Video Prompting to Teach Robotics and Coding to Students with Autism Spectrum Disorder

By

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Introduction

Video Prompting to Teach Robotics and Coding to Students with Autism Spectrum Disorder

Technology has become an essential tool in U.S. classrooms for delivering instruction and as a platform for student-driven learning. The prevalence of desktop computers, laptops, and tablets has increased access to learning opportunities, including academic content, for school-aged children (Sheppard & Brown, 2014). At the same time, these technologies offer teachers a versatile vehicle for teaching and learning. Over 90% of U.S. children use computers and tablets at school (National Center for Education Statistics, 2003), and 93% of all U.S. classrooms have internet-enabled devices available for students on a daily basis (Gray & Lewis, 2010). With increased availability to rapidly evolving technologies, many special education teachers have harnessed the utility of these technologies to effectively teach children with autism spectrum disorder (ASD) and intellectual disability (ID) a variety of skills (Knight, Huber, Kuntz, Carter, & Juarez, 2018). However, as instructional technologies advance and new technologies become more accessible, it is critically important to distinguish between effective technology-based strategies and those that are based on anecdotes or unproven fads (Knight, McKissick, & Saunders, 2013).

A frequently used type of technology-based instruction in special education research is video-based modeling (VBM). VBM is built upon social learning theory, which proposes that learning happens when individuals observe and then imitate others (McCoy & Hermansen, 2007). Bandura's (1977) foundational research in this area demonstrated that children learned a variety of skills through observational learning or modeling, which helped lay the foundation for its use in special education. Based on the flexibility to watch and re-watch a targeted skill being modeled, VBM uses the fundamental ideas of observational learning theory to increase independent completion of a variety of tasks. That is, a model is recorded completing a skill or task, and an exemplar video is created to allow a learner to watch the model prior to opportunities to engage in that skill or task (Mason, Davis, Ayres, & Davis, 2016). Perhaps due to an apparent aptitude in processing visual stimuli (Bryan & Gast, 2000) or due to strengths in systemizing behaviors (Baron-Cohen, 2009), VBM has been particularly effective in supporting independent skill development for children with ASD (Kimball & Smith, 2007; Knight et al., 2013; Pennington, 2010).

Although terminology in special education research has not always been consistent, most recently VBM has been used as an umbrella term to describe video models with an intended goal of showcasing tasks or skills to be imitated (Mason, Davis, Boles, & Goodwyn, 2013). There are, however, variations within VBM, including video modeling (VM), video prompting (VP), and video chunking (VC). VM involves a participant viewing a skill being modeled in its entirety before completing the skill for himself/herself (Shukla-Mehta, Miller, & Callahan, 2010). VP breaks a video of a complete task or skill into individual steps. The participant views a portion of a video and completes that single step before viewing the next step demonstrated in the video (Banda, Dogoe, & Matuszny, 2011). VC is a combination of VM and VP, in that it involves merging multiple steps from a task analysis into "chunks" of manageable tasks that are viewed and completed prior to attempting the next chunk (similar to VP; Sigafoos et al., 2007).

Each variation of VBM offers two options for the presentation format of the model. These include video self-modeling (VSM) or video model of another individual (video model other [VMO]) to demonstrate the target skill or task (Mason et al., 2013). Both peers and adults can serve as VMO. Further, VBM variations can use either a first-person (point-of-view [POV]) or third-person a perspective to demonstrate the model (Shukla-Mehta et al., 2010).

Current Reviews of VBM

I identified seven meta-analyses and comprehensive, systematic literature reviews evaluating VBM for school-age students with ASD and intellectual disability (ID) in the published literature. Overall, researchers identified positive results related to the use of VBM. However, four of these reviews included studies that primarily examined functional or developmental outcomes (e.g., social or communication skills). Three of these reviews focused on academic outcomes, and one of these focused specifically on STEM outcomes.

For example, Ayres and Langone (2005) examined the use of video interventions to teach social and functional life skills to students with ASD. Of the 15 reviewed studies, 60% (n = 9) included VBM interventions. Further, 90% of all participants in studies using VBM met mastery criteria of the targeted social and life skills. None of the studies targeted academic skills. Likewise, Bellini and Akullian (2007) identified 23 studies using VM or VSM interventions for students with ASD and/or ID. They found that VM and VSM were effective intervention strategies for teaching communication skills, functional life skills, and behavioral functioning skills in 22 of the 23 studies. Over 90% of participants demonstrated positive therapeutic change for a variety of aforementioned dependent variables. None of the reviewed studies, however, attempted to teach academic skills to any the participants. Odom et al. (2015) reviewed 30 studies using technology-aided interventions to teach adolescents with ASD, and 20 of the 30 reviewed studies incorporated VBM (i.e., VM, VP). Eighteen of these studies focused on vocational, social, or daily living skills. The remaining two studies measured acquisition of targeted math or science skills, respectively. There were only five participants with ASD across these two studies, and all participants met mastery criteria for skill acquisition. Wong and colleagues (2015) categorized VBM as an evidence-based practice (EBP) for students with ASD for teaching social, communication, behavior, joint attention, play, school, school-readiness, academic, motor, adaptive, and vocational skills. However, their review was limited in the following ways: (a) out of a total of 31 single case design studies, authors included only one study (Marcus & Wilder, 2009) addressing academic skills; (b) the review aggregated multiple and disparate dependent variables into one outcome; and (c) the majority of VBM studies focused on social or communication skills for young children aged 1 to 5 years.

In contrast, Knight et al. (2013) found 29 studies that used technology-based interventions (e.g., computer-assisted instruction, VBM) to teach academic skills to students with ASD. All of the reviewed studies targeted language arts or literacy skills with three studies also including targeted math skills, and no studies were found evaluating science, technology, engineering, or social studies. Only four of the reviewed studies used VBM as any component of the intervention, and all of the VBM studies targeted literacy skills. Likewise, Prater, Carter, Hitchcock, and Dowrick (2012) identified eight studies that used VSM interventions to improve academic performance for students at risk for academic difficulty. Of the included studies, only four included participants with disabilities, which was 6.6% of the total number of participants across studies. However, of the 12 including participants with disabilities (i.e., ASD, ID), and 11 (91.7%) met mastery criteria for their academic skills via VBM interventions. Of the four studies that included students with disabilities, each focused on literacy skills or on-task behaviors.

Wright, Knight, and Barton (2019) reviewed the literature using VBM to teach science, technology, engineering, and math (STEM) skills to students with ASD. Only 10 single case experimental studies were identified meeting their criteria, 80% of which demonstrated positive effects for students with ASD. However, none of the included studies focused on engineering skills; two studies focused on science skills and one study focused on technology skills. The majority of studies (90%) targeted at least one math dependent variable. Ultimately, researchers only found sufficient data to support VBM as an evidence-based practice for teaching math skills to students with ASD, leaving a substantial set of academic STEM skills insufficiently examined in regards to the efficacy of VBM.

VBM and STEM Research

As the use of portable technology (e.g., laptops, tablets, smart devices) in classrooms has increased over the last several decades, so too has VBM research in special education classrooms (Knight et al., 2013). Research into the efficacy of VBM with participants with disabilities other than ASD also exists for a wide-range of skills. For instance, VBM interventions have improved outcomes for students with emotional behavioral disorders (e.g., Axelrod, Bellini, & Markoff, 2014; Lonnecker, Brady, McPherson, & Hawkins, 1994) and developmental and intellectual disabilities (e.g., Charlop-Christy & Daneshvar, 2003; Hepting & Goldstein, 1996). Further, VBM research has effectively targeted social communication skills (e.g., D'Ateno, Mangiapanello, & Taylor, 2003; Simpson, Langone, & Ayres, 2004), functional skills (e.g., Norman, Collins, & Schuster, 2001; Shipley-Benamou, Lutzker, & Taubman 2002), and vocational skills (e.g., Bennett, Gutierrez, & Loughrey, 2016; Kellems & Morningstar, 2012). However, research evaluating the effectiveness of VBM to support acquisition of academic skills for students with disabilities, specifically ASD and ID, is lacking. Further, in a survey of over 500 special educators, Knight, Huber, Kuntz, Carter, and Juarez (2018) reported that VBM was the least used EBP from a list of 18 commonly researched EBPs for students with ASD or ID.

Clearly, additional research is needed to understand how to support *academic* skill development using VBM, specifically academic skills beyond language arts and literacy.

As an educational buzzword, STEM has become synonymous with innovation and twenty-first century skills. The National Science Foundation (2017) has called for early participation in STEM activities for *all* students due to their practical application and connection to a healthy economy. Further, Common Core State Standards (CCSS) incorporated scientific and technical literacy into approved strands, and the Next Generation Science Standards specifically address the teaching of science and engineering content and practices (NGSS, 2013). STEM is an area of growing interest in education but there is a dearth of STEM research in special education, which is reprehensible and needs remediation. STEM education is uniquely positioned to offer students with disabilities the ability to access a full range of educational opportunities. STEM is an interdisciplinary approach, often using technology, to teach this academic content in an applied and authentic way (Israel, Maynard, & Williamson, 2013). In a comprehensive review of pertinent literature, Spooner, Knight, Browder, Jimenez, and DiBiase (2011) underscored the importance of scientific inquiry and discovery-based learning as components of STEM education.

The task analytic nature of many STEM activities aligns well with VBM interventions, as these interventions focus on adherence to step-by-step processes, which are vital in the development of STEM skills. Further, Baron-Cohen (2009) posited that students with ASD often have a particular proclivity for behaviors that are systemizable, like those represented in VBM interventions. Wei et al. (2013) indicated that although students with ASD are the third lowest among all disability categories to enroll in college, they are disproportionately selecting STEM coursework and college majors in STEM fields. Yet, little research exists examining the use of VBM to support development of STEM skills for students with ASD or ID.

Knight, Wright, Buchanan, and Wright (2019) examined the use of model-lead-test explicit instruction to teach basic coding skills to elementary school children with ASD. Researchers used markers, paper, and a set of three- and four-color codes to program color-sensing robots with optical sensors. All participants learned to calibrate, move robots in four different ways, and program robots to speed up (i.e., nitro speed). Further, each participant generalized acquired skills to untaught codes to further manipulate robots. Knight, Wright, Wilson, and Hooper (2019) used a digital block-based coding programming platform to evaluate the effects of teaching one code using model-lead-test on the following dependent variables: (a) acquisition of the explicitly-taught code (i.e., movement); (b) generalization of the explicitly-taught code to other codes, and (c) students' self-directed coding. Results of the multiple-probe across participants design demonstrated that all students acquired the code, generalized the skill to a novel code, and generated and evaluated their own coding.

The Current Study

In the current study, I extended the findings of these previous robotics studies to include middle school students with ASD and ASD/ID. Further, in an effort to examine the utility of VBM for this population, I created video models of three functionally equivalent coding skills. After being trained to fidelity on instructional procedures and data collection, a special education teacher implemented the VBM procedures, which supports the social and ecological validity of the study. At the conclusion of the study, special educators naïve to the conditions and outcomes of the study were emailed a questionnaire about VBM, STEM, and the feasibility and efficacy of practices demonstrated in randomly selected baseline and intervention video clips. My research questions were as follows:

1. Does a teacher implemented VBM intervention increase accuracy of robotics coding skills to middle school students with ASD and/or ID?
2. Do acquired robotics coding skills generalize to novel codes?
3. Do special educators rate VBM as a feasible and effective intervention for teaching robotics and coding to students with ASD and/or ID?
4. Do special educators report using VBM materials to teach robotics coding when provided with the requisite materials?

Method

Participants

After receiving Institutional Review Board (IRB) and Metropolitan Nashville Public Schools (MNPS) approval for the current study, I recruited staff and students from MNPS by contacting middle school principals and special education teachers. I extended an existing district approval to include the use of a web-enabled block-based (drag and drop) coding system to teach a more complex coding protocol for middle school students with ASD. Further, I created video models for these advanced coding skills, and they served as the instructional intervention. After consenting the special education teacher, she sent home consent forms to parents on my behalf to protect the privacy of students and their contact information.

Implementer. I recruited one special education teacher to act as the implementer for this project. The implementer met the following criteria: (a) consented to participate in this project in this role; (b) provided diagnostic and testing information, as well as Individualized Education Plans (IEPs) to confirm ASD or multiple disabilities (including ASD/ID) diagnoses and to confirm current level of instructional support; (c) taught special education students in grades 5 through 8; (d) provided space for video prompting intervention in their classroom; (e) committed to at least three sessions per student per week; and (f) would not remove student from inclusive core content instruction. The implementer was a special education teacher with an instructional relationship with all recruited participants. The implementer was a white woman with a Masters degree in special education and three years experience as a middle school special education teacher. A $200 stipend was given to the implementer at the end of the study, which was delineated during consenting.

Student Participants. I recruited three middle school students with disabilities to participate in the study. The three participants had ASD and two had an additional diagnosis of ID. Participants met the following inclusion criteria: (a) enrolled as a student in a public middle school in grades 5 through 8; (b) received special education services under the categories of ASD or multiple disabilities (including ASD); (c) communicated in English; (d) had sufficient motor skills to complete basic tablet operations with their fingers (e.g., drag and drop images, use drop down menus, start a video, fast forward a video); (e) had parental consent; (f) provided verbal assent; and (g) could appropriately attend to an academic task for approximately 10-15 minutes with redirection and reinforcement. Students who used augmentative and alternative (AAC) devices for communication would have been considered for this study, provided that AAC device had the capacity to program project-specific words, however none were identified during screening.

I used a combination of teacher recommendation, observational data collection, formal assessments, and informal assessments to identify students who met the inclusion criteria. I spoke with school staff (e.g., special education teachers, administration) and provided a checklist of characteristics to identify teachers interested in implementing the project and students who would potentially meet inclusion criteria (see Appendix A). I asked middle school administrators to share information about the study with their staff. Once a potential teacher participant was identified, I provided consent forms for parents for any students identified using the checklist.

I observed potential student participants on a minimum of two occasions during academic instruction to assess their ability to engage in instruction and stay on task. Observation sessions lasted between 20 and 30 minutes each. I recorded information regarding reinforcement, redirection, engagement, communication, and motor skills (see Appendix B). Prior to inclusion, students were screened for specific motor skills relating to operating a video on a tablet, using drag and drop skills, using a drop down menu, and reading basic robotic coding words (see Appendix C).

A total of four consented student participants met the criteria for participation. However, one student's parents withdrew from the study prior to commencing data collection. Therefore, three participants participated beyond the screening phase of this research study. Diagnosis of ASD was confirmed by existing Autism Diagnostic Observation System, Second Edition (ADOS-2) assessment information in each participant's cumulative file. Further, demographic information indicated none of the participants qualified for free or reduced lunch.

Simon. The first student participant, Simon, was 13-year old Caucasian male with ASD enrolled in the seventh grade. His full scale IQ was 72 as identified by Wechsler Intelligence Scale for Children-Third Edition (WISC-3). He received one-on-one paraprofessional support in his core content (inclusion) courses and qualified for special education services due to his ASD diagnosis. Support services for Simon consisted of frequent breaks, visual aids for all new content, pre-training for pertinent vocabulary, a rehearsed daily schedule, support to stay on task, and systems of reinforcement. Additionally, Simon received weekly speech therapy. Teacher report and behavioral observations indicated that Simon engaged in some verbal, repetitive stereotypy, however these did not preclude him from participating in inclusive courses. Simon was adept at locating and viewing videos on a tablet, but he had no experience with robotics or coding prior to participation in the study.

Elias. The second student participant, Elias, was a 14-year old, Caucasian male with ASD and ID. Elias' full scale IQ score was 52, as indicated by the results of Stanford Binet Intelligence Scale-Fifth Edition. Elias qualified for special education services as a student with ASD and moderate ID, and he received weekly speech therapy. He received one-on-one paraprofessional support for throughout his entire day, and he received daily support for taking notes, staying on task, and modifying core content assignments. Elias took state mandated alternate assessment for students with cognitive disabilities. Teacher report and behavioral observations showed that Elias had limited social repertoire, often relying on scripted interactions to talk with peers and adults. Elias had no experience with robotics or coding prior to participation in this study.

Arjun. The final student participant, Arjun, was an 11-year old Indian American sixth grader with ASD. His full scale IQ was 67 (WISC-3), and he qualified for special education services as a student with ASD and moderate ID. Arjun received weekly speech therapy. Additionally, Arjun had an additional diagnosis of Attention Deficit Disorder (ADD). He received one-on-one paraprofessional support throughout his entire day, primarily for on-task behaviors and adapting instruction. Teacher reports and behavioral observations indicated that Arjun needed frequent reminders to stay on task and frequent reinforcement for pro-social behavior. At home and school, Arjun used tablets to watch videos and listen to music, but he had no prior robotics or coding experience.

Questionnaire Educators. Three special educators were recruited from the nine total questionnaire respondents to receive completed video models on a tablet, robots, and WiFienabled iPads in order to implement robotics and coding instruction into their classwork. These educators met the following criteria: (a) consented to participate in this project in this role; (b) taught special education students in grades 5 through 12 with ASD and ASD/ID; (c) completed a 20-minute training session on how to operate all required technology; (d) responded affirmatively on the questionnaire that they would implement this instruction if they were given all of the requisite materials and training; (e) would not remove student from inclusive core content instruction; and (e) would complete a post-project interview with the researcher. All three educators were special education teachers with an instructional relationship with multiple students with ASD and ASD/ID. Two participant educators (one female, one male) had masters' degrees in special education, and one participant (a male) had a bachelor's degree in education. All were Caucasian, and had 3, 7, and 8 years experience as middle school special education teachers. Their ages were 33, 32, and 44, respectively.

Setting

This study took place in a large, urban school district in the southern United States. All three participants were enrolled in the same middle school. For each target participant, the video prompting sessions took place during non-instructional time (i.e., advisory, intervention block, enrichment block) in a special education classroom. This setting included reliable access to campus WiFi signal to incorporate internet-enabled coding tool known as OzoBlockly. A clean table in the special education classroom was used for all sessions to avoid technology glitches due to dust or particle build up on the robots.

To ensure consistency across all experimental conditions and to simulate the environment in which a special education teacher would implement this video prompting intervention, the special education classroom was not expected to be void of other peers or paraeducators. Sessions took place at a table in a low-traffic work area (i.e., corner) within the classroom. Baseline and intervention sessions were conducted 3-5 times per week for each participant in the same classroom, however no participants on this project were present in the classroom when other participants were engaged in the intervention.

Materials

Ozobot and Ozoblockly. Ozobot is a hand-held, smart robot and was the target robotic vehicle of all coding activities. The Evo version of Ozobot was recommended for students in grades 6-12 and has optical and proximity sensors that allow it to be digitally programmed. It was programmed using a free, internet-based program call OzoBlockly. Launching OzoBlockly on a tablet allowed for a participant to drag and drop blocks of code (e.g., movements, light effects, sounds) using their fingers. Participants incorporated advanced programming of the Ozobot through built-in drop-down menus that allow for choice in coding opportunities (see Figure 1 for a photo of OzoBlockly and samples of block-based codes).

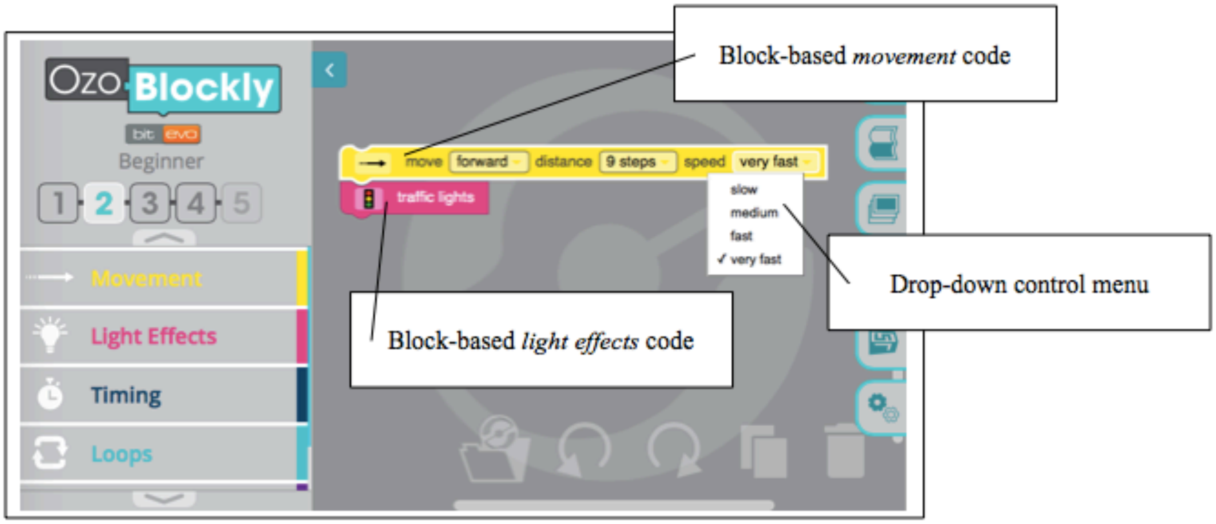

Figure 1. OzoBlockly digital interface and sample block-based codes

Tablets. A 9.7" iPad WiFi 32 GB was used to access the OzoBlockly interface, requiring school officials to allow the special education teacher access to school WiFi to make OzoBlockly function for this intervention. A 7" Samsung Galaxy 4-8 was used to record and view the video models for participants.

Survey Tool. REDCap is a secure, web application commonly used to survey participants. This tool was used to create and send a social validity questionnaire to special educators naïve to the conditions of the intervention.

Target Skills and Video Clips. Guided by the requirements to make the Ozobot operable and perform basic functions with it, three video clips were created. The first video model taught participants to calibrate the robot to accept digital codes. The second video taught participants how to move their robot in a zigzag pattern and adjust the robot to move very fast. Additionally, this video taught participants how to turn on rainbow lights on the robot. Finally, the last video model instructed participants on all of the possible movements and light effects available and modeled how to choose their own set of codes (without explicitly telling them which codes to choose). Each participant watched the identical clips. Two consultants with Evollve, Inc., the creator of the Ozobot smart robot, verified the researcher's belief that the three skills were functionally equivalent.

Response Definition and Data Collection

The special education teacher measured the dependent variables through in vivo direct observations using a paper-and pencil recording system (see Appendix D for the Data Collection Forms). The dependent variable was comprised of the percentage of correct tasks completed in the task analysis for each of the three taught skills. Participant responses were scored as correct if he initiated a step in the task analysis within 5 s and correctly completed it within 15s of the task direction. Data was collected using a trial-by-trial format in which each step in the total task analysis was evaluated. The percent correct was calculated by tallying the number of correctly completed steps, divided by the total number of steps, multiplied by 100.

The three target skills in this study were independent and functionally equivalent. That is, introduction of the independent variable did not bring about a change in other tiers, and the effect of the introduction of the independent variable was replicated across tiers. Additionally, consultation with two OzoBlockly project managers confirmed the comparable difficulty of the task analyses. Appendix E shows the task analysis for all three dependent variables. Participants were required to show at least 80% mastery of the task analysis for a minimum of three consecutive sessions to move to subsequent tiers of the intervention. The dependent variable of the first tier of this study involved calibration of the Ozobot. There were nine steps in the task analysis. The dependent variable for the second tier involved coding a specific movement and light effect in a 10-step task analysis. The dependent variable for the final tier was self-directed coding of a movement and light effect from a menu of 10 and 8 options, respectively. See Figure 2 for an example of the movement and light effect options.

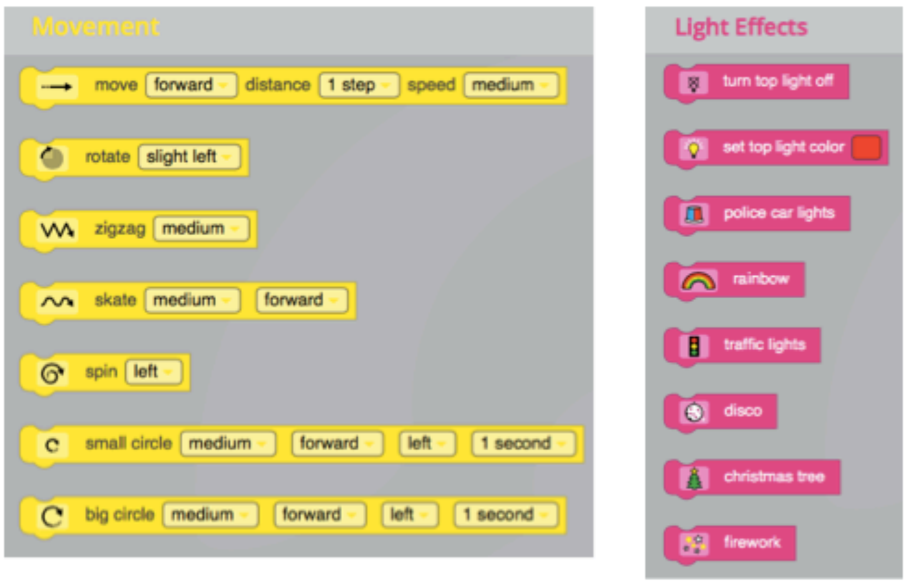

Figure 2. Options for self-direction movement and light effects codes

Interobserver Agreement. The special education teacher collected data on the dependent variable during each session. I also independently collected data on 35.6% of randomly selected sessions balanced across all participants and conditions to calculate interobserver agreement (IOA). IOA was calculated using a point-by-point method for all students by dividing the number of agreements by the number of agreements plus disagreements and multiplying the quotient by 100. IOA data were required to average at least 80% to continue with the study, and retraining would occur should any session fall below 80%.

Procedural Fidelity

Procedural fidelity was assessed concurrently with IOA. I evaluated teacher behavior using a checklist of expected teacher behaviors during each IOA session. The number of teacher behaviors correctly completed was divided by the total number of teacher behaviors expected and multiplied by 100. Procedural fidelity was required to be 80%, and retraining would occur should it drop below 90% for any session.

Implementer Training. The first author trained the special education teacher (with 100% implementation fidelity) in the procedures for baseline, intervention, and technology training following implementation fidelity checklists developed by the first and second authors. The special education teacher was trained to fidelity in all experimental procedures in a two-hour training session prior to the start of the study. During the training session, fidelity for the special education teacher ranged from 93.3% to 100% for all conditions. The average fidelity was 97.5%. During experimental conditions, at least 90% correct implementation was expected before retraining would have been required. This was not necessary as procedural fidelity never fell below 94.7% and averaged 98.1%.

Experimental Design

I used a multiple-probe across skills design and evaluated the intra-participant replication of effects of teaching robotics coding using VP on the ability of three students to: (a) calibrate the Ozobot; (b) acquire an explicitly taught block-based code (i.e., zigzag movement with ‘very fast' drop-down control, rainbow light effects); and (c) acquire novel movement and light effects codes (Gast, Lloyd, & Ledford, 2018).

A multiple-probe design includes a series of intermittent baseline probes of level of performance before intervention for each skill and probes to determine what change the intervention had on the level of performance of the skill (Cooper et al., 2007). Multiple-probe designs are often used when the repeated measurement of baseline, required by a multiple-baseline design, may be aversive for participants in the study (Cooper et al., 2007). A minimum of three stable data points was required in all tiers before any participant entered intervention. Upon mastery of a skill, intermittent probes of untaught skills were used to assess whether newly acquired skills (learning), history, or maturation might impact the level of mastery of subsequent skills. Once stability was ensured, participants entered the next tier of intervention. Generalization and maintenance probes were periodically used to assess the ongoing skills of all participants.

Following guidelines by Barton et al. (2018), I graphed data for purposes of visual analysis as illustrated in Figures 3-5. Visual analysis was used to examine the relation between the implementation of the video prompting intervention and the acquisition of targeted robotics coding skills. I examined the level, trend, and variability of data within and across conditions. I also examined the amount of overlap, immediacy of effects, and consistency of data patterns across adjacent conditions. Experimental control is established in multiple probe designs when immediate change in the dependent variable occurs with the introduction of the independent variable and not in untreated tiers. Three consistent replications of behavior change are required to demonstrate a functional relation, which is evaluated using vertical visual analysis.

Procedures

General. Sessions were held three to four times a week for the duration of the study in the participants' special education classroom. The study lasted approximately three months, including spring break and several district-wide holidays. Participants were not removed from any core content inclusion classes. The special education teacher pre-arranged materials and made them ready and available to participants. The special education teacher then explained the learning goal of the session (e.g., "Today you are going to learn about robotics.").

Pre-training. Prior to baseline data collection, the special education teacher taught each participant four coding- and robotics-specific vocabulary words to decrease the likelihood of misunderstanding during viewing of video models or during probe measurement. Using constant time delay, participants were first taught the words *robot* and *calibrate* with associated picture cards and labels. Each participant met mastery criteria using 3-second constant time delay. The average accuracy was 90.7% with a range from 83.3-100%. The vocabulary word *code* was introduced in the second session. The term *programming area* was introduced in the final session. Appendix G shows data collection sheets for vocabulary pre-training sessions. (See Figure 6 for sample vocabulary cards).

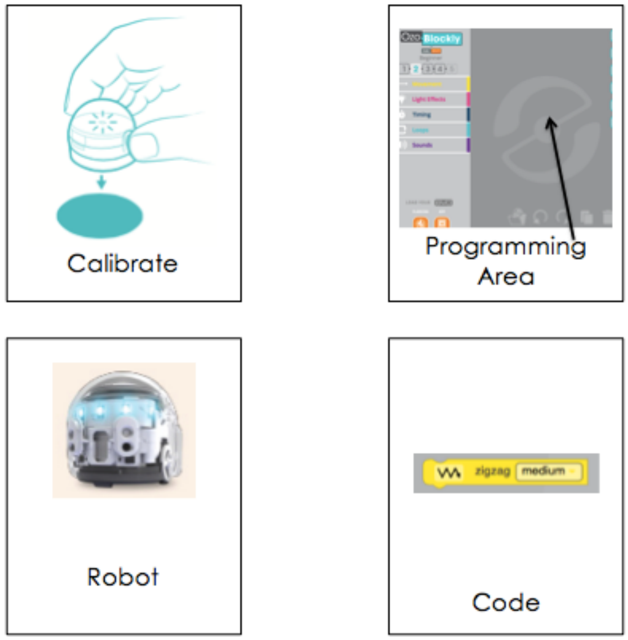

Figure 6. Sample vocabulary cards of pre-training coding and robotics terminology

Baseline. During baseline, the special education teacher began each session by providing all needed materials (e.g., Ozobot Evo, OzoBlockly program on iPad). The special education teacher provided an attentional cue (i.e., “Show me you are ready to work.”). Students were told to “do their best,” and that they can say, “I don’t know” if they could not complete the task. The special education teacher marked a response as correct (+) if the participant began the step within 5 s and completed the step within a total of 15 s. The special education teacher marked incorrect (-) if the participant made an error and marked no response (NR) if the participant did not begin within 5 s. NR was considered incorrect in the task analysis. The special education teacher used a variable ratio of three (VR3) schedule of reinforcement for attending to task and materials, but she did not praise participant for correct responses. Additionally, the special education teacher did not provide error correction. Baseline stability dictated when this condition ended based on level, trend, and variability of data.

Technology Training. The purpose of this condition was to teach the participant how to navigate the video model on the Samsung tablet to complete a task on the iPad. The special education teacher selected a skill familiar to all participants (opening *Notes* on the iPad and typing name and date), and I recorded an exemplar video model for the skill on the Samsung tablet. Participants watched the video model and completed the task on the iPad. If a participant did not begin task within 5 s or complete the task within 15 s, the special education teacher delivered prompts using a system of least prompts (i.e., verbal, model, physical). Technology training ended for each participant when he successfully completed 80% of steps of the task independently for three consecutive sessions. See Appendix H for sample of technology training procedures and data collection form.

Video-prompting Intervention. Intervention began for each participant when they demonstrated mastery of the technology training phase. Each participant began the intervention on the same day, however the participants were not present in the room when others were participating in the intervention. The special education teacher followed general procedures for this condition and also gave the task direction for the appropriate skill. The task direction for the first skill was, "Calibrate your robot." The task direction for the second skill was, "Code your robot to move zigzag very fast and turn on rainbow lights." The task direction for the final skill was, "Code a new movement and light effect code for the robot." The special education teacher and observers recorded data on the percent of steps independently completed for the task analysis of each skill. Single opportunity probes were conducted for evaluating the use of video models to code the robots. See Appendix E for task analysis of each of the three dependent variables.

Maintenance. I collected maintenance data two and three weeks after each individual student reached mastery, during which time participants had no access to Ozobots, OzoBlockly, or intervention videos. Had a student not met mastery of VBM demonstrated skills by the end of the school year, no maintenance data would have been collected. However, all students met mastery of all skills and maintenance data were collected. During maintenance, given the same task directions for each skill, participants were expected to perform the robotics coding skills without the assistance of the video model or teacher support. Data collectors used the same data collection sheet used during intervention.

Generalization. Generalization was measured during third tier for each participant. By offering choice, and modeling it in a video, participants had the option to select untaught movement and light effects. To measure generalization to novel codes, participants also were asked to code a *sound*—an untaught coding skill—for their robot. This type of generalization data was collected throughout the intervention for each student. As the task direction for the novel code, the participant was told to "Code your robot to make a sound." Had a student not met mastery of VBM demonstrated skills by the end of the school year, generalization probes might still have been used to assess acquisition of novel codes. However, all students met mastery of the skills demonstrated in the video models.

Social Validity

Social validity measures were collected using several formats. First, prior to beginning the study, parents or guardians gave consent for their child to participate. This suggested that the family values acquisition of these STEM skills as worthy academic endeavors. Second, participants also gave assent to participate, indicating their interest in the subject of robotics and coding. Third, the teacher was the implementer of this intervention which suggests the intervention procedures were feasible, and highlighted potential facilitators and barriers to undertaking this kind of project in a typical special education classroom.

Fourth, in a semi-structured interview at the end of the project, the participants and implementer were asked about the enjoyment and effectiveness of the intervention. The implementer was also asked about the feasibility of the intervention and the likelihood of using video prompting and robotics in her classroom moving forward outside of the current study and without researcher support.

Fifth, an additional measure of social validity was evaluated at the conclusion of the study. A REDCap questionnaire was created to examine several questions related to STEM and VBM for students with ASD. It was sent to 10 special educators of students with ASD and ID; these raters were naïve to the purpose and outcomes of the study. This questionnaire also included a randomly selected sample of video clips of baseline and intervention sessions (two of each). Questions related to the feasibility and effectiveness of the procedures highlighted in the video clips were used to gauge these educators' impression of the intervention.

Sixth, educators who indicated on the questionnaire that they would be interested in implementing VBM robotics in their classrooms were given the identical videos used in the intervention, a set of robots, and tablets to use in their classroom. Each educator had possession of the materials for 15 instructional days. I conducted a follow-up interview with each of these educators to evaluate the extent to which they used VBM materials to teach robotics and coding?

Additionally, I examined the perceived feasibility and effectiveness of VBM to teach STEM skills to students with disabilities, including ASD and ASD/ID.

Appendix F shows the social validity interview template for participants and implementers, the survey sent to special educators naïve to the conditions of the study, and the follow-up interview of social validity robotics implementers.

Results

Video Prompting

Data on the increase accuracy of robotics coding and generalization to novel coding skills (i.e., dependent variables) across all participants and conditions were graphed following the guidelines outlined by (Barton, Lloyd, Spriggs, & Gast, 2018). A visual analysis of graphed data indicated that all three participants learned to calibrate the robot, learn explicit codes to make the robot move in a zigzag pattern and turn on rainbow lights, and learn novel, self-selected movement and light effects codes.

There is a functional relation between the implementation of VBM intervention and the acquisition of robotics and coding skills. The current study reports a sufficient number of data points in all conditions for all participants, as well as a change in level and trend between the baseline and intervention conditions. Baseline data for all three participants showed a lack of correct responses to the task directions (e.g., 'Calibrate your robot.'). Participants either had no response or said, "I don't know" when given a task direction. Upon introduction of the independent variable (i.e., VBM) there was an immediate change in level of responding. This increase highlighted a significantly improved trend in correct responding with minimal variability once VBM was introduced. Further, there were no overlapping data points in the adjacent baseline and intervention conditions. The immediacy and consistency of effect across conditions for all participants also helped to indicate a functional relation (Barton et al., 2018). Closed circles in Figures 3-5 show the percentage of steps of the task analysis independently completed for each participant.

Technology training

Analysis of data on acquisition of the necessary skills to operate the video models and the iPad showed that all participants mastered the skills required to successfully operate the technology used in the intervention. Mastery criteria required three consecutive sessions at 80% independent completion of the technology training task analysis. Each participant met the mastery criterion to operate the video on the Samsung tablet (e.g., start, pause, fast forward, rewind) and iPad (e.g., touch icons, use keyboard) within three sessions. For the purposes of visual analysis, data for technology training are graphed as part of the first tier (see Figures 3-5).

Student Participants

Simon. During baseline, Simon (Figure 3) completed 0% of steps of the first skill, calibration, correctly. Because there was baseline stability in the other tiers, he began technology training in the fourth session. During technology training, Simon demonstrated 100% mastery of the task analysis in all three sessions. He began the VBM intervention during the next session. He quickly responded to the presentation of the video prompting intervention with three consecutive sessions above 80%, which met mastery criteria. His average percent correct was 92.6% (range 88.9-100%). Baseline data for the remaining skills remained at zero levels, and after 10 sessions, Simon began intervention on the second skill, coding a specific movement and light effect. Needing only three sessions to meet mastery requirements, Simon completed 100% of the task analysis for the second skill independently using video prompting. With baseline level for the final skill, novel movement and light effects (self-directed) still at zero levels, Simon began the video prompting intervention for the final skill after 16 sessions. His average percent correct of the final task analysis was 96.7% (range 90-100%). None of the minor errors in any of the Simon's completion of the task analyses followed any identifiable pattern. Overall, Simon required only 18 sessions to master all three robotics coding skills.

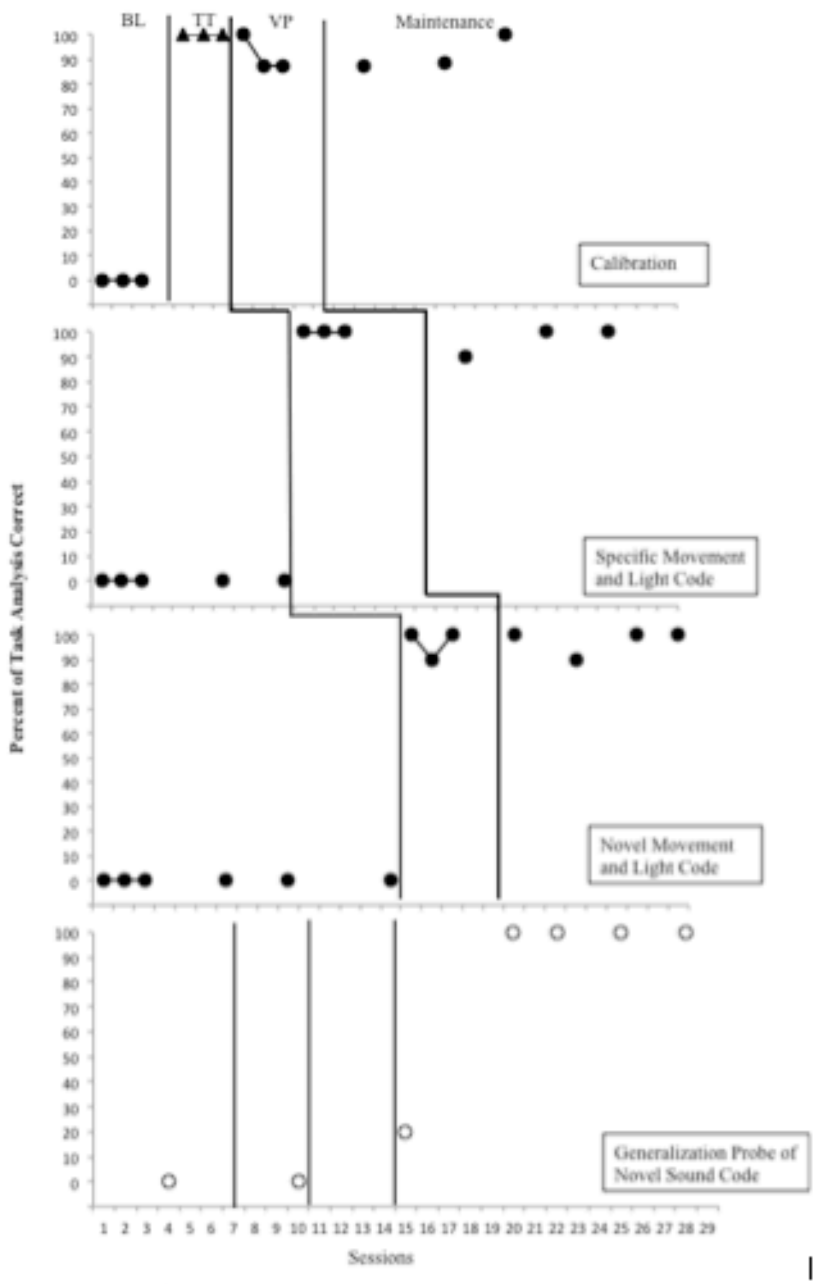

Figure 3. Data for Simon. BL = Baseline, TT = Technology Training, VP = Video-prompting intervention. Condition lines in fourth tier indicate when participant intervention for each skill.

Elias. During three baseline sessions, Elias averaged 0% correct for the steps of the task analyses for all three skills (see Figure 4). He began technology training in the fourth session. In Elias' first technology training session, he omitted the final two steps in the video and was 80% accurate in independently finishing the task analysis items. Prior to the next session, he was given a behavioral prompt to watch and pause the videos until all 10 steps were completed. The subsequent two sessions were 100% accurate for independent completion of the task analysis items. He began VBM intervention in the next session. After the introduction of the video prompting intervention for the first skill, Elias averaged 88.9% correct in the task analysis for calibration. Elias often struggled with allowing the robot to freely move during the final step of calibration, causing an error in the final step each time. Elias began intervention for the second skill after 11 sessions and met mastery in only three additional sessions. He averaged 86.6% correct (range 80-90%). Minor issues involving keeping his hands off of the robot while it processed code continued to be the main source of errors. The implementer maintained use of standard behavioral prompts, "Use the video to help you with the next step." or "Watch the video to complete the step on the iPad." Elias began intervention for the third skill on the fifteenth session and required three sessions to meet mastery. His average percent correct was 96.7% (range 90-100%). Elias was much more engaged when he was able to self-direct his coding choices and no longer required behavioral prompting (i.e., to return to the video for support).

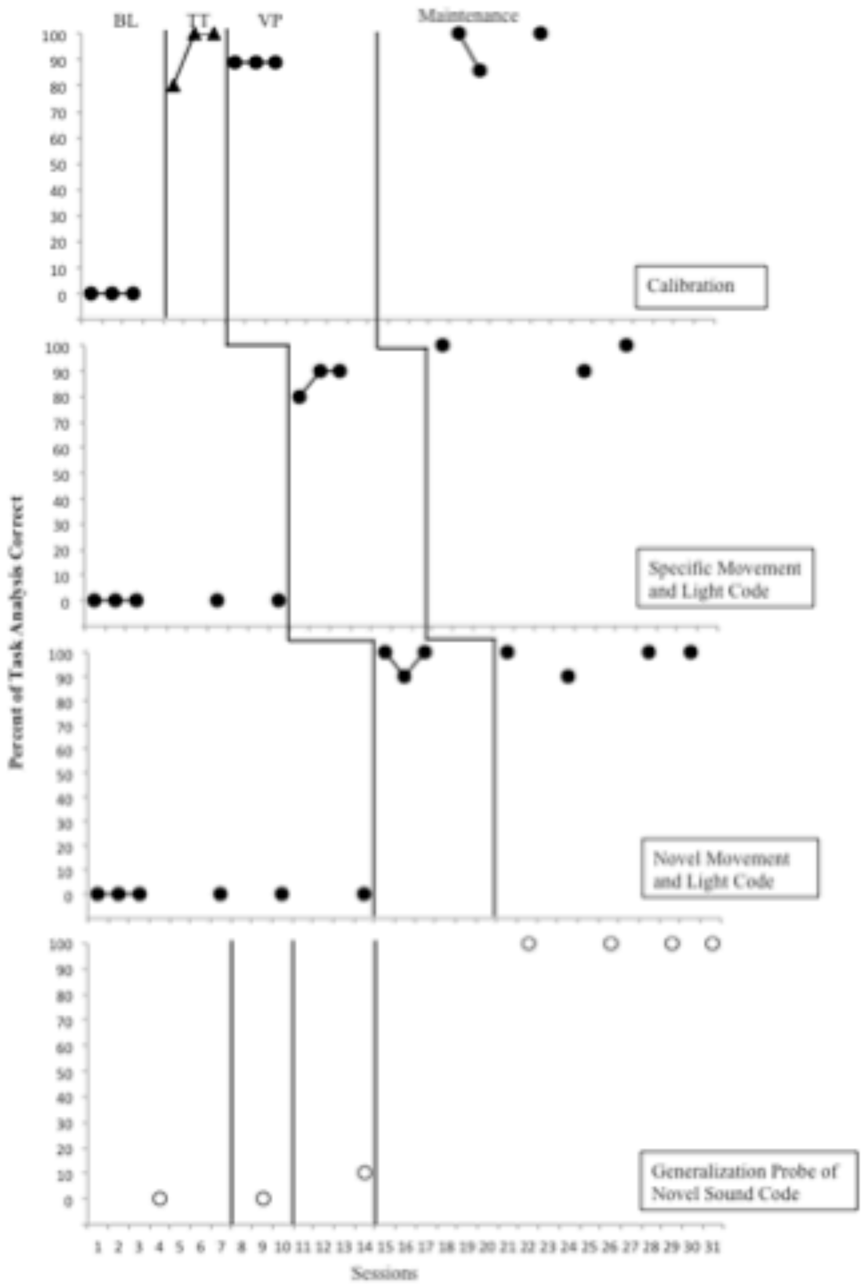

Figure 4. Data for Elias. BL = Baseline, TT = Technology Training, VP = Video-prompting intervention. Condition lines in fourth tier indicate when participant intervention for each skill.

Arjun. Arjun demonstrated stable, zero levels of responding for all baseline sessions across skills (see Figure 5), and began technology training in the next session. Arjun's accuracy for independently completion the task analysis during three technology training sessions were 90%, 100%, and 100%, respectively. He failed to watch the end of the video during the first of these sessions and was given a behavioral reminder (i.e., *Use the video to help you with the next step*) prior to beginning the next session. He began video prompting intervention after six sessions. During his first intervention session, he struggled to remember to pause the video after each step to perform the task on the iPad. His percent correct for this session was 75%. The implementer used behavioral prompting, “Use the video to help you with the next step.” to emphasize the importance of the video procedures. Arjun’s percent correct on the task analysis for the next three sessions was 88.9%, which met mastery criteria, and he began video prompting intervention for the second skill on the twelfth session. Although initially demonstrating 80% and 90% correct steps in the task analysis for the first two sessions of intervention for the second skill, Arjun dropped to 40% correct during session 14. Arjun needed frequent reminders to stay on task, and this lack of focus often translated into becoming ‘lost’ when trying to find the next correct step on the video prompt. The subsequent three sessions each started with an emphasis on the attentional cue, “Show me you are ready to work.” Arjun still needed minor behavioral redirection, but demonstrated 80% correct on the next three sessions. Due to the variability in Arjun’s behavior and the concern that he hadn’t truly mastered the skill, researchers ran an additional intervention session. His percent correct on the task analysis increased to 90%. Overall, his percent correct was 77.1% (range 40-90%). Arjun moved to the video prompting intervention for the third skill on session 19. He required only three sessions to meet mastery of this skill with an average score of 93.3% (range 90-100%). The implementer noticed that Arjun was much more focused during these sessions than in the previous five sessions (one week).

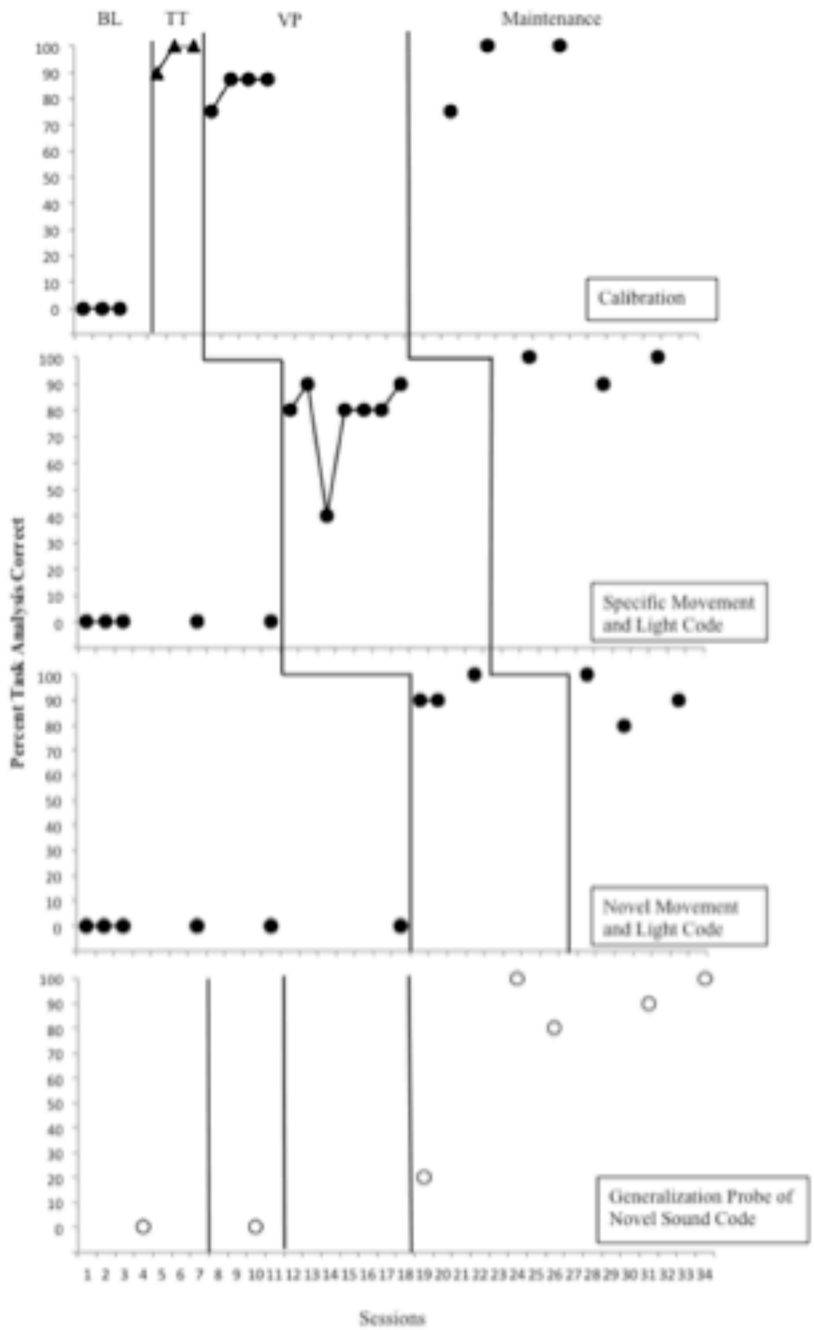

Figure 5. Data for Arjun. BL = Baseline, TT = Technology Training, VP = Video-prompting intervention. Condition lines in fourth tier indicate when participant intervention for each skill.

Maintenance. Maintenance data were collected approximately two and three weeks post-mastery of each skill. Participants were given identical task directions as listed in procedures, however they did not have access to the video prompting intervention for that particular skill. Data remained at levels observed during intervention. Simon never dropped below 80% correct completion of the task analysis for any of the three skills, averaging 92.1%, 96.7%, and 97.5% respectively across the skills. Similarly, Elias maintained above 80% correct and independent completion of the task analysis for all skills with an average of 95.3%, 96.7%, and 97.5% respectively. Arjun's independent completion of the calibration skill dropped to 77.8% during the first maintenance probe, however the subsequent two probes were both 100% for a 92.6% average percentage correct. He demonstrated 80% correct or higher on the remaining maintenance probes. The average percentage correct for the second and third skills was 96.7% and 90% respectively.

Generalization to Novel Codes. Throughout baseline and intervention, the implementer assessed generalization with probes for acquisition of sound codes (untaught codes that are part of Ozoblockly's programming repertoire). The fourth tier of each participant's graphed data highlights the percentage correct for each generalization probe to code a sound for the robot. Each participant remained at 0% correct until they began the video prompting intervention for the second skill. During session 15, Simon's percentage correct for this novel code increased to 20%. The subsequent four generalization probes, after mastery of the third skill, were all 100%. Similarly, in session 14, Elias' percentage correct on the generalization probe increased to 10%, and his subsequent four generalization probes were 100% (each after demonstrating mastery of the third skill). Arjun's percentage correct of the task analysis for the generalization probe was

20% during session 19. After meeting mastery criteria for the third skill, Arjun's percentage correct of subsequent generalization probes ranged from 80-100% correct across four probes (average 92.5%).

Reliability and Procedural Fidelity

IOA data were collected for 35.6% of all sessions across conditions and participants. Overall IOA was 99.2% (range 96.4%-100%). To identify risk of bias due to drift or other factors, a naïve coder was trained on data collection procedures. The coder watched the identical randomly selected session via video recording as the initial observer. IOA was 97.5%. All observers calculated IOA after each observation to detect discrepancies.

Procedural fidelity data were collected simultaneously with IOA data was calculated to be 96.5% (range 88.9-100%). This indicated that procedures for all conditions were implemented as anticipated with minimal errors.

Social Validity

Student Participants. During a semi-structured interview, each of the participants responded 'yes' to the following questions: (a) Do you like coding robots; (b) Would you like to do more robotics at school; and (c) Would you like to do robotics and coding during science class with your friends? When asked about the favorite part of the robotics work they did with their teacher, two participants reported that they liked to make the robot move. The other participant reported that he liked using the iPad to do science.

Implementer. The implementer, a middle school special educator, indicated that she believed that this intervention was enjoyable for all participants, effective in teaching them coding and robotics skills, and it was feasible for special educators to implement in their classrooms. She noted that creating video models would require most teachers to learn new technology skills, which would probably be a barrier for most busy special educators. The implementer said she was *very likely* to use more video prompting and robotics in her classroom.

Questionnaire Respondents. A REDCap questionnaire was sent to ten special educators naïve to the purpose and outcomes of the study. Nine educators (90%) completed the survey. The 30 item questionnaire asked respondents to rate their answers to VBM- and STEM-related statements or questions as they apply to students with disabilities, including those with ASD and ASD/ID on their caseload. Questionnaire items had a scale from 1 to 5. A '1' indicated the lowest level of familiarity, frequency, agreement, or likelihood for the statement, and a '5' indicated the highest level of familiarity, frequency, agreement, or likelihood for the statement.

Questionnaire respondents indicated they were overall familiar with VBM (M = 4.1), but they rarely, if ever, used them for any instruction with students receiving special education services (M = 2.6). Overall, the respondents agreed that VBM was a feasible procedure to use with special education students (M = 3.9). They also agreed that teaching STEM to students with disabilities was important (M = 4.0). Finally, if provided with all of the materials and video clips, respondents were likely to implement VBM to teach robotics and coding to their students (M = 4.2). See Table 1 for these questionnaire results.

Table 1

Summary of VBM and STEM questionnaire items

Questionnaire Item	Response M (Range)
Video modeling uses short video clips to teach students a step-by-step method for completing a skill or task. How familiar are you with video modeling?	4.1 (3-5)
I currently use video modeling with students who receive special education services.	2.6 (1-4)
Video modeling is a feasible instructional tool for special educators?	3.9 (3-5)
Video modeling is an effective instructional tool for special educators?	4.0 (3-5)
Learning science, technology, engineering, and math (STEM) is important for students who receive special education services.	4.0 (2-4)
If you were provided with all of the robotics materials AND all of the video models needed to teach robotics coding to your student(s) receiving special education services, how likely would you be to implement this instruction with your student(s)?*	4.2 (3-5)

Note. Questionnaire participants (n = 9); Using a scale from 1 – 5, 1 indicated the lowest level of familiarity, frequency, agreement, or likelihood for each statement. 5 indicated the highest level of familiarity, frequency, agreement, or likelihood; M = arithmetic mean; R = range.

*This was the final question of the questionnaire.

After viewing randomly selected baseline and intervention session clips (respondents were blind to the condition they were watching), questionnaire respondents rated the robotics and coding skills of the students in the intervention sessions (M = 4.2) higher than the skills demonstrated in the baseline sessions (M = 2.9). Further, respondents believed that the coding skills of the students in intervention were stronger (M = 3.5) than other middle school students, but the skills of participants in the baseline videos were weaker (M = 2.6) than other middle school students. This indicated that the intervention increased the perceived robotics and coding skills of the participants. Across both conditions, respondents believed the instructional procedures were feasible for students receiving special education services (M = 4.0). Despite rarely using VBM in their current classroom (M = 2.6), respondents increased the reported likelihood of using VBM to teach students with disabilities (M = 3.6) after watching the use of VBM to teaching coding and robotics. See Table 2 for these questionnaire results.

Table 2

Summary of questionnaire after watching exemplar video clips

Questionnaire Item	Video 1 (Intervention with Elias) M (Range)	Video 2 (Baseline with Arjun) M (Range)	Video 3 (Baseline with Elias) M (Range)	Video 4 (Intervention with Simon) M (Range)
The instructional procedures in this video clip seem feasible for students who receive special education services.	3.9 (3-5)	4.1 (3-5)	3.6 (2-4)	4.2 (4-5)
The student in this video clip appears to successfully code the robot.	4.1 (3-5)	2.8 (1-4)	3.0 (2-5)	4.2 (3-5)
How likely would you be to use the strategies of the adult in this video when working with students with a disability?	3.6 (3-5)	3.7 (3-5)	3.3 (2-5)	3.9 (3-5)
Based on other middle school students you know, how would you rate this child's robotic coding skills?	3.1 (2-4)	2.3 (1-4)	2.9 (1-4)	3.9 (3-5)

Note. Questionnaire participants (n = 9); Using a scale from 1 – 5, 1 indicated the lowest level of familiarity, agreement, or strength of skills for each statement. 5 indicated the highest level of familiarity, agreement, or strength of skills; M = arithmetic mean; R = range.

Questionnaire Educator Participants. Upon affirmatively answering the questionnaire that they were 'very likely' to teach their students how to code robots using VBM if provided with all requisite materials and technology, including video models, three educators consented to incorporate this project into their classroom work with students with ASD and ASD/ID. Each participating educator was given a teacher manual on how to introduce the technology to students, describe the procedures to use the video models, and allow *independent* access to materials as appropriate for that educator. See Appendix I for teacher manual. Additionally, since students would be using the materials with minimal/no teacher guidance, a visual aid for students was given to the teacher to help support self-directed use of the VBM and robotic materials. (See Appendix J). After approximately 15 instructional days, each educator was interviewed to assess the feasibility and effectiveness of implementing a VBM to learn coding of robots for their students. All educators reported using VBM to teaching their students robotics coding. An examination of the browser history of the iPad indicated frequent (almost daily) access to the Ozoblockly website during each of the intervals the materials were in classrooms. They also reported that VBM was feasible for their students and effective in teaching robotics and coding skills. Each educator independently reported that his or her students were both engaged in the robotics and coding tasks, as well as interested in teaching peers how to code. That is, once they learned the basics of coding robots using VBM, they taught peers without the use of VBM how to code robots (see Table 3 for interview data).

Table 3

Summary of post-questionnaire educator interview

Interview Question	Educator 1	Educator 2	Educator 3
How many students used the videos? How often?	5 students; 4-5 times weekly for 30-45 minutes	4 students; daily for 20-30 minutes	5 students; daily for 20-40 minutes
Were the videos effective in teaching robotics coding?	Yes	Yes	Yes
Is this (videos + robotics + materials) feasible to use in your classroom?	Yes	Yes	Yes
Was the project (videos + robotics) engaging for your students?	Yes	Yes (student self-selected to participate)	Yes (students began to ask to use robots during scheduled breaks)
What are some obstacles to using video models for instructional purposes in your classroom?	It must have taken a lot of time to make and edit the videos. Plus, storing them would be hard.	They take too much time to create for different academic tasks.	I would want to modify the videos to break them into even smaller chunks.
Would you be more likely to use video models if they were done for you (and aligned to your curriculum and instruction needs)? If so, why?	Yes. It would be another tool to use with certain students. Not sure all students could use them for complex academics.	Yes, especially for technical skills like (Excel).	Yes. This was highly engaging for 4 out of the 5 students, all with very different support needs. Any time I can do an activity that leads to independent academic work completion is a good activity.
If there was an app that allowed to quickly film steps of a task, then organized and edited your videos into a video model, would you be likely to try using it?	Yes	Yes	Yes
Additional things you noticed?	I had several students who watched the videos teach other students how to code (didn't need to watch videos).	Students liked pairing up to do the robotics and help teach each other.	Students often narrated what they were doing back to the robot.

Discussion

The purpose of this study was to: (a) evaluate the effect of a teacher-implemented VBM intervention to increase the accuracy of robotics coding skills to middle school students with ASD and ASD/ID; (b) examine the generalization of acquired skills to novel codes; (c) report social validity data on the efficacy and feasibility of VBM to teach coding; and (d) examine the use of social validity data to further implementation of robotics-centered VBM into other special education settings. A functional relation was identified between the dependent variable, (i.e., accuracy of robotics coding) and the independent variable, VBM, for all three participants. There was an immediate change in level and trend upon introduction of the VBM intervention. Consistent patterns of responding were evident across conditions for all participants. Further, each of the three participants generalized their new skills to novel codes. These findings indicate that a teacher-implemented VBM approach to teaching robotics coding was effective in (a) increasing the accuracy of participant's acquisition of block-based coding to mastery levels for all targeted skills; (b) fostering generalization of foundational coding skills to untaught (but topographically similar) codes; and (c) supporting generalization to untaught (but novel) codes.

However, these findings also have strong social validity for three reasons. First, the teacher-implementer reported that VBM was both an effective and feasible approach to teaching robotics and coding. Second, special educators (n = 9) naïve to the purpose or outcome of the project also indicated that the VBM procedures were feasible for the special education classroom. They identified the procedures as effective in teaching robotics and coding skills, and ultimately indicated that the participants had stronger than average skills after completing the VBM intervention. Finally, as new technologies continue to be developed, educators are challenged to use new innovative strategies to teach STEM in their classrooms, particularly with students with disabilities (Ehsan, Rispoli, Lory, & Gregori, 2018). However, three questionnaire respondents—each of whom had never previously used VBM for STEM (e.g., robotics, coding) in their classrooms—indicated they would be willing to try VBM to teach coding in their classroom. All three implemented robotics and coding practice into their classroom when they were given the video models, required technology, and guiding documents to support implementation (e.g., teacher manual, visual aid for students). These preliminary findings suggest teachers might be willing to try VBM when the materials are readily accessible and prepared; although additional research is needed in this area.

Findings from the current study contribute to the extant literature in several additional ways. First, interventions that harness the potential of visual media are gaining legitimacy and momentum in special education (Spriggs, Knight, & Sherrow, 2015). VBM has a proven research history for a variety of skills, but few studies have examined STEM skills beyond mathematics (Wright et al., 2019). Authors in a recent review of STEM interventions for students with ASD called for more experimental studies focused on the acquisition of technology or engineering skills while using effective instructional methods (Ehsan et al., 2018). Two research questions of the current study directly addressed this issue. Additionally, the current study adds to the literature indicating high rates of skill acquisition for students with ASD using VBM (Charlop-Christy, Carpenter, LeBlanc, & Kellet, 2002). VBM also provides non-socially mediated stimuli that might increase appropriate academic behavior leading to a potentially more rapid acquisition of targeted skills (Spriggs et al., 2015). VBM might be more reinforcing to students with ASD than face-to-face instruction in a STEM or science class, as watching the video model itself potentially acts as a natural reinforcer for the target behavior (Nikopoulos & Keenan, 2004).

Second, VBM interventions are often seen as effortful and require substantial technical skills, perhaps leading to technophobia (Knight et al., 2018b). Social validity results of the current study suggested that teacher-implemented VBM projects might be more feasible and manageable with proper, but minimal training and access to materials than previously hypothesized. The implementer of the current study and the participating educators who introduced this project as a result of participation in the social validity questionnaire all indicated that this kind of STEM work is feasible for and effective in special education classrooms. Each indicated and increased interest in using VBM, especially if included alongside task analyses typically associated with STEM curriculum.

Analysis of maintenance data indicated that students with ASD and ASD/ID demonstrated mastery of coding skills without the use of VBM several weeks after the intervention ended. Generalization data showed that these participants independently applied their knowledge of learned skills to untaught codes. Each participant increased their accuracy of responding to generalization probes after mastering the second skill (coding specific movement and lights). The consistent timing and magnitude of change suggest students might be more likely to generalize skills once they are taught specific codes. These findings support Baron-Cohens' (2002) assertion that students with ASD have a proclivity for systemizable skills, often seen in STEM activities.

Next, social validity measures included in research into STEM for students with ASD have been limited. In their systematic review of STEM instruction for students with ASD, Ehsan et al. (2018) found only four VBM research studies that included social validity measures. Hart and Whalon (2012) used a questionnaire with one cooperating teacher whose classroom was the setting of the researcher-implemented study. Three studies (Burton et al., 2013; Weng and

Bouck, 2014; Yakubova et al., 2016) interviewed a combined ten participating students and six special educators involved in the study. Each study questionnaire focused on student engagement and implementation challenges of VBM interventions. In the current study, I gathered social validity data from participants, a VBM-implementing special education teacher, nine special educators naïve to the outcomes of the study who watched baseline and intervention sessions and responded to a 30-item questionnaire, and three cooperating special educators who, based on questionnaire responses, were recruited to independently implement robotics and coding for their students with ASD. These social validity measures provided a deeper understanding of the enjoyment, engagement, efficacy, feasibility, and barriers to implementation relative to all past similar research.

Federal education reforms (U.S. Department of Education, 2016) and standards-creating entities (NGSS, 2013) have asserted that STEM education for *all* students will lead to a more developed set of inquiry and problem-solving skills. This, in turn, could expand the pipeline of students entering STEM related fields as post-secondary options, regardless of disability (Israel et al., 2013). Coding and robotics is an engaging access point for students with disabilities to learn foundational STEM skills, and minimally be given the opportunity to explore how STEM skills might resonate in their leisure or vocational lives (Taylor, Vasquez, & Donehower, 2018). The current study demonstrated that students with ASD and ASD/ID rapidly acquire basic robotics and coding skills and stay engaged in instruction. Participants indicated that using VBM to learn robotics and coding was enjoyable and something they want to do more of in their coursework.

Limitations

There are several limitations to note. First, all participants were from the same middle school and worked with the same special educator, which limits the external validity of the results. Future replications could strengthen the findings by using a variety of implementers across various settings. Next, the special educator implementing the VBM intervention was supported by a researcher who observed her implementation and procedural fidelity. This was potentially motivating for the implementer and not necessarily reflective of naturalistic use of VBM in a special education classroom.

In the data from the social validity questionnaire (n = 9), one participant's responses were outliers in the baseline video clips for in response to the statement: *The student in this video clip appears to successfully code the robot.* The respondent chose *Agree* and *Strong Agree* to the two video clips during baseline. In each video, the student either said, "I don't know" or sat still when prompted to code the robot. These responses might be evidence of social desirability in responding or inaccurate responding. A larger questionnaire population of naïve respondents could increase the confidence in the results of the questionnaire.

Additionally, prior to beginning the current study, the first author completed an internship at the school where the three questionnaire educator participants worked. This previous relationship might have impacted their willingness to participate in the current study and impacted their responses regarding the feasibility and efficacy of VBM to teach coding.

Finally, the number of generalization probes to novel codes (seen in the fourth tier of the graphs) during baseline were not sufficient to make a clear statement of stability. Subsequent studies should have at least three stable generalization probes in baseline for all participants.

Implications for Practice

As Knight et al. (2013) indicated, of the few studies examining the use of VBM for acquisition of academic skills for students with ASD, most have methodological flaws preventing efficacy conclusions from being made. Using an assessment of risk of bias (Reichow, Barton, & Maggin, 2018) and quality indicators from the CEC standards for establishing an EBP using single subject designs in special education (Cook et al., 2014), Wright et al. (2019) found an insufficient amount of research to support VBM as an EBP for teaching STEM, specifically for technology and engineering, for students with ASD. The current study adds to the experimental research base for acquisition of STEM skills, particularly for technology and engineering, for students with ASD and ASD/ID. The current study meets all of the CEC quality indicators for single subject research design for a *methodologically sound* research study. Additionally, eight of the nine categories on the Risk of Bias tool are 'low' risk of bias. Only in the category of sequence generation, a subcategory of selection bias, did the current study score an 'unclear' due to lack of random assignment of tiers.

STEM tasks are often broken down using the scientific methods into a variety of steps that can be task analyzed to support independent student learning, especially students with moderate and severe disabilities (Agran, Cavin, Wehmeyer, & Palmer, 2006). VBM provides a unique opportunity to use a well-researched practice while increasing independent completion of academic STEM work. Students with ASD seem to have a particular proclivity for tasks that are systemizable (Baron-Cohen, 2009). In the current study, students acquired complex coding skills with minimal in vivo adult prompting. Reduced dependence on adults for successful completion of academic tasks is a potentially significant outcome for students who often have 1-1 paraprofessional support in core content classes. Also, participants generalized their understanding of robotics coding to untaught skills. This finding is particularly important for practitioners as it is evidence of application of participants' developing skill set, perhaps highlighting the need to incorporate generalization probes into STEM instruction.

Developing STEM skills is an interdisciplinary endeavor that involves academics, vocational skills, leisure skills, and overall post-secondary success (Israel et al., 2013). Due to lack of knowledge or lack of human or material resources, educators might struggle to harness some of the inherent strengths of many students with ASD relative to learning more complex STEM skills. However, incorporating STEM into a variety of content areas for *all* students is vital in creating a well-informed, technologically-savvy citizenry (NSF, 2017). Further, an examination of STEM research for students with ASD indicated that students with ASD are less likely to pursue postsecondary education than their typically-developing peers (Wei, Yu, Shattuck, McCracken, & Blackorby, 2012), but when they do post-secondary work, they enter STEM-related majors in college at a disproportionate rate (Wei et al., 2014). The current research highlights potential STEM capabilities for students with ASD and ASD/ID and offers insight into their post-secondary use of STEM skills to create a better life for themselves.

Implications for Future Research

The current study adds to the literature indicating that VBM is feasible and effective for teaching STEM skills to students with ASD and ASD/ID. Additionally, when presented with a complete package of VBM and supporting materials (e.g., implementation guides, graphic aids for students), special teachers will implement VBM projects with their students. By preparing VBM for special educators in advance, researchers were able to demonstrate that special education teacher will implement complex STEM projects with their students with ASD. This preparation of video models helped to overcome two commonly reported obstacles for using VBM, namely the effortfulness of VBM creation and technophobia (Knight et al., 2018b). Future research into STEM education for students with ASD should include prepared video models alongside the task analyses to gain buy-in from special educators to increase implementation of STEM activities in special education or inclusive classrooms.

Students with the most significant intellectual disabilities are often left out of academic research supporting STEM development for students with intensive support needs (Ehsan et al., 2018). The current study included two participants with intellectual disability who learned to code and manipulate the movements of a smart robot. Post-secondary success for *all* students means including students with the most significant needs into the research that fosters applicable academic (e.g., STEM) skill development (NGSS, 2013).

As there have been only a handful of studies focusing on acquisition of STEM skills for students with ASD and ASD/ID, researchers need to continue examining the efficacy of VBM to teach STEM skills. Due to the small sample size (n = 3), replication of these findings would strengthen the validity of outcome of the current study. Systematic replications of the current study would strengthen these findings and add to the literature supporting the use of VBM to teach STEM to students with ASD and ASD/ID as a well-researched and a potential evidence-based practice. These replications might include: (a) expanding this study to students with ASD and ASD/ID in elementary school or high school; (b) using more complex coding features of this smart robot, specifically requiring creation of unique codes (not just codes available in the online application); and (c) using paraprofessionals as implementers of VBM interventions to teach STEM to students receiving 1-1 special education services .

In the current study, educator interviews indicated that many students with ASD often shared their coding and robotics knowledge (gained through watching VBM) with peers who did not watch the videos. Future studies could also examine how students who have learned robotics and coding via VBM can teach others to code. Additionally, research that examines training educators to create video models that are aligned with their STEM curriculum would be a valuable addition to this literature, as it would allow for a high level of individualization for students. Further, development of a VBM application for smart devices has the potential aid in the creation of point-and-shoot video models. (This is fodder for a Goal Two IES grant currently in development by the author.) This mobile application would address key gaps in existing technology (and help overcome some of the discussed technophobia) in the following ways: (a) no video editing skills would be required to create video models for individualized support of students with ASD; (b) no additional editing software would be needed to create or display video models; (c) ASD related supports for sound, light, and movement sensitivities would be built into the application; (d) multiple versions of videos (e.g., video prompts [VP], video chunks [VC], video models [VM]) would be created to scaffold support for students with higher academic support needs (i.e., severity of ID); (e) teacher training videos would be included to support professional development; and (f) video model exemplars of STEM activities would be accessible, sharable, and searchable by topic and grade level standards.

Acquisition of other STEM skills beyond robotics needs to be experimentally examined to demonstrate the feasibility and effectiveness of learning a variety of STEM skills through VBM. These might include other high interest STEM skills that are task analyzable, such as 3-D printing. Additionally, in order to capitalize on the increased availability of STEM curriculum and commercially available STEM activities, researchers can create VBM to supplement the written task analyses commonly created for these materials. By doing so, they can extend the efficacy research of VBM with STEM materials currently being used in schools. Further, VBM can be used to include more students with ASD, ASD/ID, and more intensive support needs in general education STEM classes.

Conclusion

The purpose of this study was to research the feasibility and effectiveness of using VBM to teach robotics coding to middle school students with ASD and ASD/ID. Robust social validity data was gathered and examined to better understand the validity of STEM intervention for students with disabilities. All student participants rapidly acquired the targeted robotics coding skills, and stakeholders viewed the procedures as feasible and effective for teaching students with ASD and ASD/ID. This study is an initial examination of the potential of VBM to significantly enhance the academic STEM repertoire of students with disabilities. Because of the efficiency, feasibility, and effectiveness demonstrated in this study, future research and policy should focus on STEM education to help include students with ASD, ASD/ID, and other disabilities along side their typically-developing peers. This has implications beyond the classroom and into the workforce.

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Appendix A. *Project Overview and Inclusion Checklist for Potential Participants*

VANDERBILT Peabody College

Overview of Video Prompting to Teach Robotics Coding to Students with ASD

Researchers at Vanderbilt University are conducting a project dedicated to increasing STEM skills of students with ASD. Specifically, the project will focus on using video models to teach middle school students how to program robots to move, make sounds, and light up. The project will be implemented by a special education teacher who will be trained by the research staff. The videos will be created by the research team.

For this innovative STEM project, we are looking for:

Teachers who:

- Teach students with ASD in grades 5 through 8
- Are willing to work with at least three students (one-on-one) during the duration of the project
- Can provide a space in a special education classroom to implement the project
- Are able to commit to at least three sessions per student per week for the duration of the project (with administration's approval)
- Will not remove students during inclusive core content instructional periods

Students who:

- Receive special education services
- Have a diagnosis of ASD or multiple disabilities (including ASD)
- Communicate primarily in English
- Have motor skills sufficient to operate a standard tablet (including ability to operate a video, pause, fast forward, drag and drop images on a screen, use drop down menus)
- Might love working with robots

If you are interested in participating in the project and know students who might benefit from learning robotics coding (STEM skills), please contact:

John Wright, Doctoral Student
Department of Special Education, Vanderbilt University
john.wright.2@vanderbilt.edu
512.560.2146

Appendix B. *Potential Participant Observation Summary*

Student ID Code: ____________ Observer's initials: _________ Date: _________

Start/End Time ______________/_______________

Subject: ______________

Activity: ____

Material: ____

What motor skills did student use?

- ☐ Writing
- ☐ Typing
- ☐ Used classroom materials/manipulatives (example: used a calculator)
  Explain: _______________________________________
- ☐ Other Explain: _______________________________________

Were motor skills sufficient for the task? Y N **Required support?** Y N

What motor skills did student use?

- ☐ Writing
- ☐ Typing
- ☐ Used classroom materials/manipulatives (example: used a calculator)
  Explain: _______________________________________
- ☐ Other Explain: _______________________________________

Were motor skills sufficient for the task? Y N **Required support?** Y N

What motor skills did student use?

- ☐ Writing
- ☐ Typing
- ☐ Used classroom materials/manipulatives (example: used a calculator)
  Explain: _______________________________________
- ☐ Other Explain: _______________________________________

Were motor skills sufficient for the task? Y N **Required support?** Y N

Was student redirected to stay on task? Y N **By whom?** ____________

Was a system of reinforcement used? Y N **Explain** (i.e., praise, token board)
____

Did student communicate during observation? Y N

Communication Partner		Method
Peer	Y N	Vocal verbal AAC
Teacher	Y N	Vocal verbal AAC
Paraprofessional	Y N	Vocal verbal AAC
Other (Explain:)	Y N	Vocal verbal AAC

(Question to ask teacher): Did student work appropriately today in class? Y N

Appendix C. *Motor Skills Assessment*

Student ID Code: _____________ Assessor's initials: _________ Date: _________

Start/End Time ______________/_______________

Skill	**Successfully completed?**	**Notes:**
Start video	Y N	
Pause video	Y N	
Fast forward video	Y N	
Rewind video	Y N	
Drag and drop image on page	Y N	
Uses drop down menu to select choice	Y N	
Pushes button on tablet to turn it off or on	Y N	

Appendix D. *Data Collection Sheets*

JTM Video Prompting Data Collection Sheet – Skill 1 Calibration Baseline

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Calibrate the robot.**	☐	Y N

Video Prompting	Task Watched	Task Completed	Procedural Fidelity
1. Went to ozoblockly.com	☐	+ - NR	Y N
2. Clicked "Get Started"	☐	+ - NR	Y N
3. Clicked "evo" directly under logo on the left.	☐	+ - NR	Y N
4. Clicked "2" beginner level under evo.	☐	+ - NR	Y N
5. Clicked "Flashing" on the bottom left.	☐	+ - NR	Y N
6. Closed any pop up boxes.	☐	+ - NR	Y N
7. Held ozobot on button until it was white.	☐	+ - NR	Y N
8. While holding button, ozobot placed on white outline of robot on iPad.	☐	+ - NR	Y N
9. Robot is calibrated if green. (Repeated steps 7 and 8 if robot turns red)	☐	+ - NR	Y N

\+ = completed; - = did not complete; NR = no response

% of tasks correctly completed:

% of PF correct:

JTM Video Prompting Data Collection Sheet – Skill 2 Coding Baseline

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Code your robot to move zigzag and turn on rainbow lights.**	☐	Y N

Video Prompting	Task Watched	Task Completed	Procedural Fidelity
1. Touched "Movement"	☐	+ - NR	Y N
2. Touched and dragged "Zigzag" code to programming area.	☐	+ - NR	Y N
3. Selected "Very Fast" from the "Zigzag" drop down menu.	☐	+ - NR	Y N
4. Touched "Light Effects"	☐	+ - NR	Y N
6. Touched and dragged "Rainbow" into the programming area.	☐	+ - NR	Y N
6. Connected "Zigzag" and "Rainbow" codes in any order.	☐	+ - NR	Y N
7. Turned on ozobot by quickly pressing the on button and placed it on white outline of ozobot.	☐	+ - NR	Y N
8. Clicked "Load Evo"	☐	+ - NR	Y N
9. Waited until loading completed, placed ozobot on flat surface and doubled clicked on button.	☐	+ - NR	Y N
10. Code ran successfully. (If not, turned off robot and started at step 8 again).	☐	+ - NR	Y N

+ = completed; - = did not complete; NR = no response

% of tasks correctly completed:

% of PF correct:

JTM Video Prompting Data Collection Sheet – Skill 3 Self-directed Coding Baseline

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Is the planning sheet accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Code a new movement and light effects code for the robot.**	☐	Y N

Video Prompting	Task Watched	Task Completed	Procedural Fidelity	
1. Touched "Movement"	☐	+ - NR	Y N	
2. Touched and dragged *any Movement* code to programming area.	☐	+ - NR	Y N	Novel Code? Y N
3. Selected at least one item from the drop down menu	☐	+ - NR	Y N	
4. Touched "Light Effects"	☐	+ - NR	Y N	
6. Touched and dragged *any light effects* into the programming area.	☐	+ - NR	Y N	Novel Code? Y N
6. Connected *movement and light effects* codes in any order.	☐	+ - NR	Y N	
7. Turned on ozobot by quickly pressing the on button and placed it on white outline of ozobot.	☐	+ - NR	Y N	
8. Clicked "Load Evo"	☐	+ - NR	Y N	
9. Waited until loading completed, placed ozobot on flat surface and doubled clicked on button.	☐	+ - NR	Y N	
10. Code ran successfully. (If not, turned off robot and started at step 8 again).	☐	+ - NR	Y N	

+ = completed; - = did not complete; NR = no response

% of tasks correctly completed:

% of PF correct:

JTM Video Prompting Data Collection Sheet – Skill 1 Calibration

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Calibrate the robot.**	☐	Y N

Video Prompting	Task Watched	Task Completed	If Behavioral Prompt * Needed	Procedural Fidelity
1. Went to ozoblockly.com	☐	+ - NR	A B	Y N
2. Clicked "Get Started"	☐	+ - NR	A B	Y N
3. Clicked "evo" directly under logo on the left.	☐	+ - NR	A B	Y N
4. Clicked "2" beginner level under evo.	☐	+ - NR	A B	Y N
5. Clicked "Flashing" on the bottom left.	☐	+ - NR	A B	Y N
6. Closed any pop up boxes.	☐	+ - NR	A B	Y N
7. Held ozobot on button until it was white.	☐	+ - NR	A B	Y N
8. While holding button, ozobot placed on white outline of robot on iPad.	☐	+ - NR	A B	Y N
9. Robot is calibrated if green. (Repeated steps 7 and 8 if robot turns red)	☐	+ - NR	A B	Y N

+ = completed; - = did not complete; NR = no response

*Prompts:

A = If student is making errors or skipping steps:
Use the video to help you with the next step.

B = If student is not responding/stuck:
Watch the video to complete the step on the iPad.

← Note: only behavior specific prompting during intervention
3 s to initiate; 15 s to complete

% of tasks correctly completed:

% of PF correct:

JTM Video Prompting Data Collection Sheet – Skill 2 Coding

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Code your robot to move zigzag and turn on rainbow lights.**	☐	Y N

Video Prompting	Task Watched	Task Completed	If Behavioral Prompt* Needed	Procedural Fidelity
1. Touched "Movement"	☐	+ - NR	A B	Y N
2. Touched and dragged "Zigzag" code to programming area.	☐	+ - NR	A B	Y N
3. Selected "Very Fast" from the "Zigzag" drop down menu.	☐	+ - NR	A B	Y N
4. Touched "Light Effects"	☐	+ - NR	A B	Y N
6. Touched and dragged "Rainbow" into the programming area.	☐	+ - NR	A B	Y N
6. Connected "Zigzag" and "Rainbow" codes in any order.	☐	+ - NR	A B	Y N
7. Turned on ozobot by quickly pressing the on button and placed it on white outline of ozobot.	☐	+ - NR	A B	Y N
8. Clicked "Load Evo"	☐	+ - NR	A B	Y N
9. Waited until loading completed, placed ozobot on flat surface and doubled clicked on button.	☐	+ - NR	A B	Y N
10. Code ran successfully. (If not, turned off robot and started at step 8 again).	☐	+ - NR	A B	Y N

+ = completed; - = did not complete; NR = no response

*Prompts:

A = If student is making errors or skipping steps:
Use the video to help you with the next step.

B = If student is not responding/stuck:
Watch the video to complete the step on the iPad.

← Note: only behavior specific prompting during intervention
3 s to initiate; 15 s to complete

% of tasks correctly completed:

% of PF correct:

JTM Video Prompting Data Collection Sheet – Skill 3 Self-directed Coding

Participant ID __________ Date __________ Teacher __________

	Teacher Checklist	Procedural Fidelity
Materials		
Is the correct video loaded to start at the beginning?	☐	Y N
Is the iPad on and browser window open?	☐	Y N
Is the ozobot accessible to the student?	☐	Y N
Is the planning sheet accessible to the student?	☐	Y N
Procedure		
Attentional Cue: **Show me you are ready to work.**	☐	Y N
Today you are going to learn about robotics using this video.	☐	Y N
Task Direction: **Code a new movement and light effects code for the robot.**	☐	Y N

Video Prompting	Task Watched	Task Completed	If Behavioral Prompt* Needed	Procedural Fidelity	
1. Touched "Movement"	☐	+ - NR	A B	Y N	
2. Touched and dragged *any Movement* code to programming area.	☐	+ - NR	A B	Y N	Novel Code? Y N
3. Selected at least one item from the drop down menu	☐	+ - NR	A B	Y N	
4. Touched "Light Effects"	☐	+ - NR	A B	Y N	
6. Touched and dragged *any light effects* into the programming area.	☐	+ - NR	A B	Y N	Novel Code? Y N
6. Connected *movement and light effects* codes in any order.	☐	+ - NR	A B	Y N	
7. Turned on ozobot by quickly pressing the on button and placed it on white outline of ozobot.	☐	+ - NR	A B	Y N	
8. Clicked "Load Evo"	☐	+ - NR	A B	Y N	
9. Waited until loading completed, placed ozobot on flat surface and doubled clicked on button.	☐	+ - NR	A B	Y N	
10. Code ran successfully. (If not, turned off robot and started at step 8 again).	☐	+ - NR	A B	Y N	

+ = completed; - = did not complete; NR = no response

*Prompts:

A = If student is making errors or skipping steps:
Use the video to help you with the next step.

B = If student is not responding/stuck:
Watch the video to complete the step on the iPad.

← Note: only behavior specific prompting during intervention
3 s to initiate; 15 s to complete

% of tasks correctly completed:

% of PF correct:

Appendix E. *Task Analyses for Video Prompting Skills*

Video #1: Calibration Task Analysis

1. Go to ozoblockly.com
2. Click ***Get Started.***
3. Click ***Evo*** directly under the ozoblockly logo on the left.
4. Click ***2*** (beginner level).
5. Click ***Flashing***.
6. Close any pop up boxes by clicking the small x in the upper right corner.
7. Pick up an ozobot and hold the on button until it turns white.
8. While still holding the button, place the ozobot on the white outline of a robot.
9. If ozobot turns green, it is calibrated. (Try steps 7 & 8 again if ozobot turns red)

Video #2: Coding Task Analysis

1. Touch ***Movement*** (to see movement options)
2. Touch and drag ***zigzag*** to the programming area.
3. Select ***Very Fast*** from the zigzag drop down menu.
4. Touch ***Light Effects*** (to see lighting options)
5. Touch and drag ***rainbow*** into the programming area.
6. Connect the zigzag code to the rainbow code by placing it directly above rainbow in the programming area.
7. Turn ozobot on by pressing the button once and place it on the white ozobot outline.
8. Click Load Evo
9. When loading is complete, put evo on a flat surface. Double click the on button to run the program.
10. Code successfully ran. (If not, turn robot off and start at step 8 again).

Video #3: Self-Directed Coding

1. Touch ***Movement*** (to see movement options)
2. Touch and drag ***any Movement*** to the programming area. (adjust drop down menu as needed)
3. Touch ***Light Effects*** (to see lighting options)
4. Touch and drag ***any Light Effects*** into the programming area.
5. Connect the Movement code to the Light Effects code by placing it directly above rainbow in the programming area.
6. Turn ozobot on by pressing the button once and place it on the white ozobot outline.
7. Click Load Evo
8. When loading is complete, put evo on a flat surface. Double click the on button to run the program.
9. Code successfully ran. (If not, turn robot off and start at step 8 again).

Appendix F. Sample Social Validity Interviews and Questionnaire

Robotics and Coding Participant Feedback Form

Student ID: ____________________ School: ___________________________

Date: _________________________ Completed by: _____________________

Please read each question to the participant. Circle the answer that best reflects their response. Add any notes below if the student elaborates on the response.

---

1. Do you like coding robots?	Yes	No	Unsure	No Answer

Notes:

2. Would you like to do more robotics at school?	Yes	No	Unsure	No Answer

Notes:

3. Would you like to do robotics and coding during science class with your friends?	Yes	No	Unsure	No Answer

Notes:

4. What is your favorite part of coding robots?

Notes:

Robotics and Coding Implementer Feedback Form

Student ID: ____________________ School: ___________________________

Date: _________________________ Completed by: _____________________

1. Do your students like coding robots?	Yes	Somewhat	No	
Notes:				
2. Was this intervention effective in teaching robotics coding?	Yes	Somewhat	No	
Notes:				
3. Is this intervention feasible for a special educator to implement?	Yes	Somewhat	No	
Notes:				
4. What is the likelihood that you will use more video prompting in your classroom?	Very likely	Likely	Unlikely	Very unlikely
Notes:				
5. What is the likelihood that you will do more robotics coding in your classroom?	Very likely	Likely	Unlikely	Very unlikely
Notes:				

Robotics and Coding Special Educator Feedback Form

Thank you for agreeing to complete this survey. There are 30 questions to answer. Your responses are anonymous, even if you enter your email address to get access to robotics materials or enter the gift card drawing.

Please choose the response that best reflects you or your views. Your responses will help us improve this project in the future.

1. What is your gender identity?	Woman Man Transgender Non-binary Prefer not to answer
2. What is your race/ethnicity?	American Indian or Alaskan Native Asian or Pacific Islander Black or African American Hispanic or Latino White/Non Hispanic Multiple Race/Ethnicity Other: ________________
3. What is your age in years?	____________
4. What is your level of education?	High School or GED Some College Associate's Degree Bachelor's Degree Master's Degree Doctor of Education Doctor of Philosophy
5. Do you have a special education certification?	Yes No
6. Do you primarily work with children who received special education services or have documented disabilities?	Yes No

The following five questions relate to your experience with and opinions about video modeling and STEM. Please choose the responses that best reflect your views.

7. Video modeling uses short video clips to teach students a step-by-step method for completing a skill or task. How familiar are you with video modeling?	Very familiar	Somewhat familiar	Neutral	Somewhat unfamiliar	Completely unfamiliar
8. I currently use video modeling with students who receive special education services.	Frequently	Sometimes	Seldom	Once	Never
9. Video modeling is a feasible instructional tool for special educators?	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

10. Video modeling is an effective instructional tool for special educators?	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
11. Learning science, technology, engineering, and math (STEM) is important for students who receive special education services.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Video #1 - Watch the brief video clip and answer the following four questions based on this video.

12. The instructional procedures in this video clip seem feasible for students who receive special education services.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
13. The student in this video clip appears to successfully code the robot.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
14. How likely would you be to use the strategies of the adult in this video when working with students with a disability?	Very Likely	Likely	Somewhat Likely	Unlikely	Very Unlikely
15. Based on other middle school students you know, how would you rate this child's robotic coding skills?	Much Stronger Skills	Stronger Skills	About the Same	Weaker Skills	Much Weaker Skills

Video #2- Watch the brief video clip and answer the following four questions based on this video.

16. The procedures in this video clip seem feasible for students who receive special education services.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
17. The student in this video clip appears to successfully code the robot.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
18. How likely would you be to use the strategies of the adult in this video when working with students with a disability?	Very Likely	Likely	Somewhat Likely	Unlikely	Very Unlikely
19. Based on other middle school students you know, how would you rate this child's robotic coding skills?	Much Stronger Skills	Stronger Skills	About the Same	Weaker Skills	Much Weaker Skills

Video #3 - Watch the brief video clip and answer the following four questions based on this video.

20. The procedures in this video clip seem feasible for students who receive special education services.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

21. The student in this video clip appears to successfully code the robot.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
22. How likely would you be to use the strategies of the adult in this video when working with students with a disability?	Very Likely	Likely	Somewhat Likely	Unlikely	Very Unlikely
23. Based on other middle school students you know, how would you rate this child's robotic coding skills?	Much Stronger Skills	Stronger Skills	About the Same	Weaker Skills	Much Weaker Skills

Video #4-Watch the brief video clip and answer the following four questions based on this video.

24. The procedures in this video clip seem feasible for students who receive special education services.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
25. The student in this video clip appears to successfully code the robot.	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
26. How likely would you be to use the strategies of the adult in this video when working with students with a disability?	Very Likely	Likely	Somewhat Likely	Unlikely	Very Unlikely
27. Based on other middle school students you know, how would you rate this child's robotic coding skills?	Much Stronger Skills	Stronger Skills	About the Same	Weaker Skills	Much Weaker Skills

Please answer the final three questions.

28. If you were provided with all of the robotics materials AND all of the video models needed to teach robotics coding to your student(s) receiving special education services, how likely would you be to implement this instruction with your student(s)?	Very Likely	Likely	I don't know	Unlikely	Very Unlikely
29. If you are interested in more information regarding access to video models for teaching robotics AND access to hand-held, programmable robots, please supply your email address.	Email:				
30. If you are interested in entering the random drawing for one of the $20 gift cards, please supply your email address.	Email:				

Social Validity Post-Survey Teacher Interview

Teacher ID:	
Date:	
Interviewer:	Wright

1. Did they use the videos as: VM or VP
Notes:

2. How many students used them? ____________
How often? _______________
Notes:

3. Were the videos effective in teaching robotics coding? Y N

4. Was the project (videos + robotics) engaging for your students? Y N

5. Is this (videos + robotics + materials) feasible to use in your classroom? Y N

6. What are some obstacles to using video models for instructional purposes in your classroom?

7. Would you be more likely to use video models if they were done for you (and aligned to your curriculum and instruction needs)? Y N

Why?

8. If there was an app that allowed to quickly film steps of a task, then organized and edited your videos into a video model, would you be likely to try using it? Y N

For what skills/tasks?

9. Additional things you noticed?

Appendix G. *Vocabulary Training Data Collection Sheet*

Participant ID _______________ Date _____________ Teacher ______________

Procedure:
1. Teacher places a random field of 3 vocabulary cards (2 wrong, 1 correct) in front of participant.
2. Reshuffle cards after each word.
3. Follow the sequence below.

Attentional Cue: **"Show me you're ready to work."**

Task Direction: "Show me the word that means _________."

Definitions:

Robot means *a machine we control with codes*.
Calibrate means *make the robot ready*.
Code means *rules for a robot*.
Programming Area means *a place to gather codes.*

Session 1 = Calibrate & Robot	
0-second delay	
"Show me the word that means …"	
…make the robot ready.	
…a machine we control with codes.	
…make the robot ready.	
…a machine we control with codes.	
3-second delay	
"Show me the word that means …"	
…a machine we control with codes.	B A NR
…make the robot ready.	B A NR

B=before prompt; A=after prompt; NR=no response

Session 2 = Calibrate, Robot, & Code			
0-second delay			
"Show me the word that means …"			
…rules for a robot.			
…a machine we control with codes.			
…make the robot ready.			
…a machine we control with codes.			
…rules for a robot.			
…make the robot ready.			
3-second delay			
"Show me the word that means …"			
…rules for a robot.	B	A	NR
…a machine we control with codes.	B	A	NR
…make the robot ready.	B	A	NR

B=before prompt; A=after prompt; NR=no response

Session 3= Calibrate, Robot, Code, & Programming Area			
0-second delay			
"Show me the word that means …"			
…make the robot ready.			
…a machine we control with codes.			
…rules for a robot.			
… a place to gather codes.			
…a machine we control with codes.			
…rules for a robot.			
… a place to gather codes.			
…make the robot ready.			
3-second delay			
"Show me the word that means …"			
…rules for a robot.	B	A	NR
…make the robot ready.	B	A	NR
…a machine we control with codes.	B	A	NR
…a place to gather codes.	B	A	NR

B=before prompt; A=after prompt; NR=no response

Appendix H. *Technology Training Procedures and Data Collection Form*

Video Prompting Training

Materials: Sample video, iPad (Video is cued up; iPad is on to the home screen)
Attentional Cue: "Show me you are ready to work."

Procedural Fidelity
1. Y N
2. Y N
3. Y N
4. Y N
5. Y N
6. Y N
7. Y N
8. Y N
9. Y N
10. Y N
11. Y N
12. Y N
13. Y N

Today we are going to learn how to use a video to complete a task. The video will tell us each step to do. After each step, we pause the video and do that step. I am going to show you how to do it. Then you are going to try.

1. **I start the video and watch until the first step is done**. (turn on video)
2. **Now I pause the video after step 1 like this**.
3. **The first step on the iPad was Touch the Notes, then Notepad icons.** (complete step 1)
4. **I did the first step. So, now I watch the video for the second step. Restart the video like this.** (restart video)
5. **I pause the video after step 2 like this**.
6. **The second step on the iPad was to Touch anywhere and type my name.** (complete step 2)
7. **I did the second step. So, now I watch the video for the third step. Restart the video like this.** (restart video)
8. **I pause the video after step 3 like this**.
9. **I forgot this step 3. I rewind the video like this.** (go back to the beginning of step 3)
10. **I can rewatch that step.** (start video).
11. **I pause the video after step 3 like this**.
12. **The third step on the iPad was Touch the 123 button in the corner and type the date**. (complete step 3)
13. **Let's see if we finished all the steps.** (turn on video). **We finished all the steps.**

Now it's your turn to show me how to use the video to learn each step. (return the video to start & close out of notes on iPad)

Task Direction: **Use the video to do each step one at a time. Remember to pause the video after each step and do that step on the iPad.**

	Student Response	Prompt Needed
1. Watched step 1	Y N	V VM P
2. Paused after step 1	Y N	V VM P
3. Completed step 1 – *Touched Note, then Notepad icons*	Y N	V VM P
4. Watched step 2	Y N	V VM P
5. Paused after step 2	Y N	V VM P
6. Completed step 2 – *Touched anywhere and typed name*	Y N	V VM P
7. Watched step 3	Y N	V VM P
8. Paused after step 3	Y N	V VM P
9. Completed step 3. – *Touched 123 button and typed date*	Y N	V VM P
10. Watched end of video.	Y N	V VM P

If student is making errors or skipping steps:
Use the video to help you with the next step.
If student is not responding/stuck: **Watch the video to complete the step on the iPad.**

Notes: 3s CTD to initiate;
15s to complete

Mastery: 3 sessions at 100%

Appendix I. *Post-questionnaire Robotics and Video Prompting Procedures for Participating Educators*

Teacher: The following are steps to take to introduce and implement robotics and video prompting into your classroom.

Step 1: Introduce the technology to your student(s).

- Show the hand-held smart robot, Evo.
  - The bottom has sensors, so indicate to students that they should avoid putting their hands on the bottom.
  - Show the 'on' button. Demonstrate how to simply press it once to turn it on. Press it again to turn it off.

Step 2: Introduce the small Samsung tablet

- Show the 'on' button.
- Show the 'Gallery' to find the videos.
  - There are 3 videos they can watch to learn to control Evo.

Step 3: Introduce the iPad and OzoBlockly icon.

- Make sure iPad is connected to WiFi.
- Show the 'on' or 'home' button.
- Passcode: 246824
- Touch the 'OzoBlockly' icon to launch the coding program.

Step 4: Describe the procedures to student(s)

- Watch videos on Samsung tablet. Pause, rewind, fast forward as needed to watch and re-watch the steps.
- As you watch the videos, make sure OzoBlockly is launched on the iPad so students can follow along and complete the steps on the video.

Step 5: Allow independent access to video models as often as you wish and track how often students used video models/coded robots.

Student	Accessed videos/coded robots
Example: Sally	IIIII II