings, and building an argument from evidence (NGSS, 2013). Learning science practice skills can promote students' knowledge and active participation in STEM while fostering 21st-century skills of critical thinking, perseverance, and creativity (Osborne, 2014). Students with a strong repertoire of science practices and knowledge in STEM are more likely to participate in daily problem-solving and decision making (Morrison 2006; Katehi, Pearson, & Feder; 2009), in addition to having greater employment opportunities (Basham & Marino, 2010; Zollman, 2011). To ensure students gain the skills required to thrive in today's STEM-driven society, all learners must have access to a comprehensive STEM education that teaches practice skills and content knowledge (NGSS, 2013; UNESCO, 2018).

Over the last several decades, promoting students' STEM literacy has been at the forefront of educational and political interest across North America as the rise in STEM-related programs and employment opportunities continue to grow (DeCoito, 2016); National Research Council, [NRC] 2012). Yet, most educational programs and instructional approaches related to STEM learning are designed and developed for neurotypical students (Taylor et al., 2020; Therrien et al., 2011). Diverse learners, including students with neurodevelopmental disorders (NDD), often require differentiated strategies and support to access STEM instruction taught in the general classroom (Rizzo & Taylor, 2016; Therrien et al., 2011). However, systemic barriers frequently constrain educational policies promoting access to the general curriculum (e.g., the limitation of finances, support, and professional staff development; Olson & Ruppar, 2017) and research guiding equitable access to STEM learning for students with NDD is lacking (Knight et al., 2020). As a result, STEM instruction taught in the general classroom is often beyond reach for students with NDD (Rizzo & Taylor, 2016; Therrien et al., 2011).

1.1.1 Intellectual Disabilities and Neurodevelopmental Disorders

Neurodevelopmental disorders are a group of conditions related to the neurological system and categorized by difficulties with personal, social, academic, and occupational functioning appearing within the developmental period (American Psychiatric Association [APA], 2013). Students with NDD often experience difficulties related to language and speech, motor skills, behaviour, memory, and learning which can change throughout one's lifespan. Examples of diagnoses under the NDD category include autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), intellectual disability, and specific learning disabilities. In Canada, five percent of school-aged children have a disability; of these students, approximately 75 percent have a NDD (Arim, Findlay & Kohen, 2016).

Under the category of NDD, intellectual disability (ID) refers to a heterogeneous group of disabilities characterized by lifelong limitations in general mental ability and adaptive functioning (APA, 2013). The ID diagnosis is further divided by severity of need, including mild, moderate, severe, and profound categories (APA, 2013). Globally, the prevalence of ID ranges from 0.05 to 1.55% (McKenzie et al., 2016); however, within Canada, it ranges from 1.8 to 8% (Friedman et al., 2018). People with ID typically present with difficulties in problem-solving, planning, communication, and daily living skills across home, school, work, and community life. For children who cannot be reliably tested, the term global developmental delay is used under the diagnostic category of ID (Battaglia & Carey, 2003). Students with ID and other NDDs often face barriers to science and STEM instruction taught within the general classroom (Rizzo and Taylor, 2016; Therrien et al., 2011; Therrien et al., 2017).

1.1.2 *Science, Technology, Engineering, and Mathematics Education*

STEM is an acronym used in the field of education to represent learning related to science education with an effort to incorporate components from technology, engineering, and mathematics (Government of Ontario, 2022). There is some debate on the definition of STEM education with some stakeholders emphasizing the need for equal representation of all four STEM disciplines (NRC, 2012). Discrepancies between the definition of STEM education in research vary based on education level (Breiner et al., 2012) with elementary STEM (i.e., K-6) education primarily focusing on science and mathematics education. In the context of elementary education, the Ontario Ministry of Education's Science and Technology curriculum (2022) states that STEM subjects can be taught separately although an effort to incorporate components from all subjects should be made in addition to a focus on integrating two or more STEM subjects. The interdisciplinary approach to learning STEM is expected to equip students to develop diverse problem-solving skills and to be innovators and leaders of change in society (NGSS, 2013; NRC, 2012).

In today's technology-driven society, an applied understanding of STEM is necessary (UNESCO, 2018). The application of STEM concepts and knowledge are required to address challenges that arise across social, political, environmental, economic, and personal spheres (NGSS, 2013). STEM skills are an integral part of evaluating scientific claims, making informed decisions, such as deciding whether to purchase an energy-efficient vehicle or choosing an alternative medical treatment, and participating in public policy concerns (NRC, 2012). In recent decades, the framework used to teach STEM has shifted from teaching content knowledge, such as facts, principles, and theories to an emphasis on teaching underlying science practices that equip students to become successful analytic thinkers and contribute to the demands of the 21st century (NRC, 2012).

Of the research on teaching science to students with NDD and ID, the NGSS (2013) is the primary framework used to assess the integration of science practices (Knight et al., 2020). Importantly, the standards and guidelines produced by the NGSS were developed for educators in the United States of America (NGSS, 2013). Scientific practices include: (1) asking questions; (2) developing and using models (e.g., diagrams, drawings, physical replicas); (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using math and computational thinking; (6) constructing explanations; (7) engaging in argument from evidence; (8) evaluating and communicating information (NGSS, 2013).

The integration of scientific practices and knowledge in science and STEM education are required to engage students in inquiry learning (National Academies of Science, Engineering, and Medicine, 2012). Inquiry learning allows students to explore natural phenomena as they investigate and engage in scientific experimentation (Martin-Hansen, 2002). In this context, inquiry learning encompasses a range of approaches from structured, guided, coupled, and open inquiry (Martin-Hansen, 2002). The continuum of inquiry learning ranges from teacher-led to a transition to completely student-led investigation. Inquiry learning involves formulating a question that can be answered through investigation (Martin-Hansen, 2002).

1.1.3 Science, Technology, Engineering, and Mathematics Education for Students with Intellectual Disabilities and Neurodevelopmental Disorders

For students with ID and NDD, a repertoire of science practice skills used across contexts has real-life implications; learning how to ask questions and evaluate evidence can be generalized to solve problems in areas of the home, school, and community life (Knight et al., 2020). For example, a student might learn about climate change in school and then question how they can reduce household waste. Students can solve real-world problems by gathering information about product decomposition, creating hypotheses, and testing which household products decompose most efficiently. In addition to gaining functional problem-solving skills, learning science practice skills may improve the quality of life well into adulthood for all students, including students with ID and NDD, as they explore personal hobbies via self-directed and interest-led investigations. Despite the benefits of learning STEM, students with ID and NDD continue to underperform in STEM achievement compared to their peers (Basham & Marino, 2013; Access STEM, 2007).

Students with ID and NDD face a myriad of academic learning barriers when instructional practices in the general classroom fail to extend beyond traditional teaching methods (Pivik et al., 2002). Although many educators understand the importance of inclusive education within the general classroom, they often experience systemic barriers to implementing such practices (Olson & Ruppar, 2017). The combination of individual learning needs and a movement toward greater access to the general curriculum for all students present challenges for educators who are simultaneously required to meet curriculum standards, accommodate individualized education programs (IEPs), and provide differentiated instruction to support all students in the classroom (Ernest et al., 2011). The educational support needs of students with ID and NDD vary in the context of STEM education (Rizzo & Taylor, 2016; Taylor et al., 2020; Therrien et al., 2011), where the dominant approach to teaching is grounded in inquiry-based learning (Thibaut et al., 2018).

Inquiry-based learning is engrained into the use of science practices, yet this approach often lacks the embedded support students with ID and NDD require to learn science practices (Therrien et al., 2017). Students are traditionally taught to explore natural phenomena while integrating science practice steps (Pedaste et al., 2015). Using science practices in inquiry learning requires an inherent application of ordinal steps where the success of each step is contingent upon the previous step (e.g., making predictions, planning an investigation, conducting the investigation, and communicating results; NGSS, 2013). Without embedded instruction and support in applying and mastering science practice steps, traditional STEM learning environments often pose barriers to full classroom participation for students with ID and NDD (Rizzo & Taylor, 2016; Brigham et al., 2011; Therrien et al., 2011).

Given the systematic nature, applying a framework of science practice skills to STEM problem-solving might support the cognitive and social difficulties commonly experienced among students with ID and NDD (Knight et al., 2020; APA, 2013). For example, providing support for the ordinal use of science practice skills could remove learning barriers related to the cognitive and memory demands of unstructured problem-solving (Therrien et al., 2011). Further, following explicit instructions to complete science practices might provide a framework for social interaction and communication among peers as students work collaboratively to describe materials, ask questions, and make predictions (Knight et al., 2020). Despite these benefits, interventions focused on supporting science practice skills in STEM learning for students with ID and NDD are understudied.

1.1.4 Systematic Instruction used to Teach Science, Technology, Engineering, and Mathematics

In general and segregated science classes, Rizzo and Taylor (2016) conducted a systematic review evaluating inquiry-based instruction to teach science to middle school students with ID and NDD (i.e., ID, ASD, ADHD, and learning disabilities). Of the studies reviewed (n = 12), the authors concluded that components of systematic instruction could support students with ID and NDD in inquiry-based science lessons. Similarly, a meta-analysis of science instruction for students with learning disabilities conducted by Therrien and colleagues (2011; n = 12) reported that students could learn science through an inquiry approach with structured, systematic instruction.

Systematic instruction is grounded in the principles of Applied Behavioural Analysis (Collins et al., 2018), including (a) socially valid skills, (b) operationally defined target skills, (c) monitoring progress through data collection, (d) methods of stimulus control transfer, (e) and the generalization of target skills (Browder & Spooner, 2011). A range of skills has been taught to students with ASD and ASD/ID using systematic instruction, including vocational skills (Gilson et al., 2017), object play skills (Barton et al., 2020), and academic skills (e.g., English language arts, mathematics; Browder et al., 2008; Knight et al., 2013). Much of the current literature on teaching STEM to students with ID and NDD examines science learning alone, with an emphasis on teaching conceptual knowledge (Spooner et al., 2011); however, there is an emerging shift towards teaching science practices (Knight et al., 2020; Therrien et al., 2017). In this research, systematic instruction has been identified as an evidence-based practice (EBP) in teaching science content and practices to students with ID and ASD (Apanasionok et al., 2019; Knight et al., 2020; Spooner et al., 2011).

Spooner and colleagues (2011) conducted a systematic review of research published between 1985 and 2009 focused on teaching science to students with ID to identify EBP using criteria from Horner et al. (2005). Of the research reviewed (n = 14), systematic instruction was identified as an empirically supported approach to teaching science content. The literature specifically endorsed the use of task-analytic instruction (n = 6) in teaching chained skills (e.g., application of first-aid skills) and time delay (n = 8) in teaching discrete skills (e.g., science vocabulary definitions). Over half of the research reviewed focused on science content (n = 8), and just one study focused on teaching science practice skills (i.e., planning and carrying out experiments; Agran et al., 2006). Similarly, Taylor and colleagues (2020) conducted a meta-analysis examining the effectiveness of interventions to support science learning for students with ASD from 2000 to 2018. Using an effect size analysis (i.e., percentage of non-overlapping data [PND] and Tau-U calculations), the use of task analysis and graphic organizers emerged as effective interventions, with large effect sizes (i.e., PND effect sizes of 90% and above), when supporting science learning among students with ASD. Although this literature supports systematic instruction to teach science to students with ASD and ASD/ID, most studies focus on teaching science content (Taylor et al., 2020; Spooner et al., 2011). Knight and colleagues (2020) conducted an updated literature review examining instructional methods used to teach science content and practices to students with ASD and ASD/ID. The researchers evaluated twelve studies published between 2009 to 2018 and found empirical support for components of systematic instruction. Intervention packages including task-analytic instruction (n = 6) showed positive increases in the performance of science practice skills. Compared to previous reviews that primarily focus on teaching science content (Apanasionok et al., 2019; Taylor et al., 2020; Spooner et al., 2011), all studies included in the review by Knight et al. (2020) incorporated at least one science practice skill. Notably, only one article included all eight NGSS (2013) standards. Of the three reviews (Spooner et al. 2011; Apanasionok et al., 2019; Knight et al., 2020), most studies focused on teaching science and mathematics; no study focused on engineering, and only one study taught technology concepts to students with disabilities. Therefore, further research is needed to focus on an integrative approach to teaching STEM.

1.1.5 Task-Analytic Instruction and Science Practices

1.1.5.1 ***Knowledge Charts***

Task-analytic instruction is a strategy used to teach a target skill or a task that can be broken into smaller sequential steps (Annett & Stanton, 2000). The majority of research focused on teaching science practices to students with ASD and ASD/ID using a KWHL knowledge charts (i.e., what do you **K**now?; **W**hat do you want to know?; **H**ow will you find out?; what did you **L**earn?; KWHL; Knight et al., 2020). The KWHL chart follows several science practice skills set out by the NGSS Leads States (2013), such as asking questions, planning investigations, conducting experiments, and communicating findings. The KWHL chart is a “procedural facilitator” that visually organizes procedural steps for students to complete via written or verbal responses (Baker et al., 2002). KWHL charts are often combined with other components of systematic instruction (e.g., prompting reinforcement, multiple exemplars) for optimal learning (Knight et al., 2020).

For example, Jimenez, Browder, and Courtade (2009) examined the effects of the KWHL chart used on the generalization of science concepts (i.e., chemical reactions and precipitation) and practices (i.e., KWHL chart skills). A single-case multiple probe design across science units was used with concurrent between participant replication for three students, ages 11 to 13, with moderate ID. The KWHL chart was combined with a constant time delay and multiple exemplar training to teach students to perform an inquiry-based science experiment in a segregated classroom. All students demonstrated mastery criteria across science units, and students generalized the use of the KWHL chart in a general science classroom. Unanticipated generalization effects of the KWHL chart across science units weakened the functional relationship. Future research should employ multiple baseline designs across participants to avoid unanticipated generalization effects of the KWHL chart. Although the KWHL chart has been found to promote science practices during inquiry learning among students with ID and NDD (Jimenez et al., 2009, 2012; Smith et al., 2013; Therrien et al., 2017), it fails to include all science practice skills as outlined by the NGSS (2013).

1.1.5.2 ***Visual Activity Schedules***

The NGSS (2013) science practice components lend themselves well to task-analytic instruction during experimentation as the success of each step (e.g., asking questions, planning investigations, conducting experiments, analyzing findings, and constructing explanations; NGSS (2013) is dependent on the completion of the previous step (Pedaste et al., 2015). In this context, visual activity schedules (VAS) might serve as an instructional strategy to support sequential learning of science practice steps through images, pictures, or photographs depicting target skills. The goal of VAS is to visually prepare the learner for the next step within a task for transitions between tasks (Kliemann, 2014). VAS supports the belief that visual processing support is more feasible for some learners than following auditory or written information (Kliemann, 2014). The cognitive, memory and attention demands of following verbal or written science practice instructions within the KWHL chart might pose barriers to learning for students with ID and NDD (Brigham et al., 2011).

VAS are considered an EBP in supporting social and leisure skills among students with ASD (Knight et al., 2013) and are primarily used to encourage on-task and transitioning behaviours for students who have acquired skills (McClannahan & Krantz, 2010; Knight et al., 2015). However, in recent years, leveraging technology has enhanced VAS with embedded interventions used to teach students novel skills, with established efficacy in teaching social skills (Osos et al., 2021). For example, electronic VAS utilizes technology (i.e., computer, iPad, smartphone, tablet) to embed static photos, text, and/or video clips depicting examples of target behaviours. Within STEM learning, the literature supports the use of video-enhanced VAS as an EBP in teaching mathematics to students with ASD and/or ID; however, there is insufficient evidence to consider this intervention as effective when applied to science, technology, or engineering subjects (Wright et al., 2020). Furthermore, there is a paucity of research involving video-enhanced VAS in teaching STEM as an interdisciplinary whole (Wright et al., 2020; Knight et al., 2013).

1.1.6 Video-Based Modelling Interventions

VBM is built on decades of research supporting observational learning theory (Bandura, 1977), a component of social learning theory, which suggests that learning transpires as an individual observes the completion of a skill or task and then imitates that behaviour. Informed by this theory, VBM incorporates technology-based instruction to display previously recorded video clips of an individual correctly modelling the target behaviour (Nikopoulos & Keenan, 2006). Before engaging in a target task, learners can watch and re-watch video clip exemplars to increase the likelihood of correctly completing a task (Keenan & Nikopoulos, 2006). For some learners, observing the completion of a task in a single video does not lead to skill acquisition; instead, breaking the skill into manageable steps is more effective (Park et al., 2019). This process is known as video-prompting (VP). It incorporates methods of VBM and task-analytic instruction to provide cues in the form of short sequential video clips as learners watch a video and complete a single step before viewing the following video (Banda et al., 2011). By integrating technology as a support mode, VBM allows for the repeated use of video clips, reducing prompt reliance on implementers and increasing independent completion of tasks among learners (Spriggs et al., 2015; Wright et al., 2020).

To date, there are several comprehensive literature reviews evaluating the efficacy of VBM in teaching skills to students with a focus on ASD, ASD/ID, and ADHD; however, most studies focus on functional outcomes (e.g., vocational and social skills; Odom et al., 2015; Wilkes-Gillin et al., 2021) or select academic skills (e.g., language arts and mathematics; Knight et al., 2013) and only one review examines STEM skill acquisition (Wright et al., 2020). Wright et al. (2020) examined ten methodologically sound studies using VBM to teach STEM skills to students with ASD and/or ID published between 2012 and 2018. Of the studies evaluated, 90% (n = 9) used VBM to teach mathematic skills and three studies focused on a combination of mathematics and science skills. One study examined technology-based skill acquisition. Based on the findings, VBM emerged as an EBP for teaching mathematic skills to students with ASD and/or ID; however, there was not sufficient evidence to consider VBM as an equally effective tool across other domains of STEM learning or for STEM as an interdisciplinary whole, indicating an apparent need for additional research to fill this gap.

Knight et al. (2019) used VP to teach technology-based skills (i.e., robotics and coding) to three students aged 11 to 14 with ASD and ASD/ID. A single-subject multiple probe research design across skills was used to demonstrate high rates of skill acquisition and maintenance of skills at follow-up sessions. Moreover, participants showed generalization of coding skills to novel codes without the support of the VP intervention. Notably, the task-analytic instructions only focused on calibrating and coding robots using video-prompting alone. Research indicates that the effects of VBM and VP are strengthened when components of systematic instruction are integrated (e.g., least-to-most prompting, reinforcement, task-analytic instruction, VAS; Oso et al., 2020; Park et al., 2019). While Knight and colleagues provide efficacy of VP to support technology skills among students with ASD and ASD/ID, expanding this intervention to include multicomponent that support a range of cognitive, academic, and social needs of students is required.

Yakubova et al. (2020) used an intervention package including VBM, concrete manipulatives, a self-monitoring checklist, and a comprehension check to teach proper fraction solving to three middle school students aged 12 to 13 with ASD. A multiple probe across participant design demonstrated positive changes among learners when the intervention package was implemented. Two of the three learners generalized proper fraction problem solving to improper fraction solving. Yakubova and colleagues utilized a self-monitoring checklist printed on paper to reduce adult prompting and support memory recall. Two participants self-faded the self-monitoring checklist, and one participant relied on it throughout the study. In a classroom setting, using a self-monitoring checklist adds preparation for educators while requiring students to retain additional paperwork. To support memory recall and reduce adult prompting, future research might benefit from embedding VBM into a VAS (Kliemann, 2014). Thus, the current study will expand the research of Knight and colleagues (2020) and Yakubova and colleagues (2020) to examine the efficacy of a multi-component intervention package with an embedded video-enhanced VAS to eliminate a range of academic, cognitive, and social barriers to learning STEM.

1.1.7 Video-Enhanced Visual Activity Schedules

Educators have access to technological resources (e.g., computers, tablets, iPads) that are portable and commonly used among students with and without disabilities across subjects (Chauhan, 2017). By leveraging such resources, video-enhanced VAS (i.e., VAS with embedded VBM) be easily accessed and socially reinforced within the classroom (Blood et al., 2011). In the context of STEM learning, the task-analytic sequence used to teach science practices (e.g., describing observations, asking questions, making predictions, planning an investigation, carrying out the investigation, observing the results) pairs well with the chained sequence of video-enhanced VAS (Wright et al., 2020).

Spriggs and colleagues (2015) evaluated the effects of using video-enhanced VAS on math, technology, writing, and daily living skills among four participants with ASD and ID between 17 to 19 years old. The researchers evaluated four separate video-enhanced VAS using a single-subject multiple baseline design across participants. Two of the four participants showed improvement in acquiring target skills (i.e., data entry on a computer, solving an algebra equation, writing a paragraph, setting the table). All students displayed independent transition skills and generalized the visual activity schedule to new exemplars (e.g., solving algebra equations presented in identical operational formats using novel numbers). While Spriggs and colleagues provide evidence of the benefits of using video-enhanced VAS, additional research focused on teaching procedural skills in STEM as an interdisciplinary subject is required.

Similarly, Elmaci and Karaasalan (2021) used video-enhanced VAS and a prompting hierarchy to teach seventh-grade students with ASD to solve mixture separation experiments in science class. Using a multiple-baseline design across participants, all three participants demonstrated mastery criteria of target skills while generalizing the skills to different settings and instructors. Notably, video-enhanced VAS instruction in this context was limited to three experiments (i.e., separating a mixture with a magnet, separating a mixture through filtration, and separating a mixture with density difference). Although providing support for using a video-enhanced VAS in teaching scientific experiments across examples, target skills taught through this intervention fail to extend beyond the context of mixture separation tasks. Therefore, there is a need to widen the research related to teaching science practice skills, as outlined by the NGSS (2013), that can be generalized to solve novel problems across STEM disciplines, not science alone.

Despite the benefits of participating in STEM learning, academic interventions supporting cross-curricular STEM education for students with ID and NDD are understudied. In this research, KWHL charts are considered efficacious in teaching science practice skills, yet the graphic organizer does not encompass all eight components of science practice skills as outlined by NGSS. Although the task analytic nature of VBM lends itself well to teaching NGSS science practice (Knight et al., 2020) current research in this domain has not explored the effects of VBM in teaching STEM as an interdisciplinary subject (Knight et al., 2019a). Combining VBM with VAS and other components of systematic instruction might be an effective avenue to teach science practices explicitly.

1.2 The Current Study

1.2.1 Aims

The current study aims to contribute to the scarcity of research examining STEM learning interventions for students with ID and NDD. This is the first study evaluating the effectiveness of a video-enhanced VAS intervention package on the science practice skills among students with a range of learning needs. Following the 2007 Ontario Science and Technology educational curriculum, the current study used lesson plans primarily based on science education integrated with components of mathematics, technology, and engineering. Extending previous literature, the current study will use a multi-component intervention package (i.e., video-enhanced VAS, a KWHL chart, least-to-most prompting, and naturalistic reinforcement) to teach science practice components outlined by the NGSS (i.e., asking questions, use models [e.g., diagram, physical replica, drawings], plan/carry out investigations, analyze/interpret data, use math/computational skills, construct explanations, argument from evidence, and obtain, evaluate, and communicate information).

To capture the complexity and intricate nature of research on academic intervention for students with ID and NDD, the current paper will present two studies examining a video-enhanced VAS intervention package on the performance of science practice skills for one student with ID and two students with NDD.

1.2.2 *Objectives*

The current study will investigate the following questions:

1. What effects does a video-enhanced VAS intervention package (i.e., VAS with embedded VBM clips, least-to-most intrusive prompting strategies, reinforcement, and KWHL chart) have on the percentage of correct and independently completed science practice steps within a pre-defined task analysis for one student with ID?
    a. What effects does the video-enhanced VAS intervention package have on a secondary measure of students' percentage of correct and independently completed questions within a STEM knowledge assessment?
    b. What is the social significance and importance of the video-enhanced VAS intervention among the participant and caregivers?
2. What effects does a video-enhanced VAS intervention package (i.e., VAS with embedded VBM clips, least-to-most intrusive prompting strategies, reinforcement, and KWHL chart) have on the percentage of correct and independently completed science practice steps within a pre-defined task analysis for three students with NDD?
    a. What effects does the video-enhanced VAS intervention package have on a secondary measure of students' percentage of correct and independently completed questions within a STEM knowledge assessment?

b. Can the effects of the video-enhanced VAS intervention package be maintained over time?

c. Can the effects of the video-enhanced VAS intervention package be generalized to a novel instructor?

d. Does participation in the study increase learners' interest and attitudes towards STEM learning?

e. What is the social significance and importance of the video-enhanced VAS intervention among participants and caregivers?

Chapter 2

2 Methods

The following subsections outline the methodology for two studies. Differences in methods used for study 1 and study 2 are subsequently described in detail.

2.1 Ethics Approval

The study protocol was reviewed and approved by the Research Ethics Board at the current university. All procedures performed in studies involving human participants followed the ethical standards of the institutional and national research committees.

2.2 Recruitment

Children aged 8 to 11 years old with an intellectual and/or developmental disability were recruited through community-based organizations serving families with children with disabilities (e.g., caregiver support groups, tutoring services, intensive behaviour interventions/ABA services, etc.) in Southern Ontario. Caregivers interested in the study underwent an initial phone screening interview to assess the inclusion criteria through a verbal caregiver report. If inclusion criteria were met, caregivers and participants were invited to attend a virtual pre-assessment interview to evaluate the inclusion and exclusion criteria further.

2.3 Inclusion and Exclusion Criteria

Participants met the following inclusion criteria: (a) between the ages of 8 to 11 years of age; (b) had a diagnosis of an intellectual and/or developmental disability from a practitioner as confirmed by a caregiver; (c) had normal or corrected vision and hearing as confirmed by a caregiver; (d) communicated in English; (e) could attend to a screen for a minimum of 20 seconds; (f) could attend to a 1-hour learning session with appropriate breaks; (g) could follow one-step directions; (h) could speak in sentences comprised of at least three words; (i) had parental consent; and (j) provided verbal assent. None of the participants met exclusion criteria defined as independently demonstrating eight or more of the target behaviours. Due to school closures related to corona-virus-19 (COVID-19) disease containment measures, participants in both studies had experience with virtual learning.

2.4 Interventionist

The interventionist was a Master of Arts student in School and Applied Child Psychology and served as the primary data collector. The interventionist had previous experience piloting the current program on four students with ID and NDD prior to implementation, as well as experience facilitating a STEM and social skills program for students with ASD. Aside from these experiences, the interventionist did not have a strong background in teaching STEM subjects.

2.5 Setting

The study took place over Zoom. The participant and the interventionist joined virtual sessions from a study space within their homes, including a desk and chair with limited distractions and reliable Wi-Fi. Participants and the interventionist used computers or tablets with webcam and audio features to join virtual sessions. Sessions were conducted at the participants' desks or on the ground to provide additional workspace. Caregivers were present in the home during sessions, often in a nearby room if the participant required assistance.

2.6 Materials

2.6.1 Vineland Adaptive Behavioural Scale

The Vineland Adaptive Behavior Scales, Third Edition (VABS-3; Sparrow et al., 2016) is a norm-based, individually administered assessment. The current study used the interview format (study 1) and the Q-global electronic version (study 2) of the parent/caregiver form to evaluate the adaptive functioning of participants across three domains (i.e., daily living, communication, and socialization skills). Items are rated using a three-point Likert scale to indicate the frequency (i.e., 0 = Never; 1 = Sometimes; 2 = Usually) in which a child independently performs a behaviour without prompting. Internal consistency reliability for the VAB-3 Parent/Caregiver form is excellent, ranging from .96 to .98.

2.6.2 STEM Lesson Plans

Twenty-one STEM lesson plans were developed by a research assistant who was a certified elementary school teacher completing a Master of Arts degree in Education. The lesson plans included STEM units taught within the Ontario education curriculum for grades three to five (Government of Ontario, 2017; see Appendix B for a list of all units). Each unit began with a short video or description of the concepts to be taught, followed by five to ten short experiments. Lesson plans included all eight NGSS science practice standards components, outlined in table 1. For sample lesson plans, see Appendix C.

Table 1. NGSS Science Practice Standards as Incorporated into STEM Lesson Plans

NGSS Standard	**Coverage of NGSS Standard in the STEM Lesson**
Asking questions	Target skill (i.e., ask questions)
Using models	Embedded use of diagrams and physical replicas (e.g., model of lungs, model of plans orbiting sun)
Plan/carryout investigation	Target skill (i.e., plan experiment; conduct experiment)
Analyze/interpret data	Target skill (i.e., observe results; describe results) when combined with experiments requiring data collection or an analysis of evidence
Use math/computational skills	Embedded use of mathematics (i.e., operations used to determine resting heart rate, measuring distance/weight)
Construct explanations	Target skill (i.e., state what you learned)
Argument from evidence	Target skill (i.e., State what you learned) when embedded with experiments to compare and contrast outcomes (i.e., which shape is more stable?; which material is more soluble?)
Obtain, evaluate, and communicate information	Target skill (i.e., observe materials; describe materials; state what you know; ask questions; make a prediction; observe results; describe results, state what you learned)

Science practices, as outlined by NGSS, are incorporated into STEM lesson plans. Target skills appeared in all lesson plans, and embedded content appeared in some lesson plans.

2.6.3 STEM Knowledge Assessments

Twenty-one knowledge assessments corresponding to each STEM lesson plan were used to determine participants' STEM knowledge. Modelled after Smith et al. (2013), unit quizzes were used to measure concrete STEM knowledge at the end of each unit through a ten-item quiz. After completing the unit, participants were asked to respond to similar questions in difficulty and response mode (i.e., multiple-choice). The questions were developed by a certified teacher and based on curriculum standards taught within the unit; each quiz included key vocabulary taught in the unit. For example, within the Earth Science lesson, the facilitator asked participants, "*What causes seasons on earth?*". They were given three response options, including the correct answer (e.g., *"tilt*") and two distractors (e.g., "*orbit*" and "*the moon*"). See Appendix D for example.

2.6.4 STEM Materials

General materials required to facilitate STEM activities, including markers, tape, paper, and pencils, were used for the study. Additional materials relevant to STEM units (e.g., Ozobots, electrical snap circuits, building materials [cardboard ramps, playdoh boat, toothpick structures] optical lenses, rocks and minerals etc.) were also required. Materials for each unit were packaged in paper bags and labelled with numbers corresponding to experiments. All bags were placed into plastic containers, labelled as STEM kits with the corresponding unit name, and delivered to participants' homes.

2.6.5 Video-Enhanced Visual Activity Schedule Intervention Package

2.6.5.1 *Video-Modelling Clips*

Thirty video modelling clips ranging from 5 to 10 seconds were created for the current study. Three exemplar experiments (i.e., buoyant raisins, coding Ozobots, and building a balloon rocket) outlining all ten task analysis steps were used to teach the target skills. The video models included experiments the participants had previously conducted (i.e., bouncy raisins, coding Ozobots) and an experiment not included in the lesson plans (i.e., building a balloon rocket). Each video depicted two child actors manipulating materials as they conducted experiments at a table in an outdoor setting. No verbal reinforcement was shown in the video clips, only science practices following the operational definitions in the task analysis.

2.6.5.2 Visual Activity Schedule

Personalized VAS were developed (e.g., Springs et al., 2015; Osos et al., 2020) using the Microsoft PowerPoint application. Each VAS was individualized to include the participants' names on the first electronic page (e.g., Rebecca's Activity Schedule) with subsequent pages containing embedded VBM clips of the target skills. Under each video, the step number and written phrase of the step were provided (e.g., Step 2: Describing materials). To encourage engagement, VAS incorporated participants' personal interests through clip art characters embedded within the schedule (e.g., Mario cart and Pokémon characters). See Appendix E for an example of a static VAS.

2.6.5.3 Knowledge Chart

As part of the intervention package, a physical copy of the KWHL chart (i.e., a graphic organizer outlining: [K] What I **K**now? [W] What I **W**ant to know? [H] **H**ow will I find out? [L] What did I **L**earn?) was provided to participants as a visual aid used to facilitate the use of STEM practice skills. KWHL charts were laminated, and participants were encouraged to use a dry-erase marker to fill out the columns. See Appendix F for an example.

2.6.5.4 *Prompting and reinforcement*

To support the demonstration of target skills, a system of least to most prompting was used (see Appendix G). In addition, naturalistic reinforcement, in the form of social praise (i.e., "Great work!"; virtual high fives; smiling) was used if participants demonstrated a target skill.

2.7 Phone Screening Interview

Caregivers who responded to recruitment posters underwent an initial twenty-minute phone screening interview. During this interview, the researcher further explained the study, and caregivers verbally responded to the screening questionnaire outlining the inclusion criteria. A follow-up pre-assessment interview was scheduled to further assess the inclusion criteria if inclusion criteria were met. If the inclusion criteria were not met, the researcher thanked the participant for their time and explained that their child did not meet the criteria needed to participate in the study.

3 Study 1

3.1 Participant

Paige was an 8-year-old female diagnosed with global developmental delay by a practitioner and enrolled in the third grade. She had additional diagnoses of apraxia, developmental coordination delay, and epilepsy. On the Domain Level Caregiver Form of the VABS-3, Paige ranked in the 1st percentile in Communications Skills, the 2nd percentile for Daily Living Skills, and the 16th percentile for Socialization Skills. According to Paige's mother, STEM was an area she was interested in.

3.2 Experimental Design

An AB design comprised of a baseline and treatment condition was used to evaluate the efficacy of the video-enhanced VAS intervention package in teaching target STEM practice skills as outlined in table 2. A minimum of three stable baseline points were required in the baseline phase before the participant moved to the treatment condition (Ledford & Gast, 2018). Mastery criteria were defined when participants correctly demonstrated eight out of ten steps correct across at least three consecutive sessions in the intervention phase.

Table 2. Target Skills and Definitions for Study 1

Science Practice NGSS (2013)	Behaviour	Definition

Obtain, evaluate, and communicate information	1. Observe materials	The participant uses at least one of their senses (look/touch/smell/listen/taste) to evaluate the materials for at least 5 seconds.
	2. Describe Materials	The participant states at least one descriptor of the material and/or names the material.
	3. State what is known	The participant states what they know about the materials.
Ask questions	4. Asking questions	The participant states a question related to what they want to know about the materials.
Obtain, evaluate, and communicate information	5. Making Predictions	The participant states an expected outcome based of the experiment.
Plan/Carryout investigation	6. Plan Investigation	The participant states how they will measure their prediction.
	7. Carry out Investigation	The participant completes experimental testing by following procedures from their investigation plan.
Obtain, evaluate, and communicate information	8. Observe Results	The participant uses at least one of their senses (look/touch/smell/listen/taste) to evaluate the experimental outcome for at least 5 seconds.
	9. Describe Results	The participant states an outcome action, event, or object from the experiment.
Construct explanation	10. Describe overall learning take away	The participant states something they learned from the experiment.

Target skills, definitions, and corresponding NGSS science practices for study 1.

Response to Definition and Data Collection

3.2.1 STEM Practice Skills

The interventionist collected the occurrence and non-occurrence of target STEM practice skills during sessions. The percent of independent STEM practice steps completed in the task analysis served as the primary dependent variable. This was measured through event recording, in which the percent of task analysis steps completed correctly and independently was obtained. Correct responses were recorded when the student independently responded following the defined operational definition for the target behaviour. Prompted responses were recorded when the participant responded following the defined operational definition for that task after being prompted. Prompted responses were recorded as incorrect; recording responses using this framework assessed the level of prompting support participants required. Incorrect responses were recorded when the participant did not respond following the defined operational definition for that task regardless of whether they received a prompt or not (see Appendix H for scoring criteria). The total steps completed correctly and independently were calculated to a percent obtained by dividing the number of correct steps by the total number of steps and multiplying by 100.

3.2.2 Interobserver Agreement

To assess the degree to which different observers scores target skills, inter-observer reliability was collected. A research assistant collected point-by-point interobserver agreement (IOA) data on 30% of sessions across all participants and phases. Before independent observation, the research assistant achieved 90% reliability with the primary data collector. Agreements were scored when both observers recorded the same code for steps in the task analysis. Disagreements were scored when both observers register different codes for steps within the task analysis. IOA was calculated by dividing the number of agreements by the number of agreements and disagreements and then multiplying by 100.

3.2.3 Treatment Fidelity

A checklist outlining the intervention procedure was used to ensure all session components were correctly implemented by the facilitator (see Appendix I). Procedural fidelity checklists were completed by a trained research assistant who reviewed randomly selected video-recorded sessions. Treatment fidelity was calculated by dividing the number of agreements by the number of agreements and disagreements and then multiplying by 100.

3.2.4 Pre-Assessment Interview

To confirm that the inclusion criteria were met, participants who passed the initial phone screening then completed an hour-long pre-assessment interview over the Zoom application. After consent and assent protocols were complete, caregivers were administered a demographic questionnaire and participants were asked to view a short video to ensure they could attend to a video for at least 20 seconds. STEM practice skills were then assessed by conducting a short STEM experiment. The VABS-3 was administered in interview format by a Ph.D. student in School Psychology trained in standardized test administration.

3.2.5 General

Individual sessions were held three to five times per week, each session was an hour in length, and the study lasted approximately seven months. Approximately 85 1-hour sessions were completed. All sessions were conducted during after-school hours, with sessions continuing during winter break. All sessions began with the participant choosing a "brain break" activity and they were reminded to ask for break when needed. The interventionist then instructed the student to retrieve a specific STEM kit and corresponding bag. After opening the bag, the interventionist explained the learning concept (e.g., "today we are learning about buoyancy") and encouraged the participant to "try their best."

3.2.6 Baseline

During baseline, responses were marked as correct if the student began the step within 5 to 10 seconds and incorrect if the student made an error or did not respond within 10 seconds. If the participant did not respond within 5 seconds, the interventionist asked, "what is next?". After the student opened the bag, the interventionist provided information for the experiment (e.g., "in this experiment, we are going to use the materials to build a structure to support a load of books"). No planned reinforcement was given after the participants responded regardless of whether their response was correct or incorrect.

3.2.7 Video-Enhanced Visual Activity Schedule Intervention Package

During the intervention sessions, the KWHL chart was introduced at the beginning of each lesson. The interventionist explained each section of the KWHL chart during initial training sessions. The video-enhanced VAS was shared on the screen by the interventionist, and the interventionist started each experiment by stating "we are going to conduct an experiment using our VAS." Each step was introduced by saying, "on step number (insert step), we are going to (insert target behaviour). Watch the video of the students showing an example of how to do this, then it will be your turn to complete this skill". After watching the embedded video clip, the facilitator contrived a situation where the participant had the opportunity to demonstrate the learned skill. The interventionist provided social praise for correct responses and for incorrect answers, the interventionist stated, "nice try, next time remember to (target behaviour), just like they did in the video."

A system of least-to-most intrusive prompting was used when participants did not respond following the video clip. After demonstrating the target behaviour, the interventionist occasionally prompted the participant for more target skills (e.g., after describing one material, the intervention stated, "what else can you describe?"). This additional prompting was not coded.

3.3 Social Validity

To determine whether the STEM program was valuable to participants, social validity was assessed after the STEM program was complete. Social validity is a crucial component to high-quality interventions. It is used in single-subject research to evaluate the relevance, effectiveness, and appropriateness of such research among the people involved (Horner et al., 2005). The current study utilized four questions, modified from previous research by Yakobova et al. (2020) to assess the effectiveness of the STEM program. A research assistant conducted semi-structured interviews with participants and recorded, verbatim, what was stated. The following questions were asked: (1) did you like the activities in the study; (2) what did you like/what did you not like; (3) was it easy to learn using the materials (e.g., VBM, KWHL chart, VAS) we gave you; (3) would you like to use these strategies again; (4) is there anything else you would like to tell us about your participation in the study. All questions were read aloud, and visual support was used for participants to respond to the "*yes*" and "*no*" questions.

3.4 Study 1 Results

Figure 1 demonstrates Paige's performance of target skills during baseline and treatment conditions.

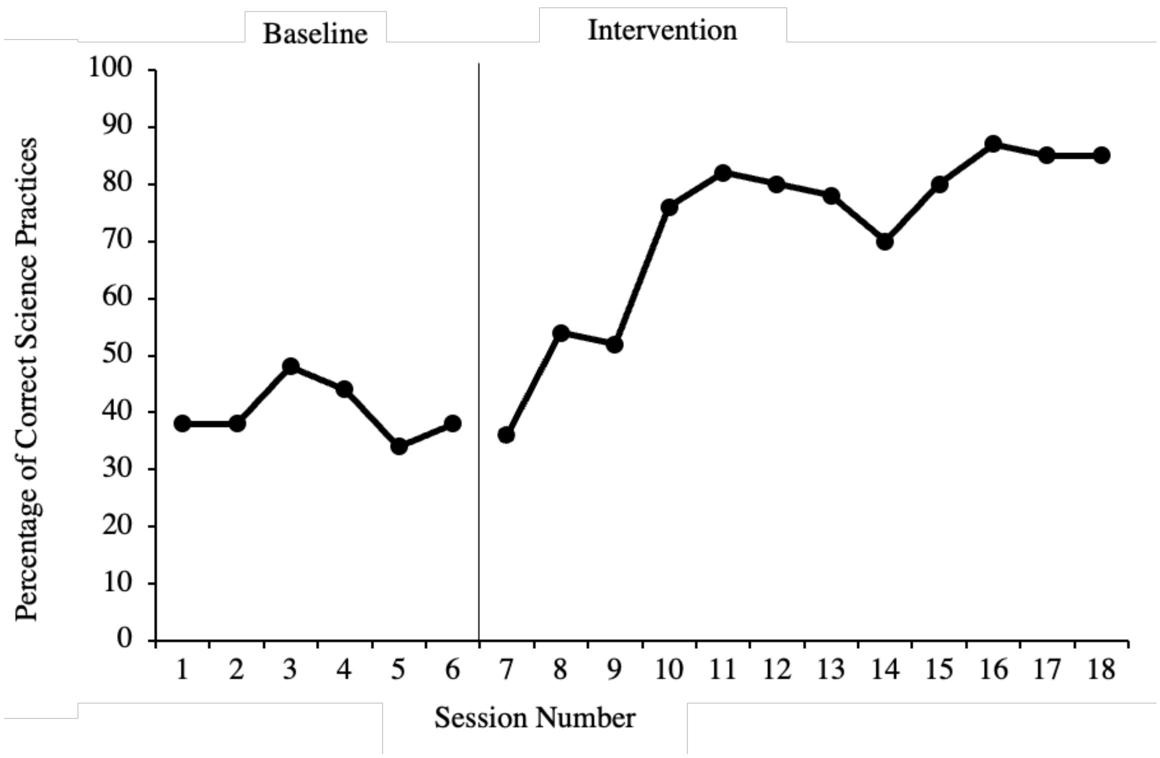

Figure 1. Percentage of science practices performed correctly for study 1

During the baseline phase, Paige demonstrated few target skills with some variability completing an average of 40% steps accurately (range = 34% to 48%) with no trend in data. Data varied within the intervention phase, averaging 70% accuracy (range = 36% to 87%), with the most significant variability in sessions seven to eleven (range = 36% to 82%). The data moved in an upwards trend, and the participant demonstrated moderately high levels of the target behaviour following session ten at consistent levels of responding. Variability within session ten to 18 was limited, with the exception of session

14 (accuracy = 70%). The introduction of the video-enhanced VAS intervention package in the treatment phase resulted in the gradual increase of target behaviour, with mastery being met by session 17. The percentage of non-overlapping data was 92%.

3.5 Knowledge Assessment

Knowledge assessment data was not collected for Paige due to time constraints. Each experiment took approximately 1-hour to complete, and the interventionist often ran out of time in the session to review STEM knowledge.

3.6 Interobserver Agreement and Treatment Fidelity

IOA data for the participant's performance on the task analysis was collected across 33% of sessions using a random number generator. Overall, IOA is 97% (range = 94% to 100%). Treatment Fidelity was assessed for 30% of randomly selected intervention sessions using a checklist outlining the intervention implementation procedures. Overall, treatment fidelity was 97% (range = 95% to 100%).

3.7 Social Validity

The participant and a caregiver completed the semi-structured interview. The participant stated that she enjoyed the intervention and liked using the videos-models. Her favourite STEM unit included the robotics and coding lessons. A caregiver responded stating they thought the repetitive nature of teaching problem-solving skills was helpful for their daughter. They noted Paige enjoyed sharing what she learned in STEM with her friends at school, including writing her fourth-grade speech on the experiments she completed in the study.

4 Study 2

4.1 Participants

Three students with NDD from Southwestern Ontario were recruited to participate in the study. Talia was a 9-year-old white female diagnosed with attention deficit hyperactivity disorder (ADHD) by a practitioner and enrolled in the fourth grade. During the investigation, Talia had an individual education plan (IEP) although she was not identified as having an exceptionality category as determined by the Identification Placement and Review Committee (IPRC). On the Domain Level Caregiver Form of VABS-3, Talia ranked in the 27th percentile in Communications Skills, the 19th percentile for Daily Living Skills, and the 21st percentile for Socialization Skills. Her overall behaviour function composite was reported as the 16th percentile rank. According to Talia's mother, STEM was an area she was very interested in; she especially enjoyed learning about electricity and robotics.

The second participant, Carlos, was a 10-year-old white male diagnosed with ASD and auditory processing disorder by a practitioner and enrolled in the fifth grade. During the study, Carlos qualified for an IEP under the intellectual exceptionality category as determined by the IPRC. On the Domain Level Caregiver Form of the VABS-3, Carlos ranked in the 10th percentile in Communications Skills, the 55th percentile for Daily Living Skills, and the 39th percentile for Socialization Skills. His overall adaptive behaviour functioning composite was reported as the 25th percentile rank. According to Carlos's mother, STEM was a difficult area for him, and he could easily be discouraged from complex tasks.

The third participant, Ronin, was a 9-year-old white male diagnosed with a learning disability by a registered psychologist and enrolled in the fourth grade. Ronin had an IEP in school; however, information regarding his exceptionality category was unavailable. On the Domain Level Caregiver Form of the VABS-3, Ronin ranked in the 6th percentile in Communications Skills, the 75th percentile for Daily Living Skills, and the 45th percentile for Socialization Skills. His adaptive behaviour composite percentile rank was 32. According to Ronin's mother, STEM was an area of interest for Ronin. He enjoyed learning about the weather, natural disasters, and storm watching.

4.2 Additional Materials

4.2.1 Student Attitudes towards STEM Survey

Participants' attitudes towards STEM were measured at pre-and post-assessments using the Student Attitudes towards STEM Survey, the upper elementary version for grades four and five (S-STEM; Friday Institute for Educational Innovation, 2012). The S-STEM measure is used to determine students' confidence and efficacy among five scales: Math, science, technology, engineering, and 21st-century skills, using a five-point Likert scale to indicate the degree to which respondents agree with the question (i.e., Strongly Disagree to Strongly Agree). A different scale on the S-STEM survey assesses the degree of interest respondents have towards 12 different STEM career fields using a four-point Likert scale (i.e., Not at all interested to very interested). The final questions of the S-STEM include respondents' school performance expectations in STEM subjects, whether respondents know adults working in the STEM fields, and if respondents have plans to attend post-secondary education. Internal consistency reliability for the S-STEM is very good, ranging from .82 to .87.

4.3 Experimental Design

A multiple probe across participants design was used to evaluate the efficacy of the VBM intervention package in teaching target STEM practice skills (see Table 3 for definitions of target skills). Notably, revisions were made to target skills and definitions based off study 1 (i.e., Step 1: Explore materials; Step 2: Describe materials; Step 3: State what is known). A minimum of three stable baseline points were required in each phase before participants moved between phases (Ledford & Gast, 2018). In the intervention phase, fading procedures were planned to be followed when participants met mastery criteria (i.e., eight out of ten steps correct across at least three consecutive sessions). Upon reaching mastery criteria, post-training probes were used to assess target skills and maintenance and generalization of the video-enhanced VAS intervention package. The design above evaluated a secondary measurement of STEM knowledge; however, the movement between phases depended on the accuracy of the science practice skills.

Table 3. Target Skills and Definitions for Study 2

Science Practice NGSS (2013)	**Target Skill**	**Definition**
Obtain, evaluate, and communicate information	1. Explore materials	The participant uses at least one of their senses (look/touch/smell/listen/taste) to evaluate the materials for at least 5 seconds.
	2. Describe Materials	The participant states at least one attribute of the material.
	3. State what is known	The participant states what they know about the materials using previous knowledge.
Ask questions	4. Asking questions	The participant states a question related to what they want to know about the materials.
Obtain, evaluate, and communicate information	5. Making Predictions	The participant states an expected outcome of the experiment.
Plan/Carryout investigation	6. Plan Investigation	The participant states how they will measure their prediction.
	7. Carry out Investigation	The participant completes experimental testing by following procedures from their investigation plan.
Obtain, evaluate, and communicate information	8. Observe Results	The participant uses at least one of their senses (look/touch/smell/listen/taste) to evaluate the experimental outcome for at least 5 seconds.
	9. Describe Results	The participant states an outcome action or event from the experiment.
Construct explanation	10. Describe overall learning take away	The participant states something they learned from the experiment.

Target skills, definitions, and corresponding NGSS science practices for study 2.

4.4 Response to Definition and Data Collection

4.4.1 STEM Practice Skills

The interventionist collected the occurrence and non-occurrence of target STEM practice skills during sessions. The percent of independent STEM practice steps completed in the task analysis served as the primary dependent variable. This was measured through event recording, in which the percent of task analysis steps completed correctly and independently was obtained. Correct responses were recorded when the student independently responded following the defined operational definition for the target behaviour. Prompted responses were recorded when the participant responded following the defined operational definition for that task after being prompted (see Appendix G for prompting hierarchy). Prompted responses were recorded as incorrect; recording responses using this framework assessed the level of prompting support participants required. Incorrect responses were recorded when the participant did not respond following the defined operational definition for that task regardless of whether they received a prompt or not (see appendix H for scoring criteria). The total steps completed correctly and independently were calculated to a percentage obtained by dividing the number of correct steps by the total number of steps and multiplying by 100.

4.4.2 STEM Knowledge

In addition to the acquisition of independent STEM practice skills, a secondary outcome of the study was to assess STEM knowledge through unit quizzes. Approximately ten questions were verbally administered to participants following the end of a STEM unit. A correct response required the participant to verbally state the correct response independently. The correct responses were calculated to a percentage obtained by dividing the number of correct answers by the total number of responses and multiplying by 100. The interventionist collected the occurrence and non-occurrence of target STEM knowledge during sessions.

4.4.3 Interobserver Agreement

To assess the degree to which different observers scores target skills, inter-observer reliability was collected. A research assistant collected point-by-point IOA data on 30% of sessions across all participants and phases. Before independent observation, the research assistant achieved 90% reliability with the primary data collector. Agreements were scored when both observers recorded the same code for steps in the task analysis. Disagreements were scored when both observers record different codes for steps within the task analysis. IOA was calculated by dividing the number of agreements by the number of agreements and disagreements and then multiplying by 100.

4.4.4 Treatment Fidelity

A checklist outlining the intervention procedure was used to ensure all session components were correctly implemented by the facilitator (see Appendix I). Procedural fidelity checklists were completed by a trained research assistant who reviewed randomly selected video-recorded sessions. Treatment fidelity was calculated by dividing the number of agreements by the number of agreements and disagreements and then multiplying by 100.

4.5 Procedures

4.5.1 Pre-Assessment Interview

To confirm that the inclusion criteria were met, participants who passed the initial phone screening then completed an hour-long pre-assessment interview over the Zoom application. Following caregiver consent and participant assent protocols, participants were administered a demographic questionnaire and asked to view a short video to ensure they could attend to a video for at least 20 seconds. STEM practice skills were then assessed by conducting a short STEM experiment followed by completing the S-STEM. Due to resource constraints, adaptive behaviour functioning was assessed using the VAS-3 during the baseline phase of the study. Additional information was gathered from caregivers regarding the exceptionality category their child had on their IEP through a short meeting near the halfway through the study.

4.5.2 General

Individual sessions were held two times per week for each participant, sessions were an hour in length, and the study lasted approximately four months. Approximately 22 1-hour sessions were conducted for the first participant, 19 1-hour sessions for the second participant, and eight 1-hour sessions for the third participant. All sessions were conducted during after-school hours or on weekends, and the study continued through march break. All sessions began by reviewing the session rules, and participants were asked to choose a "brain break" activity before beginning experiments. During all study phases, participants started each unit by watching a short video or listening to a short lesson on the STEM concepts for the following lessons. All sessions began with the interventionist stating, "today we are learning about (unit concept)."

4.5.3 Baseline

The interventionist began each session during baseline by instructing the student to retrieve a specific STEM kit and open the paper bag with the required materials. Students were told to "try their best." Responses were marked as correct if the student began the step within 5 seconds and incorrect if the student made an error or did not respond within 5 seconds. If the participant did not respond within 5 seconds, the interventionist asked, "what is next?". After the student opened the bag, the interventionist provided information for the experiment (e.g., "in this experiment, we are going to use the materials to build a structure to support a load of books"). No planned reinforcement was given after the participants responded, regardless of whether their response was correct or incorrect.

4.5.4 Video-Enhanced Visual Activity Schedule Intervention Package

All intervention sessions began with the interventionist instructing the student to retrieve a STEM kit and open a corresponding bag. The participant was then shown the VAS with embedded VBM clips and told, "today we will learn some new ways to conduct STEM experiments with our VAS." As the student worked through each step in the VAS, the interventionist gained the participants' attention and stated, "We are going to learn how to (target behaviour). Watch the video of the students showing you an example of how to do this skill, then it will be your turn to do this skill". After watching the embedded video clip, the facilitator contrived a situation where the participant had the opportunity to demonstrate the learned skill. The interventionist provided social praise for correct responses such as, "good job, you did it just like they did in the video!". For incorrect answers, the interventionist stated, "nice try, next time remember to (target behaviour), just like they did in the video."

A system of least-to-most intrusive prompting was used when participants did not respond following the video clip. The KWHL chart was also introduced at the beginning of the lesson to support students during this time. The interventionist explained each section of the KWHL chart and encouraged participants to use it during the experiment. Fading procedures were planned to be applied when mastery level criterion was met (i.e., 80% accuracy over three consecutive sessions).

4.5.5 Fading

Participants in study 2 self-faded the embedded VBM clips although original fading procedures are outlined here. In the first phase of the fading procedures, the videos-clips in the task analysis were only presented once. Following mastery criteria (three consecutive sessions of 80% accuracy) of this phase, the video clips were only played if participants did not initiate the target behaviour within 5 seconds or if they demonstrated an error in the target behaviour. In the third phase, no video clips were available, only static photos of the target skills within the VAS. If the participant's response accuracy declined or showed no change over two sessions, the fading procedure was terminated, and the student had access to the video clips. This decision is based on the belief that a VAS could remain in a classroom as a support if needed in a real-world situation.

4.5.6 Post-Training Probes

After participants demonstrated mastery of the target STEM practice skills in the task analysis following the VBM intervention package, post-training probe sessions were readministered and occurred in the same manner to assess the effectiveness of the intervention. In this phase, participants used the video-enhanced VAS intervention package supports as needed. The interventionist contrived situations to evoke the target behaviours, and participant responses were recorded.

4.5.7 Generalization and Maintenance Sessions

Stimulus generalization sessions were conducted for each participant to assess the generalization of target skills across instructors. In this phase, STEM sessions were facilitated by a research assistant and participants' ability to demonstrate target STEM practice skills was recorded. Maintenance sessions were also conducted during the generalization phase at three-week follow-up sessions. During this time, participants had access to the video-enhanced VAS.

4.5.8 Social Validity

To determine whether the STEM program was valuable to participants, social validity was assessed after the STEM program was complete. Social validity is a crucial component of high-quality interventions. It is used in single-subject research to evaluate the relevance, effectiveness, and appropriateness of such research among the people involved (Horner et al., 2005). The current study utilized four questions, modified from previous research by Yakobova et al. (2020), to assess the effectiveness of the STEM program. A research assistant conducted semi-structured interviews with participants in which the following questions were asked: (1) did you like the activities in the study; (2) what did you like/what did you not like; (3) was it easy to learn using the materials (e.g., VBM, KWHL chart, VAS) we gave you; (3) would you like to use these strategies again; (4) is there anything else you would like to tell us about your participation in the study. All questions were read aloud, and visual support was used for participants to respond to the "*yes*" and "*no*" questions.

4.6 Study 2 Results

4.6.1 *STEM Practice Skills and STEM Knowledge*

We identified a functional relation between the implementation of the video-enhanced VBM intervention package and the acquisition of science practice skills. Figure 2 displays the percentage of steps in the task analysis completed independently, as demonstrated with circles, and the percentage of STEM knowledge questions completed correctly, as shown with triangles.

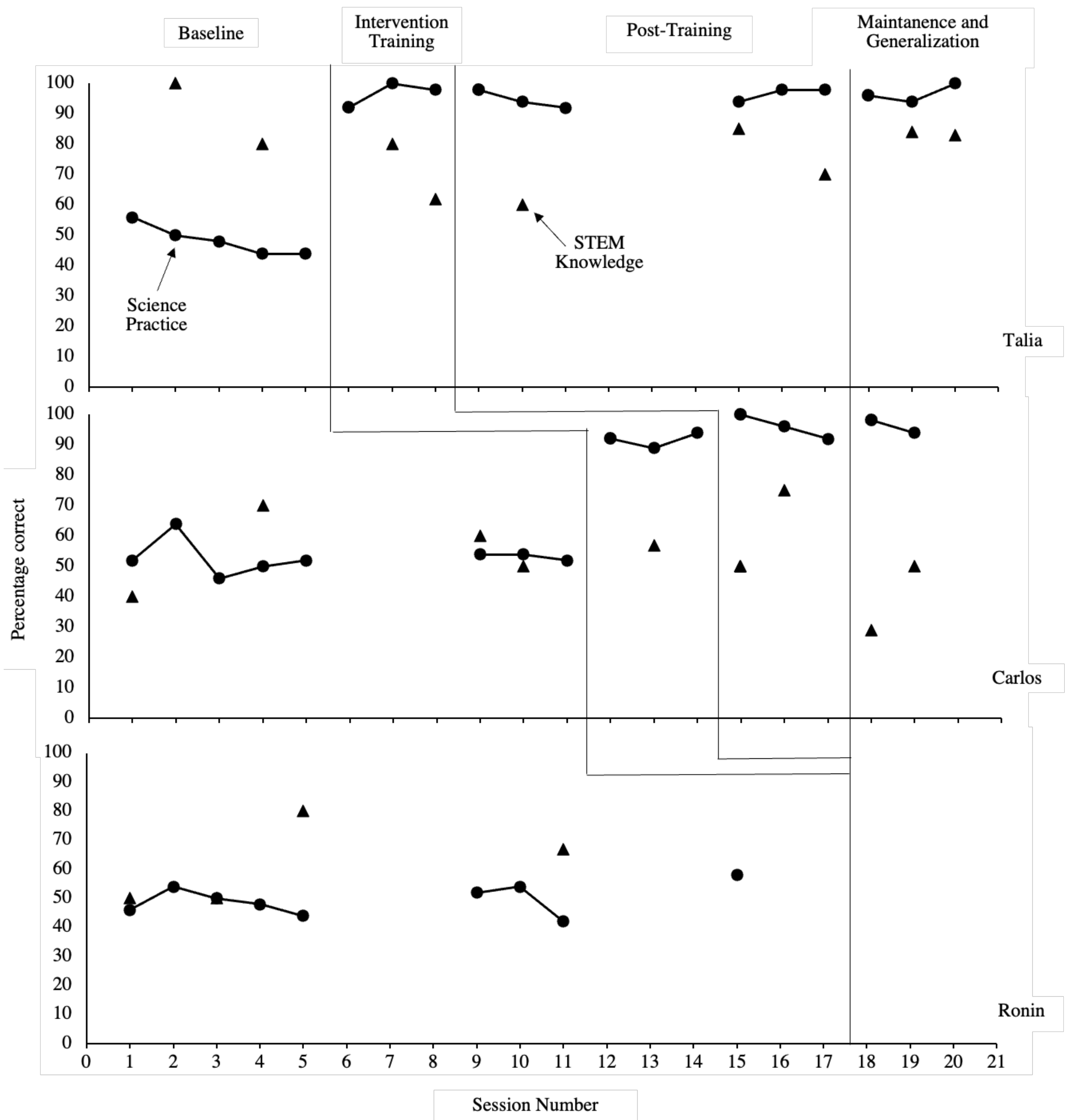

Figure 2. Percentage of science practices and STEM knowledge performed correctly for study 2

4.6.1.1 *Talia*

Talia showed a moderate level of responding, which moved in a slight downward trend across baseline probes (*range* = 44% to 56%) and began intervention training in session six. Talia's accuracy for independently completing the task analysis during three intervention training sessions was stable at 92%, 100%, and 98%, respectively. In the intervention training phase, she demonstrated a clear, immediate change in high-level responding compared to baseline sessions. During the second training session Talia self-faded the VBM component of the intervention before fading procedures were implemented by explicitly stating that she did not want to watch the embedded VBM as she knew the skills. Talia met mastery criteria in the third training session. In the ninth session, she began post-training probes, relying on the static VAS to complete steps. Talia struggled to describe materials and make a prediction, although she continued to demonstrate stable high-level responses (range = 92% to 98%). During the initial training sessions, she often watched the videos of skills she was unsure of before completing the step.

Across phases, there was no overlapping data between baseline and treatment conditions and Talia continually responded at high stable levels during the intervention and post-training phases. Talia often completed some skills very quickly without referring to the VAS. However, she used the static VAS for support with the following steps: (4) making a prediction, (5) planning an experiment, (9) describing results, and (10) stating what you, while independently completing the other target skills. Throughout the study, Talia often requested small brain break activities which involved movement. Talia's accuracy for independently completing the task analysis during three maintenance and generalization sessions was stable at 96%, 94%, and 100% respectively. The participant demonstrated some initial difficulties stating learning outcomes.

On a secondary outcome measure of STEM knowledge, Talia demonstrated moderate to high levels of STEM knowledge accuracy during baseline with some variability (range =

80% to 100%). During the intervention session, she showed moderate STEM knowledge with some variability moving in a downward trend (range = 62% to 80%). During post-training sessions, STEM knowledge was variable (range = 60% to 85%). The PND from baseline to treatment and post-treatment phases for STEM knowledge is 0%. The participant demonstrated some initial difficulties stating learning outcomes. Overall, there was no immediate change in STEM knowledge when the intervention package was introduced. Talia's accuracy for STEM knowledge during maintenance and generalization sessions was 84% and 86%.

4.6.1.2 *Carlos*

Carlos demonstrated a moderate level of target skills during the initial baseline probe sessions (*range* = 46% to 64%) with some variability and no trend in data. He increased the accuracy of target skills in session two (64%), the buoyancy unit, in which he stated that he had previously completed similar experiments during school which might explain his increased skill demonstration. Carlos's accuracy for independently completing the task analysis during three intervention training sessions was 92%, 89%, and 94%, respectively. In the intervention training phase, he demonstrated a clear, immediate change to high-level responding with some variability in training session two (89%). During training session two, Carlos was visibly frustrated and moved through each skill very quickly, resulting in the incompletion of some skills. The interventionists encouraged him to copy the behaviour in the video, in which he stated he did not enjoy watching the videos as it made the experiment take longer. In the following session, Carlos began to self-fade the VBM clips, using them only if he required additional support with target skills. He met mastery criteria by session three of the intervention training phase. He began post-training probes in the 15th session, relying on the static VAS to complete steps. Carlos experienced difficulties making a prediction, often becoming visibly upset, resulting in sessions ending early. He was encouraged to watch the VBM clips before making a prediction. Post-training probe sessions remained stable at high levels (range = 92% to 100%). Carlos's accuracy for independently completing the task analysis during two maintenance and generalization sessions was stable at 98% and 94%, respectively.

Across phases, there was no overlapping data between baseline and treatment conditions and Carlos continued to rely on the static VAS. Carlos often completed some skills very quickly without referring to the VAS. However, he used the static VAS for support with the following steps: (2) stating what you know, (3) asking questions, (4) making a prediction, (5) planning an experiment, (9) describing results, and (10) stating what you learned. Throughout the study, Carlos often requested to end each session, which frequently ended early, with a brain break which involved physical movement.

On a secondary measure of STEM knowledge, Carlos demonstrated moderate to low STEM knowledge during baseline (range = 40% to 70%). During the intervention phase, STEM knowledge was 57%. During the post-training session, Carlos demonstrated moderate to low STEM knowledge (range = 50% to 75%). The PND for STEM knowledge from baseline to treatment and post-treatment phases was 33%. Overall, there was no immediate change in STEM knowledge when the intervention package was introduced. Carlos's accuracy for STEM knowledge during maintenance and generalization sessions was 29% and 50%.

Due to time constraints, only two data points for generalization and maintenance sessions were collected for Carlos.

4.6.1.3 *Ronin*

Ronin demonstrated moderate levels of target skills during baseline sessions (range = 44% to 58%) with some variability and a slight downward trend. Ronin withdrew from the study before moving beyond baseline sessions. On a secondary measure of STEM knowledge, Ronin displayed high to moderate levels of STEM knowledge during baseline (range = 50% to 80%). Several STEM knowledge assessments were not administered for Ronin during baseline due to time constraints.

4.6.2 *Reliability and Treatment Fidelity*

IOA data was collected for participants' performance on the task analysis across 35% of sessions using a random number generator. Overall, IOA was 97% (range = 92 to 100%). Treatment fidelity was assessed for 30% of randomly selected intervention sessions using a checklist outlining the intervention implementation procedures. Overall, treatment fidelity data was 99% (range = 98% to 100%).

4.6.3 Social Validity

The participants and caregivers completed a semi-structured interview. Talia stated that she enjoyed participating in the study, and especially liked the electricity units. She stated that using the VAS made the experiments longer, which she did not like, and she did not want to use the VAS in the future because of this. Her mother responded by saying that she has seen an overall interest in her daughter's STEM hobbies. She stated that they enjoyed participating in sessions each week but found navigating virtual sessions with technological issues challenging. Carlos noted that he enjoyed participating in the study and especially liked the space unit. He said that the VAS helped him complete experiments, and he would use it again. Carlos did not like the frequency of sessions, saying that he would like to only participate in sessions one time per week instead of having multiple sessions per week. Carlos's mother stated that the reinforcement procedures were very motivating for Carlos as he often required encouragement and feedback during learning. Overall, both participants and their caregivers stated that they enjoyed participating in the study.

4.7 STEM Attitudes and Interest

Descriptive statistics were used to compare participants' attitudes and interest toward STEM during pre-and post-assessments. Negatively worded questions were assigned values in reverse order and post-tests were complete during generalization and maintenance sessions. Pre-and post-means and standard deviations are depicted in Table 4.

Table 4. Pre and Post Assessment of STEM Attitudes

	Pre-Assessment Mean (Standard Deviation)		Post-Assessment Mean (Standard Deviation)	
S-STEM Category	Talia	Carlos	Talia	Carlos
Science Attitudes	3.66 (1.64)	3.33 (1.15)	3.22 (.63)	3.33 (1.05)

Technology and Engineering Attitudes	3.22 (.42)	2.67 (1.25)	3.44 (.83)	2.4 (1.10)
Mathematics Attitudes	3.50 (1.94)	3.0 (1.0)	3.37 (1.87)	3.0 (.71)
21st century skill attitudes	4.9 (.29)	3.36 (.64)	4.27 (.75)	4.18 (1.26)
STEM career Interests	2.5 (.50)	1.0 (.0)	2.6 (.64)	2.16 (.37)

Pre-and post-assessment scores of STEM attitudes for participants in study 2.

4.7.1 Talia

Talia demonstrated increases from pre-to post-assessment in her attitudes towards technology and engineering (pre-assessment M = 3.22, SD = .42; post-assessment M = 3.44; SD = .83) and STEM career interest (pre-assessment M = 2.5, SD = .50; post-assessment M = 2.6; SD = .64). Decreases were found in her attitudes towards science (pre-assessment M = 3.66, SD = 1.64; post-assessment M = 3.22; SD = .63), math (pre-assessment M = 3.50, SD = 1.94; post-assessment M = 3.37; SD = 1.87), and 21st century skills (pre-assessment M = 4.9, SD = .29; post-assessment M = 4.27; SD = .75).

4.7.2 Carlos

Carlos demonstrated increases from pre-to post-assessment in his attitudes towards 21st century skills (pre-assessment M = 3.36, SD = .64; post-assessment M = 4.18; SD = 1.26) and STEM career interest (pre-assessment M = 1.0, SD = .0; post-assessment M = 2.16; SD = .37). Decreases were found in his attitudes towards technology and engineering (pre-assessment M = 2.67, SD = 1.25; post-assessment M = 2.4; SD = 1.10). No change was demonstrated in his attitudes towards science (pre-assessment M = 3.33, SD = 1.15; post-assessment M = 3.33; SD = 1.03) and math (pre-assessment M = 3.0, SD = 1.0; post-assessment M = 3.0; SD = .71).

4.8 Discussion

The current studies examined the effectiveness of a video-enhanced VAS intervention package on the science practice skills of students with ID and NDD. Specifically, the efficacy of a video-based VAS combined with a KWHL chart, a prompting hierarchy, and reinforcement procedures was evaluated. As a result of the intervention package, the findings suggest that students with ID and NDD acquired and applied science practice skills across multiple STEM lessons and units of work, as illustrated by the increase in the accuracy of target skills. As important to the intervention's effects, stakeholders (i.e., participants and caregivers) in this study found the intervention package socially important and relevant to their everyday lives.

In study 1, we examined the use of the intervention package on one participant with an ID through a single-case study comprised of a baseline and treatment condition. The participant gradually increased the percentage of science practice steps correctly performed after introducing the intervention package. In the initial treatment sessions, the video-enhanced VAS support alone was insufficient in teaching target skills. The participant relied heavily on gestural and verbal indirect prompting for most skills, except for making a prediction in which she required instructor modelling prompts. The embedded VBM clips in the VAS were used to support the demonstration of each skill except for (a) observing materials, (b) conducting the experiment, and (c) observing the results, which the participant frequently completed independently. Mastery-level criterion was reached at the 11th treatment session, and the KWHL chart was rarely used aside from occasionally referencing it before starting the experiment. Of the ten target skills, making a prediction emerged as a complex skill often requiring additional modelling prompts.

In study 2, we examined the use of the video-enhanced VAS on two participants with NDD through a two-tier multiple-probe research design. The participants immediately increased the percentage of science practice steps performed correctly after the intervention package was implemented, quickly self-fading the embedded VBM clips and relying only on the static photos and VAS. Neither of the participants used the KWHL chart and Carlos experienced ongoing difficulties making a prediction, often having to review the embedded VBM for guidance. Participants generalized the use of the intervention package to a novel instructor at three-week follow-up maintenance probes. Carlos demonstrated a significant increase in his interest related to future STEM work (pre = 1; post = 2.08) whereas Talia demonstrated a significant decrease in her ability to perform 21st century skills (pre = 4.91; post = 4.27). Lanovaz and Turgeon (2020) found that Type I error rates are low in three-tiers multiple baseline design when two tiers show a clear change. Therefore, our data may be sufficient to indicate a functional relationship between the use of the intervention package and mastery of science practice skills, as demonstrated by two participants with NDD.

4.8.1 Benefits of Multi-Component Instructional Methods

The results of the current studies indicate that integrating multiple instructional components grounded in systematic instruction assisted in eliminating barriers commonly experienced by students with ID and NDD when accessing STEM education and learning science practices. Although the positive effects of the intervention package must be attributed to the intervention package as a whole, it is important to recognize that each participant responded to the intervention differently, utilizing various degrees of support from components in the package. For Paige, the embedded VBM clips within the VAS combined with the prompting hierarchy were used more frequently during intervention training sessions when compared to Talia and Carlos. In study 2, participants self-faded the use of the VBM clips within the VAS, watching clips only if they required additional assistance with a target skill. In line with previous research, Spriggs and colleagues (2015) indicated that embedding VBM in a VAS was an effective method of supporting the individual learning characteristics of participants with ASD in various academic skills. In their study, some students progressed to using only a static VAS to support skills whereas other students continued to rely on embedded VBM clips. Taken as a whole, the differentiated level of support video-enhanced VAS combined with prompting and reinforcement offer might better assist students with a variety of learning needs in STEM education.

Although video-enhanced VAS aligns closely with the task analytic nature of science practices, current literature within the field endorses the use of KWHL charts in teaching science practices to students with ID and NDD (Knight et al., 2020). However, students in the present investigation did not engage with the KWHL chart. Notably, previous research supports knowledge chart use when combined methods of systematic instruction are included (e.g., prompting and time delay; Knight et al., 2020). In the current study, participants were introduced to the KWHL chart, but the use of the chart was not prompted, and it was considered peripheral support, which might explain the limited chart use. Notably, the KWHL chart does not encompass all eight components of science practices outlined by the NGSS. When considering the skills it supports, it might be an effective avenue to removing learning barriers for specific skills among students who require additional support outside of the video-enhanced VAS with combined prompting and reinforcement. For example, the KWHL chart might better assist with: (1) stating what is known, (2) asking questions, (3) planning the experiment, and (4) stating what was learned for students who require additional support.

In the current study, participants were provided with brief training on the KWHL chart use. In this context, remembering the KWHL prompts might have been difficult for participants based on the literacy demands required to read each section (Brigham et al., 2011). Previous research supports using video-enhanced VAS for students with ASD based on the belief that visual processing support is more feasible for some learners than following auditory or written information (Kliemann, 2014). The cognitive, memory and attention demands of following verbal or written science practice instructions within the KWHL chart might pose barriers to learning for students with ID and NDD (Brigham et al., 2011). Developing cohesive intervention packages with a range of instructional supports and methods which can be faded out as required will better support the diverse needs of all students in learning STEM.

Another method embedded within the video-enhanced VAS was the use of multiple exemplars to teach science practice skills across various STEM experiments. Teaching multiple exemplars is considered an EBP to promote generalization in science education and is recommended by Knight and colleagues (2020) when teaching science practices to students with ID and/or ASD. In the literature, multiple exemplar training is primarily used as one component of an intervention package to increase the generalization of science vocabulary or content. For example, Knight and researchers (2013) used multiple exemplars to support vocabulary placement on graphic organizers to ensure participants did not simply memorize science vocabulary words (e.g., different graphic organizers showing various landscape scenes to teach the weather cycle). When teaching science practices, presenting novel stimuli with similar features increases the likelihood of evoking the same response as the training stimuli (Cooper et al., 2007). This is especially important when applying a set of science practice skills to problem-solve across STEM experiments.

VBM is a feasible instructional practice where multiple exemplars can be embedded and watched repeatedly (Keenan & Nikopoulos, 2006). Previous research by Knight et al., 2018 instructed educators to provide multiple exemplar training via in vivo modelling to students with ASD/ID to support science content knowledge. Comparatively, in the current study, the integration of various exemplars in VBM-clips reduced the reliance on the program interventionist to model in vivo STEM experiments. In the context of a classroom, the ability to provide concrete examples of science practices, as demonstrated by multiple exemplars that students can watch and re-watch when needed, might reduce the workload of educators to provide in vivo modelling (Spriggs et al., 2015). While research using VBM to teach STEM to students is limited, it often does not include multiple exemplar training embedded into VBM clips (Knight et al., 2020). Therefore, findings from the current study support the use of this technique, specifically when teaching science practices to students with ID and NDD.

4.8.2 Areas of Support

Participants in the current study faced challenges regarding learning STEM and science practices. First, all three participants experienced difficulties formulating a prediction and required differential support to complete this skill. Carlos and Talia often used the VAS with embedded VBM after VBM was self-faded for all other skills. Comparatively, Paige required the VAS with embedded VBM in addition to gestural, verbal, and modelling prompts. Paige she often required five to ten seconds to formulate a response. Previous research supports using time delay in teaching discrete skills to students with ID, such as sight words and mathematical facts (Browder et al., 2012). However, making a prediction is a skill that requires students to store and recall information to anticipate an outcome (Hawkins et al., 2009; NGSS, 2013). Compared to discrete skills (e.g., facts and sight words), the demand for long-and-short term memory when making predictions might require additional response time for students with ID.

An avenue which might support prediction skills among students with ID and NDD are embedded use of vocabulary cards to illustrate visual cues and social scripts. Following the work of Knight and colleagues (2018), embedding social scripts and vocabulary cards which educators can use to guide student learning (e.g., "*I think the sun [visual picture of sun] will/will not melt the smores" [visual picture of melted smores])* might be effective in teaching more complex science practices like making a prediction. Likewise, in study 1, Paige experienced difficulties formulating questions, often stating "what is this" while pointing to a material that was previously described and named. When the interventionist responded, "do you know what that is?" the participant stated "yes" and when prompted to ask another question, she proceeded to experience difficulties formulating novel questions. Future research might explore the effects of social scripts embedded into the current intervention package as a support to assist students in learning science practice skills.

In addition to scaffolding support of science practice skills, social scripts might be especially beneficial for instructors with limited experience and knowledge of working with students with ID and NDD in STEM. In the current study, the interventionist had limited knowledge of STEM education which might have impacted the degree to which STEM concepts were taught using science practices. Although sessions began with a short video or brief lesson about the concept to be covered, integrating the unit concept into each STEM experiment was challenging. The disconnect between STEM concepts and experimentation might also explain participants' STEM knowledge variability. Previous research on scripted instruction to teach science to students with ASD suggests that compared to experienced teachers who have a deep knowledge of science concepts, new educators might benefit from scripted lessons (Knight et al., 2018). Further, previous research indicates that new educators often feel that they are not prepared to meet the needs of students with ID and ASD in the general classroom (Knight et al., 2019b). In this context, scripted lessons that include instructions for systematic instruction might provide a framework to assist educators in supporting students with ID and NDD in STEM learning.

It is worth noting that Carlos often displayed frustration when faced with complex experiments or challenging steps (i.e., making predictions). Although additional support might negate learning difficulties when applying STEM practices, it is essential to recognize the importance of embedding social-emotional skills into STEM learning. STEM learning encourages perseverance as students engage in challenges that require the capacity to learn from previous mistakes and revisit problems to investigate novel solutions (Stohlmann, 2022). The challenges of working with a team, investigating complex problems, or simply managing one's own emotions highlight the intertwinement of social-emotional learning in STEM education (Sousa & Pilecki, 2013). While some research focuses on the infusion of social-emotional skills into STEM learning for neurotypical students (Garner et al., 2018), such research focused on teaching social-emotional skills in STEM learning for students with ID and NDD is extremely limited. While students can benefit from social-emotional support in STEM learning (Sousa & Pilecki, 2013), these benefits might be particularly emphasized for students with ID and NDD who commonly experience underlying emotional regulation difficulties (England-Mason, 2020). Although social-emotional skills were not a targeted behaviour of the current study, Talia demonstrated a significant decrease in her attitudes regarding 21st-century skills (e.g., "I can respect all children my age even if they are different from me"; "in school and at home, I can do things well") from pre- to post-assessments. Thus, future research should consider how to further embed social-emotional support while learning science practices during STEM education.

4.9 Two-Tiered Multiple Baseline Research Designs

In study 2, we present a two-tiered multiple baseline design which does not meet current best practices, as outlined by the What Works Clearinghouse (WWC, 2012), due to a lack of evidence of effect across all three temporal independent tiers. However, work by Lanovaz and Turgeon (2020) indicate that the current recommendation of three demonstrations of effect is not grounded in empirical evidence and is instead considered "overly stringent" criteria. As a result, three-tier multiple baseline studies have a lower probability of detecting true differences between participants (i.e., power).

Lanovaz and Turgeon (2020) examined the Type 1 error rate and power in multiple baseline designs in their research. By applying the dual-criteria method to each tier, they generated 10 000 multiple baseline graphs and computed Type 1 error rate and power for various tiers depicting a clear change. Comparatively, three-tier multiple baseline designs demonstrating a clear change in all three tiers presented a Type 1 error rate of .001 and .542. Importantly, two-tier multiple baseline designs demonstrating a clear change in both tiers resulted in a type 1 error rate of .006 and higher power of .658. Although the results of Lanovaz and Turgeon have yet to be replicated by another research group and therefore should be interpreted with caution, there is evidence to suggest that the current study presents sufficient power to determine a functional relationship between the intervention package and science practices in study 2.

Chapter 3

5 Conclusion

We examined the effects of a video-enhanced VAS intervention package on the science practice skills of students with ID and NDD. In study 1, the participant with an ID took longer to acquire target skills and required video-clip examples throughout the study. Comparatively, the participants with NDD in study 2 acquired the target skills immediately following the intervention while self-fading the video clips and relying on static photos alone in the VAS. These findings suggest that video-enhanced VAS intervention packages can offer varying levels of support for students with ID and NDD when accessing STEM instruction.

5.1 Implications

5.1.1 *Practice Implications*

To ensure educators are equipped with EBP to support students with ID and NDD in learning STEM, the research community must keep up with the educational curriculum and policy changes. Although more research is needed to determine the effects of the video-enhanced VAS intervention package, the current study adds to the literature supporting systematic instruction (video-enhanced VBM, reinforcement, prompting) in teaching STEM to students with ID and NDD.

Video-enhanced VBM intervention packages might be a practical support in the STEM classroom. Educators are often bound by limitations of professional support, finances, and the demands of meeting the needs of all students in the class (Olson & Ruppar, 2017). Utilizing VBM can provide multiple exemplar training which students can watch and re-watch a video for support. In this way, VBM might be a practical and feasible way to support students in the classroom while reducing the demand of in vivo modelling on educators. Combining a VAS and other prompting and reinforcement procedures could help students' on-task behaviour during sequential steps in learning (Knight et al., 2013). Although students in the current study did not engage with the KWHL chart, previous research suggests that it can still support the science practice of students (Knight et al., 2020). Importantly, providing differentiated support for students with a range of learning, academic, and social skills will help assist in the success of all students in the classroom.

5.1.2 *Policy Implications*

The number of students accessing special education services within Ontario schools has steadily increased over the last two decades (Bennett, 2009; Bennett, 2019). Although equitable and inclusive education is described as a hallmark of Ontario's education system (Education Act, 1990), reports by the Learning Disabilities Association of Ontario (Horizon Educational Consulting, 2016) and the Ontario Human Rights Commission (2018) have identified a lack of resources and delays in the provision of special education services. Notably, many educators understand the importance of inclusive education within the general classroom, however, they often face systemic barriers to implementing such practices (Olson & Ruppar, 2017). The Elementary Teacher's Federation of Ontario (2019) has lobbied for an increase in resources (e.g., funding and training) to ensure teachers can adequately implement inclusive education practices within the general classroom. As the Ontario Ministry of Education is set to introduce a reformed STEM curriculum in the fall of 2022, it is crucial that policymakers bridge the gap between policies, research, and practice to improve STEM instruction for all students. While additional research focused on teacher training and EBP in inclusive STEM education is required, the current paper provides a direction for future research which has the potential to inform inclusive education policies and accompanying practices in Ontario.

5.1.3 Research Implications

The results of the current studies respond to the calls to action from several groups in the scientific community to expand upon intervention research in the field of STEM education for students with ID and NDD to include science practices derived from NGSS (2013; Knight et al., 2020; Jimenez et al., 2021), VBM (Wright et al., 2020), and STEM content as an interdisciplinary whole (Wright et al., 2020). While noteworthy progress has been made in the field of STEM education for students with ID and NDD in the last several decades, it is narrow in scope, primarily focusing on science or mathematics education while lacking high-quality research indicators (Knight et al., 2020; Wright et al., 2020). Despite a slow movement of intervention research focused on teaching other aspects of STEM to students with ID and NDD, such as robotics and coding (Knight et al., 2019a), it fails to integrate STEM teaching as a whole and science practices outlined by the NGSS. Thus, the current study extends previous research investigating how a multi-component intervention package utilizing visual-media supports can be used to remove barriers students ID and NDD face in STEM education.

5.2 Future Work and Limitations

Several limitations to the current studies indicate a direction and need for future research. The baseline-intervention design in study 1 is not considered a single-subject design that systematically addresses threats to validity and demonstrates experiential control (Gersten et al., 2005; Horner et al., 2005). Therefore, quality indicators, as outlined by the Council for Exceptional Children (CEC; Cook et al., 2014) cannot be reviewed. When assessing for risk of bias in study 1, two of nine categories emerged as “high risk” (Reichow et al., 2018). Firstly, the interventionist served as the primary data collector resulting in a high detection bias in the blinding outcome assessor domain. Further, the other potential source of bias category is considered high due to technical issues with the Zoom application causing the video recordings to freeze occasionally.

When assessing biases in study 2, four of the nine categories for risk of bias in single-subject research emerged as “high risk” (Reichow et al., 2018). Firstly, the introduction of the intervention package was applied in a predetermined order resulting in a high selection bias in sequence generation. Specifically, Carlos experienced frustration due to limited academic support in the baseline phase; therefore, to reduce the baseline duration, he received the intervention before the third participant, who eventually withdrew from the study. Secondly, explicit procedures to ensure the blinding of key personnel (i.e., the research assistant who collected IOA and treatment fidelity) were not used in study 2. Thirdly, the interventionist served as the primary data collector resulting in a high detection bias in the blinding outcome assessor domain. Finally, the other potential source of bias category is considered high due to technical issues with the Zoom application in which one session was not fully recorded and several recorded videos froze impacting IOA data collection. In addition, there were numerous aberrations in length between sessions for Talia, who cancelled sessions due to sickness. Importantly, all quality indicators defined by CEC (Cook et al., 2014) for sound methodological research were met except for demonstrating three tiers of experimental effect and collecting a minimum of three data points per phase. In the generalization sessions, Carlos was unable to attend a third session due to time constraints, limiting generalization and maintenance data within this phase to two data points. To address these limits, future research must use random sequence generation, explicit blinding procedures, and procedures to control for additional risks of bias to ensure internal validity is maintained. In addition, future research should ensure timelines allow for complete data collection.

In considering other constraints present in the current research, a fundamental limitation was the use of a segregated setting, which was chosen primarily to accommodate COVID-19 disease control measures. Although one-on-one instruction can be beneficial for some students (Harlacher et al., 2014), collaboration and teamwork are cornerstone principles in STEM learning as students work cohesively to solve novel problems (Osborne, 2014). Given the importance of group dynamics in STEM learning and inclusive education (Osborne, 2014; Kefallinou et al., 2020), future research should embed the current intervention package within an inclusive setting (e.g., the general classroom, STEM camps, science center programming). Further, future research should explore how participants can become actively involved in the development of VBM clips. For example, educators could consider how students with and without disabilities might work together in a classroom setting to develop VBM clips for the project. Although the current study aimed to include all eight components of NGSS science practices, future research should consider how to further embed explicit support to better assist students in complex science practices. In the current study, the use of math and computational skills was embedded within select lesson plans (i.e., human organ system, buoyancy, flight). However, the NGSS (2013) states that students should consistently learn to identify patterns in large data sets while using mathematical concepts to support explanations. Previous research has identified systematic instruction, VBM, graphic organizers, and the use of manipulatives as EBP to teach math to students with ID and NDD (Hughes &

Yakubova, 2019; Spooner et al., 2019). In addition to embedding additional opportunities for math and computation learning into lesson plans, future research might benefit from including support that focuses on these skills directly (i.e., VBM to teach applied arithmetic problems following science practices with support from manipulatives).

Importantly, literature within the field of teaching science to students with NDD, including students with ID, uses the NGSS science practices framework (2013). In the context of the Canadian education system, future research should incorporate the Smarter Science framework (Youth Science Canada, 2011), which is used to inform the Ontario science and technology curriculum and includes a framework of scientific processes required to complete an experiment. Moreover, the current lesson plans were designed, developed, and implemented following the 2007 science and technology curriculum from the Ontario Ministry of Education. Lesson plans did not incorporate an equal representation of each STEM discipline, with most lesson plans incorporating two STEM subjects, therefore, falling short of the NRC (2012) definition of STEM to include equal representation of all four STEM disciplines. Future research should consider how the current intervention package can support students in holistic STEM education.

Further, the science practice of engaging in an argument from the evidence was taught by embedding the target skill of stating what was learned during experiments when comparing outcomes. However, the NGSS highlights the need to equip students with the ability to respectfully offer and receive critiques grounded in evidence from peers. Current literature supports the use of VBM in psychosocial interventions among students with ID, ASD and/or ID, and ADHD (Odom et al., 2015; Wilkes-Gillian et al., 2021) who often experience difficulties with social and communication skills (APA, 2013). In this context, embedding VBM support to teach complex social skills (e.g., offering and receiving criticism) in a group setting might better teach students how to construct a strong argument and refutes claims.

In the current study, participants varied in STEM knowledge accuracy. To better assess the changes in STEM knowledge based on session participation, further research should assess STEM knowledge before and after STEM sessions. Additional supports such as vocabulary cards should be incorporated into lessons to support students in understanding abstract concepts (e.g., STEM concepts such as seasons, ramp, code, tilt) in addition to gaining STEM vocabulary, as used in Knight et al. (2018). Further, more research should consider how social scripts might support interventionists in connecting STEM concepts to experiments.

More research should consider using peer mediators or paraprofessional support of someone outside the research group, such as an educational assistant. In addition, raising the age range of participants to include middle and high school students would help determine the effects of the intervention package across grades. Another explorative avenue for future research is to conduct a component analysis of the current intervention package to differentiate the individual and interactive effects of the embedded instructional supports. Further, the interventionist controlled the movement between the video-enhanced VAS in the present study. Thus, future research must ensure that participants receive technology training to move through the video-enhanced VAS independently.Perhaps the most significant limitation of the current paper was the lack of students with IDs ranging in severity. Initially, students with intellectual and/or developmental disabilities were recruited; however, only one student with an ID responded to the recruitment posters. It is noteworthy to mention that the inclusion criteria guidelines posed significant barriers to participation among students with ID (e.g., participants must speak in sentences comprised of at least three words). Often, students with severe or profound ID are precluded from academic research in STEM learning (Ehsan et al., 2018), yet ensuring equitable access to STEM education and furthering the STEM skill development of all students means including students with the most extensive support needs into research (Knight et al., 2020). Thus, it is recommended that future research in STEM education design, develop, and implement research studies which account for the barriers and facilitators to the participation of students with severe and profound ID.

5.3 Final Conclusions

In summary, the presenting two studies shed light on the scarcity of research focused on STEM education for students with ID and NDD. Through a single-case design comprised of a baseline and treatment phase and a two-tiered multiple baseline research design, the current findings deepen the field's understanding of academic interventions grounded in systematic instruction to support STEM learning for students with ID and NDD. An accessible STEM education serves as a fundamental human right for all students (Education Act, 1990). While not every student with ID and NDD will gravitate towards and enjoy STEM activities, this research suggests that eliminating barriers to STEM learning is a necessary step to ensure all students have the opportunity to participate in a comprehensive STEM education.

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6 Appendices

6.1 Appendix A: Lesson Themes

Lesson Theme
Magnets
Gravity
Physical changes
Buoyancy
Electricity 1
Flight
Strong shapes
Strong materials
Energy
Mixtures and Solutions
Friction
Coding/Robotics
Heat
Light
Colours
Rocks and Minerals
Chemical changes
Electricity 2
Colours
Space
Human Organ Systems

6.2 Appendix B: Example Lesson Plan

<table>
<tr><th colspan="3">Lesson Plan 2 - Buoyancy</th></tr>
<tr><td>Lesson Sequence</td><td colspan="2">1. Sink or Float – Mixed materials
2. Sink or Float – Play Doh 1
3. Sink or Float – Play Doh 2
4. Sink or Float – Orange 1
5. Sink or Float – Orange 2
6. Dancing Raisins 1
7. Dancing Raisins 2
8. Sink a Boat</td></tr>
<tr><td>Curriculum Expectations</td><td colspan="2">Grade 3 Science and Technology Expectations
2.1 follow established safety procedures during science and technology investigations
2.2 investigate forces that cause an object to start moving, stop moving, or change direction
2.3 conduct investigations to determine the effects of increasing or decreasing the amount of force applied to an object
2.4 use technological problem-solving skills and knowledge acquired from previous investigations, to design and build devices that use forces to create controlled movement
2.5 use appropriate science and technology vocabulary, including push, pull, load, distance, and speed, in oral communication
3.1 identify a force as a push or a pull that causes an object to move
3.2 identify different kinds of forces
3.3 describe how different forces applied to an object at rest can cause the object to start, stop, attract, repel, or change direction
3.4 explain how forces are exerted through direct contact or through interaction at a distance
3.5 identify ways in which forces are used in their daily lives</td></tr>
<tr><td colspan="3">Introduce Lesson Concept:
https://www.youtube.com/watch?v=eQuW8G2QV_Q</td></tr>
<tr><td colspan="3">Experiment 1 – Sink or Float: Mixed Materials</td></tr>
<tr><th>Minute</th><th>Objective</th><th>Activity</th></tr>
<tr><td></td><td>Set Up</td><td>Place on table
- Large bowl with tap water
- Towel (in case of spills)
- Table with objects as column headings and sink or float as a row heading
- Pencil for writing
- Metal cutlery
- Plastic cutlery
- A coin
- Ball of tin foil
- A wooden stick (e.g. twig or popsicle stick)</td></tr>
<tr><td></td><td>Observing</td><td>Participant looks at and touches the materials laid out</td></tr>
</table>

	Materials	
	Describing Observations	Participant states one attribute for: Metal Cutlery: Plastic Cutlery: Coin: Tin Foil: Stick:
	Stating What is Known	Participant states what they know about the items. Encourage participant to identify the material they are made from (i.e. plastic, metal, and wood)
	Asking Questions	Participant asks “What will happen when I put these in the water?”
	Making Predictions	Participant guesses which objects will sink and which will float
	Plan Investigation	Participant plans how they will place each object in the water and record their observations
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant identifies which objects sank and which floated
	Describe Results	Participant makes a general statement about how the heavier items sank and the lighter items floated. They should not make statements about metal sinking and wood floating since the tin foil ball should have floated while the other metal objects sank
	Describe Overall Learning	Some objects float (called being buoyant) and others sink
	Clean Up	Remove all items except for the bowl and towel
	Experiment 2 – Sink or Float: Play Doh 1	
Minute	Objective	Activity
	Set Up	Add a ball of play doh to the table
	Observing Materials	Participant looks at and touches the materials laid out
	Describing Observations	Participant states one attribute for: Play doh: ____
	Stating What is Known	Participant states what they know about the items.
	Asking Questions	Participant asks “What will happen if I drop the ball of play doh in water?”
	Making Predictions	Participant guesses that it will sink/float
	Plan Investigation	Participant plans how they will drop in the play doh and make observations
	Carry Out	Participant follows through on plan

	Investigation	
	Observe Results	Participant sees that the play doh sinks
	Describe Results	Participant makes a general statement about the balled up play doh is not buoyant
	Describe Overall Learning	In a ball shape, the play doh is not buoyant
	Clean Up	Keep all items
Experiment 3 – Sink or Float: Play Doh 2		
Minute	Objective	Activity
	Set Up	Have participant design a bowl/boat made out of playdoh to test buoyancy
	Observing Materials	Participant looks at and touches the materials laid out
	Describing Observations	Participant states one attribute for: Moulded play doh:
	Stating What is Known	Participant states what they know about the items. Encourage participant to acknowledge that the play doh sank in its previous shape
	Asking Questions	Participant asks "Will the play doh float in its new shape?"
	Making Predictions	Participant guesses that the play doh will float
	Plan Investigation	Participant plans how they will place the play doh in the water and make observations
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant sees that the play doh boat floats
	Describe Results	Participant makes a general statement about how the play doh can be buoyant if it is the right shape
	Describe Overall Learning	The shape rather than weight of materials can determine if they are buoyant
	Clean Up	Remove play doh. Note, you will need the bowl of water and play doh boat later. Do not squish the play doh
Experiment 4 – Sink or Float: Orange 1		
Minute	Objective	Activity
	Set Up	Place an unpeeled orange on the table with the bowl of water and towel
	Observing Materials	Participant looks at and touches the materials laid out
	Describing Observations	Participant states one attribute for: Orange:

	Stating What is Known	Participant states what they know about the items. Encourage the participant to compare the weight of the orange to the play doh
	Asking Questions	Participant asks "Will the orange float?"
	Making Predictions	Participant guesses that the orange will sink/float
	Plan Investigation	Participant plans how they will place the orange in the water and how they will make observations
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant sees that an orange with its peel floats
	Describe Results	Participant makes a general statement about how oranges float
	Describe Overall Learning	The orange was buoyant, regardless of weight
	Clean Up	Keep all items
	Experiment 5 – Sink or Float: Orange 2	
Minute	Objective	Activity
	Set Up	Peel the orange
	Observing Materials	Participant looks at and touches the materials laid out
	Describing Observations	Participant states one attribute for: Peeled orange:
	Stating What is Known	Participant states what they know about the items. Encourage participant to acknowledge that the orange floated with its peel on
	Asking Questions	Participant asks "Will the peeled orange float?"
	Making Predictions	Participant guesses that the peeled orange will sink/float
	Plan Investigation	Participant plans how they will place the orange in the water and how they will make observations
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant sees that a peeled orange sinks
	Describe Results	Participant makes a general statement about how peeled oranges are no longer buoyant
	Describe Overall Learning	Orange peels must somehow contain air inside the orange which makes it buoyant. When the peel is removed, the water can enter in between the cracks and cause the orange to sink
	Clean Up	Remove all items

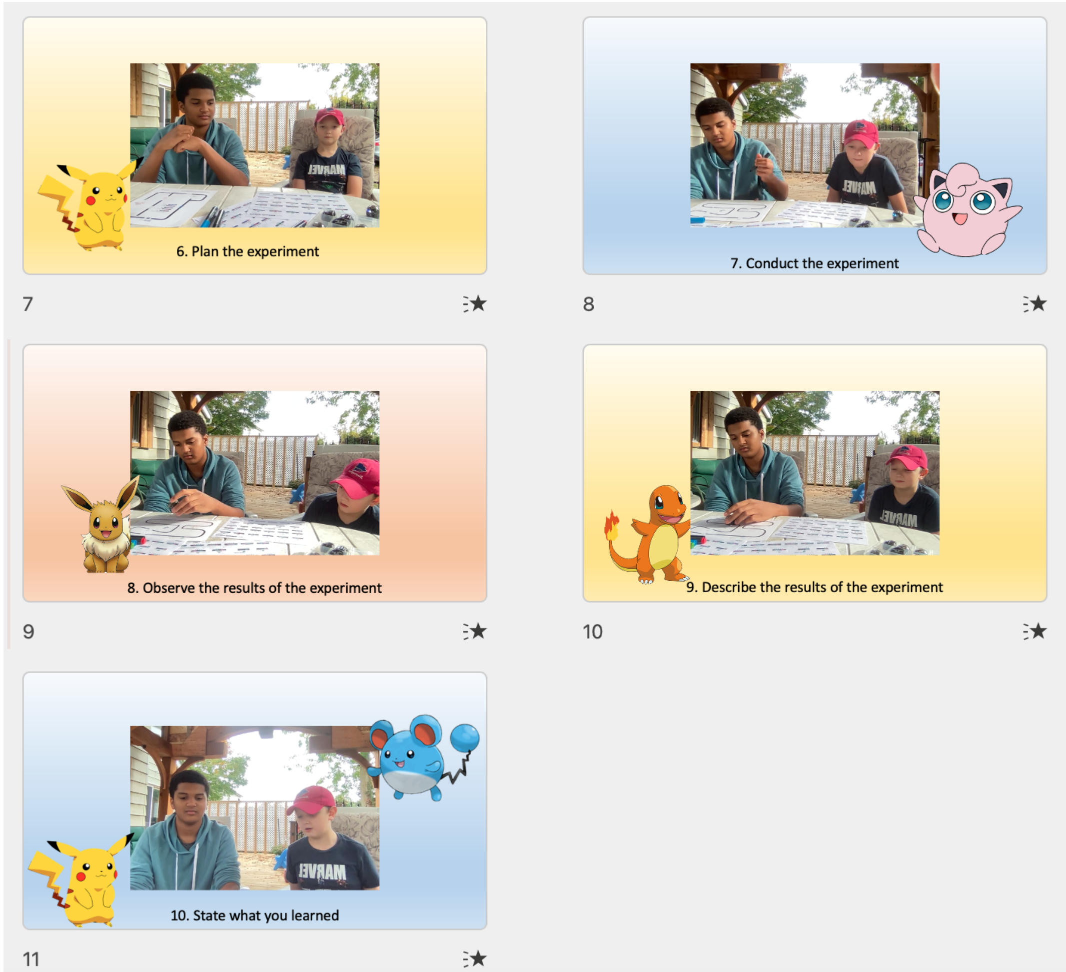
Experiment 6 – Dancing Raisins 1		
Minute	Objective	Activity
	Set Up	Place on table: - Box of raisins - Clear cup with tap water
	Observing Materials	Participant looks at and touches the materials laid out
	Describing Observations	Participant states one attribute for: Raisins: Glass of Water:
	Stating What is Known	Participant states what they know about the items. Encourage participant to notice the wrinkles on the raisins
	Asking Questions	Participant asks "Will the raisins sink or float?"
	Making Predictions	Participant guesses that the raisins will sink/float
	Plan Investigation	Participant plans how they will add the raisins (ONLY HALF) to the water and make observations
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant sees that the raisins sink
	Describe Results	Participant makes a general statement about how raisins sink
	Describe Overall Learning	Raisins are not buoyant in water
	Clean Up	Leave cup on table and the unused raisins
Experiment 7 – Dancing Raisins 2		
Minute	Objective	Activity
	Set Up	Add a clear glass with a carbonated beverage to the table
	Observing Materials	Participant looks and touches the materials laid out
	Describing Observations	Participant states one attribute for: Raisins: Carbonated drink:
	Stating What is Known	Participant states what they know about the items. Encourage participant to notice that there are bubbles in the carbonated drink. Encourage them to notice that the bubbles sometimes rise to the surface
	Asking Questions	Participant asks "Will the raisins float in the bubbly drink?"
	Making Predictions	Participant guesses that the raisins will sink/float in the bubbly drink

	Plan Investigation	Participant plans how they will add the raisins to the water
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant sees that bubbles attach to the raisins making them float to the surface but then the bubbles burst and they sink. This process repeats
	Describe Results	Participant makes a general statement about the raisins rise and fall in the liquid so they both float and sink
	Describe Overall Learning	When the bubbles attach to the raisins, they cause them to be buoyant but when the bubbles burst, they sink.
	Clean Up	Remove all items
Experiment 8 – Sink a Boat		
Minute	Objective	Activity
	Set Up	Place the bowl, play doh boat, and some coins (or other small, heavy item) on the table
	Observing Materials	Participant looks and touches the materials laid out
	Describing Observations	Participant states one attribute for: Play doh boat: Coins:
	Stating What is Known	Participant states what they know about the items. Encourage participant to identify items as buoyant or not buoyant
	Asking Questions	Participant asks "How many coins can I add before the boat sinks?"
	Making Predictions	Participant guesses that the boat can hold x number of coins
	Plan Investigation	Participant plans how they will carefully add and count and observe how the boat moves
	Carry Out Investigation	Participant follows through on plan
	Observe Results	Participant identifies the number of coins their boat could hold before sinking
	Describe Results	Participant makes a general statement about how the boat sank when enough weight was added
	Describe Overall Learning	A buoyant force can be overcome by gravity if there is too much weight added to a buoyant object
	Clean Up	Remove all items

6.3 Appendix C: STEM Knowledge Quiz

<table>
<tr><th></th><th colspan="21">Buoyancy Knowledge Assessment</th></tr>
<tr><th rowspan="12">Assessment</th><th>Question</th><th colspan="20">Response (circle student answer)</th></tr>
<tr><td>1. What word do we use to describe objects that float?</td><td colspan="10">Buoyant / Buoyancy</td><td colspan="10">Other</td></tr>
<tr><td>2. True or false: heavy items can float</td><td colspan="10">True</td><td colspan="10">False</td></tr>
<tr><td rowspan="2">3. What objects would likely float?</td><td colspan="20">Circle all that apply</td></tr>
<tr><td colspan="4">Stick</td><td colspan="4">Stone</td><td colspan="4">Empty Bottle</td><td colspan="4">Full Bottle</td><td colspan="4">Dice</td></tr>
<tr><td>4. Is buoyancy a push or pull force?</td><td colspan="5">Push</td><td colspan="5">Pull</td><td colspan="5">Both</td><td colspan="5">Neither</td></tr>
<tr><td>5. True or false: buoyancy of an object can change</td><td colspan="10">True</td><td colspan="10">False</td></tr>
<tr><td>6. Does an orange peel let water go through it?</td><td colspan="10">Yes</td><td colspan="10">No</td></tr>
<tr><td>7. Would an orange peel on its own float?</td><td colspan="10">Yes</td><td colspan="10">No</td></tr>
<tr><td>8. True or false: metal sinks</td><td colspan="10">True</td><td colspan="10">False</td></tr>
<tr><td>9. Why did the raisins stop floating?</td><td colspan="20">Response: ________________________________</td></tr>
<tr><td>10. Where do you see buoyancy in your daily lift?</td><td colspan="20">Response: ________________________________</td></tr>
</table>

6.4 Appendix D: Static Visual Activity Schedule


6. Plan the experiment
7
7. Conduct the experiment
8
8. Observe the results of the experiment
9
9. Describe the results of the experiment
10
10. State what you learned
11

6.5 Appendix E: Knowledge Chart

KWHL Chart			
What do we **K**now?	What do we **W**ant to know?	**H**ow will we find out?	What did we **L**earn?

6.6 Appendix F: Prompting Procedures

Prompt Level	**Definition**
Gestural	The facilitator uses a visual gesture (e.g., point to materials) to indicate the correct response
Verbal (general)	Using a verbal statement to indicate the correct response (e.g., "*what questions do you have about the experiment?*")
Modelling	The facilitator demonstrates the correct response (e.g., "*What will happen when we hold the light up to the moon replica?*")
Verbal (direct)	Using a direct verbal statement to indicate the correct response (e.g., "*Rebecca, say what will happen to the moon replica when we hold the light close?*)

6.7 Appendix G: Scoring Criteria

Scoring Criteria	Definition
Incorrect Response	The participant does not engage in the target behaviour or incorrectly demonstrates the target behaviour.
Prompted Response	The participant engages in the target behaviour when prompted.
Independent Response	The participant engages in the target behaviour independently without prompting.

6.8 Appendix H: Treatment Fidelity Checklist

Total Items: Total Items Scored:	Key: + happened - did not happen N/A if not applicable

#	Procedure	Check
	Prior to Intervention	
A		
B	Table and seating arrangement is set up so participant can be seen in Zoom	
C	Zoom session is fully recorded (you can clearly hear and see participant)	
	1. Intervention Administration	
1	**Participant is attending to interventionist**	
2	**Interventionist will introduce the skill to the participant** (e.g., "We are going to learn some new ways to conduct an experiment. Right now, we are going to learn how to [fill in the behaviour]… Step number [fill in step] says [fill in the behaviour]. Watch the students showing you an example of how to [fill in behaviour] then do what the student does."	
3	**Play the video** 1-2x (If faded, display the VAS)	
4	**Wait 5 seconds** for participant response	
5	**Provide correct consequence** 1. Correct response: provide access to the item/activity as the natural consequence and provide social praise. "Nice job! You (x) just like they did in the video." 2. Incorrect response "Nice try. Next time, you need to (x) just like they did in the video. Let's try again (replay video)" (no access to social reinforcement or item/activity). 3. No response: Interventionists provides prompt (gestural; verbal [general]; modelling; verbal [direct]).	
	2. Intervention Administration	
	Participant is attending to interventionist	
	Interventionist will introduce the skill to the participant (e.g., "We are going to learn some new ways to conduct an experiment. Right now, we are going to learn how to [fill in the behaviour]… Step number [fill in step] says [fill in the behaviour]. Watch the students showing you an example of how to [fill in behaviour] then do what the student does."	
	Play the video 1-2x (If faded, display the VAS)	
	Wait 5 seconds for participant response	
	Provide correct consequence 1. Correct response: provide access to the item/activity as the natural consequence and provide social praise. "Nice job! You (x) just like they did in the video.	

	2. Incorrect response "Nice try. Next time, you need to (x) just like they did in the video. Let's try again (replay video)" (no access to social reinforcement or item/activity). 3. No response: Interventionists provides prompt (gestural; verbal [general]; modelling; verbal [direct]).	
	3. Intervention Administration	
	Participant is attending to interventionist	
	Interventionist will introduce the skill to the participant (e.g., "We are going to learn some new ways to conduct an experiment. Right now, we are going to learn how to [fill in the behaviour]… Step number [fill in step] says [fill in the behaviour]. Watch the students showing you an example of how to [fill in behaviour] then do what the student does."	
	Play the video 1-2x (If faded, display the VAS)	
	Wait 5 seconds for participant response	
	Provide correct consequence 1. Correct response: provide access to the item/activity as the natural consequence and provide social praise. "Nice job! You (x) just like they did in the video. 2. Incorrect response "Nice try. Next time, you need to (x) just like they did in the video. Let's try again (replay video)" (no access to social reinforcement or item/activity). 3. No response: Interventionists provides prompt (gestural; verbal [general]; modelling; verbal [direct]).	
	4. Intervention Administration	
	Participant is attending to interventionist	
	Interventionist will introduce the skill to the participant (e.g., "We are going to learn some new ways to conduct an experiment. Right now, we are going to learn how to [fill in the behaviour]… Step number [fill in step] says [fill in the behaviour]. Watch the students showing you an example of how to [fill in behaviour] then do what the student does."	
	Play the video 1-2x (If faded, display the VAS)	
	Wait 5 seconds for participant response	
	Provide correct consequence 1. Correct response: provide access to the item/activity as the natural consequence and provide social praise. "Nice job! You (x) just like they did in the video. 2. Incorrect response "Nice try. Next time, you need to (x) just like they did in the video. Let's try again (replay video)" (no access to social reinforcement or item/activity). 3. No response: Interventionists provides prompt (gestural; verbal [general]; modelling; verbal [direct]).	
	5. Intervention Administration	
	Participant is attending to interventionist	
	Interventionist will introduce the skill to the participant (e.g., "We are going to learn some new ways to conduct an experiment. Right now, we are going to learn how	

	to [fill in the behaviour]… Step number [fill in step] says [fill in the behaviour]. Watch the students showing you an example of how to [fill in behaviour] then do what the student does.”	
	Play the video 1-2x (If faded, display the VAS)	
	Wait 5 seconds for participant response	
	Provide correct consequence 1. Correct response: provide access to the item/activity as the natural consequence and provide social praise. “Nice job! You (x) just like they did in the video. 2. Incorrect response “Nice try. Next time, you need to (x) just like they did in the video. Let’s try again (replay video)” (no access to social reinforcement or item/activity). 3. No response: Interventionists provides prompt (gestural; verbal [general]; modelling; verbal [direct]).	

Curriculum Vitae

Name:	Kailee Liesemer
Post-secondary Education and Degrees:	Western University London, Ontario Canada 2015-2019 B.A
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Honours and Awards:	Jessica Jean Campbell Coulson Award Western University 2022-2023
	Dr. Benjamin Goldberg Research Grant Western University 2021-2022
	Canadian Graduate Scholarship – Master's Social Sciences and Humanities Research Council 2020-2021
	Kay Sansom Scholarship Ontario Association of Developmental Disabilities 2019-2020
Related Work Experience	Research Assistant Western University– Neil Lab 2020-2022
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Publications:

Neil, N., Amicaelli, A., Anderson, B., & Liesemer, K. (2021). A meta-analysis of single-case research on applied behavioural analytic interventions for individuals with Down Syndrome. *American Journal on Intellectual and Developmental Disabilities*, 126, 114-141. https://doi.org/10.1352/1944-7558-126.2.114

Liesemer, K. (2019). Relating Neural and Behavioural Measures of Statistical Learning to Children's Reading Abilities. *Scholarship at Western.* https://ir.lib.uwo.ca/undergradawards_2019/4

Neil, N., & Liesemer, K. (2020). Early Intervention for Children with Intellectual and Developmental Disabilities. *Current Developmental Disorders Reports*, 7, 139-148. https://doi.org/10.1007/s40474-020-00201-1

Conferences Presentations:

Liesemer, K. (2021, March). *A proposal paper: The effects of a video-based modelling intervention package on the inquiry skill development among students with intellectual and developmental disabilities.* Paper presented at the virtual Robert Macmillan Symposium in Education, London, Ontario.

Neil, N., Puvirajah, A., Harte, A., Koufis, M., Liesemer, K. (2021, April). *S^3 case study: An informal STEM and social skills program for youth with autism spectrum disorder*. Poster presented asynchronously at the Child Health Symposium, London, Ontario.

Neil, N., Puvirajah, A., Harte, A., Koufis, M., Liesemer, K. (2020, April). *Science, technology, engineering, math, and social skills program for youth with autism spectrum disorder: Lessons learned from a pilot study*. Poster presented asynchronously at the Annual Ontario Association of Developmental Disabilities Conference: Individualizing Supports and Services, London, Ontario. https://oadd.org/2020-oadd-conference-program (Conference Canceled).

Liesemer, K., Moreau, C., Child, I., Batterink, L. J., & Joanisse, M. F. (2019, April). *Relating neural and behavioural measures of statistical learning to children's reading and language abilities*. Paper and poster presented at the Eleventh Annual Ontario Association of Developmental Disabilities Research Day. Niagara Falls, Ontario.

Moreau, C., Liesemer, K., Child, I., Batterink, L. J., & Joanisse, M. F. (2019, June). *Statistical learning and how it relates to language and reading abilities: An EEG study*. Poster presented at the Canadian Society for Brain, Behaviour, and Cognitive Science. Waterloo, Ontario.

Moreau, C., Liesemer, K., Child, I., Batterink, L. J., & Joanisse, M. F. (2019, June). *Addressing the question of whether statistical learning underlies language and reading impairments*. Poster Presented at the Fourth Annual Western University Developmental Disabilities Research Day. London, Ontario.

Neil, N., Amicarelli, A., Anderson, B., & Liesemer, K. (2018, April). *Applied behaviour analytic intervention for Down syndrome: A review of single-case design studies*. ONTABA 2018 Annual Conference. Toronto, Ontario.