Title
Examining the Effects of Application-based Instruction on Social Communication and Interaction Skills in Chinese Children with Autism Spectrum Disorders

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Publication Date
2020

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Santa Barbara

Examining the Effects of Application-based Instruction on Social Communication and Interaction Skills in Chinese Children with Autism Spectrum Disorders

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Education

by

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ACKNOWLEDGEMENTS

I thankfully acknowledge the mentors, colleagues, friends, and family members who have shared with me their expertise, caring, enthusiasm, and support during this process of discovery – you all inspired me to continue pursuing my academic goals over the years.

Foremost among these is my advisor, Dr. Mian Wang. Thank you for guiding me to find my direction in the research world, for offering me a precious opportunity to work in your lab to develop the software, and for transforming behavioral sciences into some of the coolest educational technologies I have ever had the pleasure to be involved with. It was also enjoyable to witness our cross-continental phone meetings slowly evolve into international collaborations of anything and everything pertaining to the final product and the research experiments. None of this work would have been possible without the level of support, trust, and sincerity that I have received from you. I am beyond appreciative of your encouragement, expertise, guidance, and kindness throughout my doctoral program.

I want to express my sincere thanks to my committee members, Dr. Michael Gerber and Dr. George Singer, for their ongoing and invaluable guidance. The completion of my dissertation would not have been possible without you both. Mike, thank you for your insightful comments, which made my study robust, for guiding me to become a better researcher, and for providing feedback on matters regarding my professional development. George, thank you for your enthusiasm and passion in supporting families with disabilities, which have inspired my own drive to conduct this research, and for encouraging me to work towards opportunities that I otherwise would not have found.

I extend thanks to my SPEDR cohort, who have made the ups and downs of the program fun to contend with. Yixin and Yirong, thank you for all the work and effort you put into our collaborations on the project, and for being part of this shared experience, which has added so much to my academic life. On the same note, I appreciate the teachers, students, and families who participated in this study, and the fellow engineers I have had the pleasure to work with during the product design, development, and testing process. I will always cherish your input and participation.

A deep thank you to my supervisors and colleagues at UCSB Graduate Division, who made each workday seem filled with sunshine – Robert, Shawn, Lana, and Kyle. My experience over the past three years working as the international graduate student peer advisor has been overwhelmingly positive. Thank you for choosing me to be the trailblazer who broke through the campus service gap by being proactive not only in serving as the campus-wide advisory liaison assisting students navigating graduate school, but also in identifying strategic goals and areas of improvement for our office to build partnerships and develop new initiatives to support the best practices for student success. Thank you for encouraging me to apply my scrappy mindset and entrepreneurial grit to the work. Under your support, I developed and organized 10 new programs – from small workshops and information sessions to large-scale networking and social events – directly benefiting over 530 international students from 49 departments. I also thank some of my other colleagues at the Graduate Division – Kate, Noreen, Robby, Danny, Ana, Caroline, Daniel, Nicole, Ida, Daina, and Erik. All of you have contributed to my best memories at UCSB.

For keeping me sane and alive outside of my doctoral excursions, I cannot forget my dearest friends who have been my great companions throughout countless challenging times

in the most positive way. Many thanks go to Kamal. Thank you for being my most dependable friend, the one I can count on for heartfelt advice, for handling my curveballs with patience and support, and for teaching me – through numerous examples – genuine kindness, generosity, and compassion. I will never forget all that you have done for me. Many thanks also go to Heena. Thank you for being my closest friend. I would not have survived this journey without your friendship, which has provided me with a form of healing that could not be found elsewhere. Together we made our dreams of obtaining our doctorate a reality! Many thanks also to Olga. Thank you for being my brightest and funniest friend and inspiring me to be one of the happiest people on the planet. I will miss your Italian dishes, and I am looking forward to hanging out with you in the Bay Area very soon. Many thanks to David, who offered me words of encouragement and numerous "shabash!" I still laugh when I reminisce about those squiggly extra-credit drawings, and I hope you find happiness and peace in your hometown, Seattle. Many thanks to Chloe, who has been there for me through thick and thin, always providing the most helpful advice when I have faced difficulties. I hope to meet up with you soon in Houston. Many thanks to Zhenhuan, my most ambitious friend with grit and a big, caring heart. I wish you the very best wherever you go and whatever you do; good luck to you, as always. Many thanks to Jianing, for your continuous support since college, and for sharing the purest caring and making me see what true friendship is. Many thanks to Kathy, my six-year-plus virtual friend in South Carolina, even though we did not make it to meet each other before your graduation, I wish you well as you move into your next chapter. Many thanks to Ekta, for your precious poem book gift when I needed it the most. Last but not least, to Tim, Kim, Steve, Molly, Tom, Shelly, Bill, Yvonne, Colleen, and Gary for those memorable Friday nights and holiday gatherings.

I give my most profound expression of gratitude to my family members, particularly for the sacrifices they made while I was pursuing academic excellence. I know I always have each of you to count on when times are rough. Mom and Dad, in spite of living in the opposite hemisphere, you have both walked alongside me and helped me regain my life balance during hardship. Without your constant encouragement, I could have never moved to another continent for six years to pursue a doctoral degree. Thank you for always believing in me, for cheering me on, for encouraging me to challenge myself, and for being my best friends all my life. My gratitude also goes to my beloved dogs – Laker's family, for their love, friendship, and company while growing up. Most especially, I truly thank Eric for sharing his valuable insights as a Ph.D. and equipping me with strategic planning for the last few months of graduate school. Meeting you is the best thing that has ever happened to me. Thank you for sticking by my side, being a continual source of laughter and support, and filling me with meaning and happiness every day. What we have learned from one another has strengthened our determination to live life to the fullest. I am so grateful and proud to call all of you my family. I love you all dearly, more than a simple thank you could ever express.

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ABSTRACT

Examining the Effects of Application-based Instruction on Social Communication and Interaction Skills in Chinese Children with Autism Spectrum Disorders

by

Simeng Li

Given the pervasiveness of emotional and behavioral deficits in individuals with autism spectrum disorders, there is a pressing need for effective interventions to address their difficulties in social communication and interactions. This study examines the effectiveness of a software application-based intervention (ABI) program that embeds several widely recognized evidence-based practices into an adaptive training system to directly address the challenges in core social skills faced by children with autism. This research expands the current body of studies by incorporating puppet role-play, conversation partner role-play activities with video modeling, Social Stories™, and question answering via the correction staircase approach in the program.

A sequential explanatory mixed methods design was adopted, and this divided the research into two phases. The statistical portion of the study compared the ABI group with the treatment as usual (TAU) group using a randomized controlled trial pretest-posttest design. Nineteen participants were examined in this phase. Four measures of functioning – *Social Responsiveness Scale-2*, *Gilliam Autism Rating Scale-3*, *Vineland Adaptive Behavior Scales-3*, and *Social Communication Questionnaire* – were utilized to compare the treatment approaches. Nonparametric tests (random permutation and Mann-Whitney *U*) were used to compare the treatments; the results demonstrated that participants who received ABI functioned at a significantly higher level at posttest than those who received TAU.

A multiple probe across participant design, replicated for four groups in phase two, was used to collect quantitative data across the baseline, intervention, maintenance, and generalization portions of the study. Participants significantly improved their social greeting, self-introduction, and play-initiation skills through the ABI program. The effectiveness of the intervention was evaluated based on student engagement and performance in discriminating, understanding, and expressing the target behaviors through their role-play and adaptive training sessions. Procedural reliability, interobserver agreement, and effectiveness data demonstrated that the procedures and the teachers were successful in imparting the target skills. The performance of nine out of 11 participants remained at very high accuracy levels in the maintenance probes, demonstrating stable or upward trends in target behaviors compared to the intervention sessions. The generalization probes showed that most of the students were able to generalize the skills learned to new conversation partners, and the participants performed better when interacting with new adults than with novel peers.

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Chapter 1. Introduction

Overview

A hallmark symptom of autism spectrum disorders (ASD) is impairment in the development of social communication and interaction (hereafter referred to as, “SC/I”) skills (American Psychiatric Association, 2013; Kanner, 1943).[1] Manifestations of ASD include deficits in social-emotional reciprocity, as well as in creating and maintaining social relationships (Anderson et al., 2016; Barry et al., 2003); these symptoms appear in early childhood, and they collectively limit and hinder daily functioning. As autism diagnosis methods become increasingly more refined, children can be diagnosed as having congenital and/or developmental conditions starting as early as 18 months of age (Clark et al., 2015; Wang & Singer, 2016). This has created an urgent demand for effective early intervention strategies, which seek to ensure that young children can receive individualized programs that meet their developmental needs and goals. Given the pervasive and persistent nature of social deficits, early intervention is imperative; assessing and developing a plan for a child’s needs must be addressed at the beginning of a child’s education (Bellini et al., 2007; Boyd et al., 2015; Fletcher-Watson et al., 2016; Kroeger et al., 2007).

Young children with ASD demonstrate a restricted range of SC/I skills, typically with limited abilities in: (1) initiating and responding to social greetings, (2) initiating and sustaining conversations, and (3) extending invitations and participating in games with peers

[1] According to the National Autism Center (2009), ASD is defined to include autistic disorder, Asperger’s syndrome, and pervasive developmental disorder – not otherwise specified (PDD-NOS). Children with Rett’s disorder, childhood disintegrative disorder, and who had been identified as “at risk” for an ASD but with no formal diagnosis are not included in the current study.

(Li & Wang, 2018; McConnell, 2002; Sansosti & Powell-Smith, 2008). Moreover, they experience delayed acquisition in the use of nonverbal behavior cues – such as eye contact, facial expressions, gestures, and bodily postures – to regulate age-appropriate social interaction (Barry et al., 2003; Wolfberg, 2003). Such impairments manifest concomitantly with difficulties navigating common social situations, expressing oneself, and forming friendships (Simpson et al., 2004). Difficulties in initiating and responding to social greetings, making requests, and forming friendships may impact social opportunities and development. In the long term, this may cause a variety of undesirable outcomes such as stereotyping, aggression, masochism, property destruction, and social withdrawal (Bellini et al., 2007; Flores et al., 2012). Lack of social skills during adolescence may also decrease the likelihood of employment and ability to live independently later in life (Reed et al., 2011).

Fortunately, autism is a syndrome of behavioral deficits that can be changed through structured treatments – most notably applied behavioral analysis (ABA) and positive reinforcement – that generate clinically meaningful behavioral change (Anderson et al., 2016; Arick et al., 2004; Reichow & Volkmar, 2010). Since the advent of the behavioral approach to treat ASD-related social deficits in the 1960s, researchers have documented modest progress in intervention approaches that have successfully facilitated behavioral improvements; these include but are not limited to discrete trial training, pivotal response treatment, picture exchange communication system, adult prompting, environmental modifications, naturalistic techniques, social skill groups, and peer-mediated instruction (Bellini et al., 2007; Davis et al., 2018; Odom et al., 2003; Simpson, 2005). Although each of these evidence-based strategies varies in their implementation procedures and documented limitations, the cumulative research findings provide significant guidance in the literature for addressing SC/I difficulties.

While the aforementioned techniques continue to find applications in clinics and classrooms, technology-based interventions (hereafter referred to as, "TBIs") have increasingly gained attention over the past decade (Allen et al., 2016; Burton et al., 2013; Chai et al., 2014; Fletcher-Watson et al., 2016; Flores et al., 2012; Macpherson et al., 2015; Li & Wang, 2018; National Autism Center, 2009; Sansosti & Powell-Smith, 2008). Researchers have started to gravitate toward a "more obstructive, less stigmatizing" teaching format, and technological (e.g., computer-assisted) instruction methods are likely to play an essential role in the coming years (Clark et al., 2015). Furthermore, experimental evidence has demonstrated that young children with ASD exhibit higher levels of enthusiasm for technology products than for standard toys; they also show increased learning, motivation, attention, response rate, and problem-solving abilities when a computer is used in place of human instruction (Andersen et al., 2016; Boutot & Myles, 2009; Kagohara et al., 2013; MacDuff et al., 2007; Sigafoos et al., 2013; Tetreault & Lerman, 2010; Wert & Neisworth, 2003; Whalen et al., 2010). A number of studies have demonstrated that students with ASD respond well to interventions involving videos, images, and computers (Boutot & Myles, 2009; Sansosti & Powell-Smith, 2008; Whalen et al., 2010). Trainings based on video modeling, Social Stories™, tactile prompts, audio scripts, and virtual-reality technologies have been successfully used to teach complex social skills such as pretending (D'Ateno et al., 2003; MacDonald et al., 2005; Macpherson et al., 2015; Murdock et al., 2013), recognizing emotions (Nikopoulos, 2003; Zhang et al., 2019), and making sequential requests (Sigafoos et al., 2013; Waddington et al., 2014; King et al., 2014).

Recent technological advancements have led to a shift from traditional computer-based devices to newer touchscreen devices such as smartphones, iPads, and tablets. Since the launch of the first iPad in 2010, many tablet applications have been listed for potential use in the field of developmental disability education. Studies using such applications in interventions for children with ASD have also started to emerge (Boyd et al., 2015; Burton et al., 2013; Chai et al., 2014; Clark et al., 2015; Fletcher-Watson et al., 2016; Flores et al., 2012; Kagohara et al., 2013; King et al., 2014; Lowman & Dressler, 2016).

Statement of the Problem

As students with ASD rarely initiate conversation or engage in social activities on their own accord, a one-on-one learning environment is often utilized to facilitate learning. Even when individual instruction is provided, many students are still unable to benefit due to non-cooperation, lack of motivation, behavioral difficulties, or stereotypical behavioral obsessions (Bellini et al., 2007; Koegel et al., 2014a; McConnell, 2002; Torrado et al., 2017). Application-based interventions (hereafter referred to as, "ABIs"), which are increasingly used in special education, have potential as a means of enabling new teaching methods and promoting learning in students with ASD, for whom conventional approaches may not always be appropriate, accessible, or effective.

Kagohara et al. (2013) summarized two major ways in which tablet devices/applications have been used in ASD interventions – either (1) as a medium to present videos, images, and prompts to students, or (2) as a means of teaching students to "access [the students'] preferred stimuli" (e.g., videos) – which is unfortunately contradictory with the original intention of using technological devices as interventions in themselves. The scholars also identified a gap in the literature – that there are currently no application-based instructional studies that address SC/I skills – and noted the need to design educational applications that truly incorporate the abovementioned devices as a component of the interventions, rather than simply as passive screens for delivering visual stimuli. It is, therefore, worthwhile to contemplate the design of a curriculum structure for a tablet application that can generate the best learning outcomes.

While some practices support the application of this new type of intervention, the debate regarding the relative efficacy of ABIs compared to conventional teaching formats continues. There is still a dearth of evidence-based trials and studies that rigorously assess the efficacy of technologies relative to the traditional approaches (National Autism Center 2009; Ploog et al., 2013). Although there is a rich literature on the adoption of technology to aid individuals with autism, the use of ABIs for teaching social skills to young children with ASD is a relatively new field with a multitude of possibilities. It is necessary to identify treatments in order to determine how such technology can be applied to benefit teaching and learning, as well as to explore how to optimize technology-based instruction and incorporate an intervention methodology that aligns with today's classroom instruction.

Three noticeable research trends have emerged from the literature:

Trend I indicates a need to design and develop ABIs that incorporate multiple evidence-based intervention practices into one intervention system, in order to possibly benefit a wider range of children with varying levels of ASD-related impairments.

In light of the growing number of applications for individuals with special needs, it is increasingly essential for practitioners to design effective educational products. Nevertheless, most technology-based instructional software available in the market has not undergone formative or summative evaluation of its effectiveness and clinical validation

(Boone & Higgins, 2007; Kagohara et al., 2013). As a core value of applied behavior analysts, evidence-based practice (EBP) refers to an intervention strategy that has been scientifically verified as effective for modifying a specific behavior of interest for particular participants under controlled conditions (Baer et al., 1968; Ledford & Gast, 2018). For practitioners, it is essential to be able to identify and outline the EBP treatments that are typically included in the development of the application, so as to validate the potential efficacy of the ABI.

Even if an application meets the EBP criterion for release, it may still be ineffective for certain students due to the heterogeneity of this disorder – various subgroups within the spectrum of ASD have different developmental profiles. Moreover, autism commonly occurs in association with other developmental disabilities – including fine/gross motor, receptive language, and cognitive impairments – and the severity of SC/I impairments and ritualistic behaviors varies from mild to severe. Therefore, it is unlikely that one EBP intervention approach would benefit all the subgroups equally (Quill, 2000). In order to develop a range of intervention strategies that provide the full range of functionality required by children with ASD, it is necessary to incorporate a variety of empirically validated teaching approaches into one intervention package.

Trend II suggests a need to conduct more rigorous, evidence-based studies on the effectiveness of ABIs and, further, to compare their learning outcomes with the conventional teaching methods that are currently used in school settings.

Once an application has been designed and developed, it is necessary to examine if there is a hypothesized functional relation of SC/I acquisition to an ABI that incorporates a variety of treatment approaches (Kagohara et al., 2013). Subsequently, there is a need to investigate whether an ABI demonstrates any significant learning benefits compared to the methods currently used by special education teachers. Rigorous evidenced-based investigations should be considered to ensure a systematic and scientific comparison of the students' learning outcomes from ABIs versus traditional teaching methods.

Ploog et al. (2013) suggested future studies that incorporate controlled conditions and randomized assignment of participant groups to compare the effects of different treatment approaches. After evaluating the effectiveness and applicability of a technology-based instruction package, it would be beneficial to construct a randomized controlled design in which student participants are assigned to either an application-based treatment group or a control condition. Moreover, evaluations of the effectiveness of an intervention can also be strengthened by a comparison with the treatment as usual (TAU) group as the control condition, which helps to identify a relative treatment effect (Löfholm et al., 2013).

Trend III identifies a need to explore the attitude of professionals who have experience with ABIs and to examine ways of incorporating technology-based instruction into the traditional classroom.

Teachers' attitudes toward ABIs are likely to be related to the degree to which students with ASD are encouraged and supported in using such technologies for behavior acquisition and social skill development (Clark et al., 2015). Even with an ABI that has been proven to result in faster and more robust learning, students' actual learning success continues to depend on their teachers' guidance and assistance. Therefore, qualitative data, in the form of instructor interviews and social validity questionnaires, could be collected to obtain detailed knowledge regarding training content, intervention experience, and teachers' attitudes in the current study.

Moreover, it is imperative to further investigate the potential of ABIs as a tool for SC/I instruction and to examine ways of incorporating them into traditional teaching methods. To gain further insights in this regard, research should first identify and examine key differences between conventional and technology-based instruction, before investigating the utility of tablet technology as a viable teaching component in classrooms. It would also be of practical importance to determine when to use technology-based instruction, how to assist teachers in implementing application-based methods, and how to incorporate the new approaches into the existing curriculum.

Research Questions

Qunatiandi (Li & Wang, 2018; Lin & Wang, 2018; Zhang et al., 2019), is an Android or iOS ABI program and multidisciplinary framework that directly addresses the core challenges faced by children with ASD. It incorporates the most widely recognized EBPs endorsed by the National Professional Development Center on Autism Spectrum Disorder (NPDC). Examples of the focused intervention practices[2] included in the program are video modeling, Social Stories™, discrete trial training, pivotal response treatment, direct instruction, and positive behavior support. The program also refers to certain comprehensive treatment models, such as social-communication emotional regulation and transactional support (SCERTS), strategies for teaching based on autism research (STAR), and treatment and education of autistic and related communication handicapped children

[2] A focused intervention practice is a procedure or a set of procedures that designed to address one specific learner outcome through behavioral, developmental, and/or educational approaches (Hall, 2017; Odom et al., 2010). Treatments with independent variables purely based on medications, alternative medicine (e.g., hyperbaric oxygen therapy), and/or nutritional diets are not included in the current study.

(TEACCH). This ABI program was recently designed and developed by the Pacific Rim Research Center affiliated with the University of California, Santa Barbara. The primary investigator of the study participated in the design and realization phases of the program.

To address the three lines of research described in the problem statement, four research questions are investigated in the study.

Question 1. Is there a treatment effect from using the ABI under study, which incorporates several widely recognized EBPs embedded into an adaptive training system to teach SC/I skills to children with ASD? How much of a treatment effect does the ABI have, compared to the TAU condition?

Question 2. Will the ABI program be effective in increasing target social skills for each participant in the cohorts?

Question 3. The ultimate goal of social skills training is to teach students to successfully interact with different people across situations. If the ABI cohorts are able to acquire the target behaviors, will they maintain and generalize their skills across time-points, settings, stimuli, responses, and individuals?

Question 4. What are the teachers' perceptions (such as intervention practicality and cost effectiveness) of the ABI with regard to their students' social skills acquisition?

Significance of the Study

Research design in technology-based interventions. Given the increasing popularity of technology-based teaching programs in special education classrooms, there is a crucial debate regarding whether TBIs are demonstrably more effective than traditional classroom instruction. Unfortunately, empirical investigations on this topic are very limited (Ploog et al., 2013; White et al., 2006). Publications regarding TBIs are predominantly descriptive and exploratory (National Autism Center, 2009; Wainer & Ingersoll, 2011); most studies lack the scientific and methodological rigor to convincingly demonstrate the efficacy of TBIs and to compare them to traditional teaching methods. Thus, there is a pressing need for more studies that incorporate systematic group designs to ensure a proper comparison of student learning outcomes between application-based instructions and traditional teaching methods (Clark et al., 2014; Fletcher-Wastson et al., 2016).

To shed empirical light on this topic, this study employs a single-subject design (SSD) across participants in multiple small cohorts, based on a randomized group assignment condition. This design has been chosen in order to avoid the drawbacks and limitations of an exclusive randomized controlled trial design – such as the loss of variability among individual subjects through the averaging of results, as well as limited descriptions of individual behavior and intervention conditions (Reilly et al., 2015). The approach also involves a research hypothesis with predicted expected relationships between independent and dependent variables, as well as the use of nonparametric tests to compare the treatment and waitlist (control) groups.

Importance for the special education field in China. Researchers have risen to the call to embrace cultural adaptation in providing evidence-based interventions to an increasingly heterogeneous global special education population. Wang and Lam (2017) noted the shortfall in the cultural responsiveness of interventions in the field and provided guidelines for developing more culturally adapted EBPs that take languages and cultural values into account. In this way, an intervention program would be more compatible with the specific cultural and ethnic patterns of the individuals, and therefore better support practitioners in implementing effective treatments to improve overall learning outcomes.

The field of special education in China has seen significant improvements over the past decades. However, there are still substantial challenges regarding the shortage of special education specialists and systematic ASD teacher training programs (Zhang et al., 2019). While there are ongoing appeals to establish and expand additional special education major programs in Chinese higher education institutions, the number of prospective teachers graduating from these programs has barely been able to meet the growing education demands (Pang & Richey, 2006; Kritzer, 2012). Due to high student-to-teacher ratios, special education teachers frequently face heavy workloads and intense working hours (Pang, 2010; Yu et al., 2011). Another recurring issue in the literature is the professional incompetence of the current Chinese special education teachers (Deng & Zhu, 2016; Pang & Richey, 2006). Researchers have noted that these teachers often report having little or no experience conducting systematic social interventions for students with ASD (Chen, 1996).

By providing systematic and professional training support to Chinese special education practitioners, the current study offers an ABI program as a platform that will enable them to conduct professional teaching activities targeted at a large number of students with special needs. For teachers, the ABI program is significantly less labor-intensive compared to traditional methods of instruction. Problems arising from high student-to-teacher ratios that prevent children from receiving effective instruction are also alleviated by ABIs, as constant teacher involvement is not required. With content that incorporates a number of EBPs, the application also offers training and learning support for teachers to familiarize themselves with effective special education instructional methods. Hence, all the aforementioned features of the ABI program in this study can effectively address the key challenges of China's special education field.

Chapter 2. Literature Review

No single treatment is likely to meet the needs of every individual with ASD. In order to design an intervention program that can benefit a wide range of children with varying levels of autism-related impairments, this chapter first presents an overview of the comprehensive reviews or projects in the ASD intervention literature that have aimed to identify evidence-based and emerging practices. Second, it examines assistive technology as a key intervention tool and argues for establishing technology-based treatment programs in special education as a necessary approach for advancing implementation behavioral science. Subsequently, the rest of the review focuses on outlining EBPs that were selected in this study to be included in the *Qunatiandi* program to validate its potential efficacy as an ABI.

Evidence-based Interventions for Individuals with ASD

The identification of EBPs has substantial implications for ASD intervention, yet the process of examining a practice as evidence-based is often a complex endeavor. Part of the complexity comes from the fact that there has been no universally agreed-upon standard in the field (Odom et al., 2010) until now.

The emergence of EBP identification is rooted in the science-based practice movement in the medical field (Cochrane, 1972), which was developed in response to a widespread phenomenon of medical doctors not employing scientifically verified treatments with their patients. Following this, the Cochrane Collaboration started to host reviews for examining studies of scientifically validated medical and health care treatments to promote evidence-informed health decision-making. The EBP movement later spread to the field of social science; it has affected scholars and applied researchers concerned with individuals with special needs. Before the mid-2000s, the identification of empirically supported treatments was mainly accomplished through narrative reviews (Chambless et al., 1998; Chambless & Hollon, 1998; Kratochwill & Shernoff, 2003; Odom et al., 2004). Although these reviews made preliminary contributions to the definition of EBP standards, they often failed to include a stringent review process containing the following: clearly defined literature search information, inclusion and exclusion criteria, and a summary of the research evidence, organized into sets of practices (Wong et al., 2015).

It is worth noting that some traditional systematic review processes only include studies that have employed a randomized controlled trial (RCT) and/or a quasi-experimental design as acceptable experimental design formats. Even though this type of review has contributed to identifying practices in the general field of education, little evidence has been provided regarding treatment for children with ASD. A noteworthy example is the What Works Clearinghouse (WWC) project by the Institute of Education Sciences (IES). In this review project, WWC excluded single-subject design (SSD) studies – a crucial experimental research methodology highly recognized as a valid approach (Bailey & Burch, 2002; Ledford & Gast, 2018) in the behavioral sciences – which inevitability greatly weakened their academic impact in the area of ASD intervention, where a vital body of literature has been conducted by SSDs. Caution should be taken when considering systematic review projects that have not included SSDs as evidence of efficacy (NCAEP: the national clearinghouse on autism evidence and practice, 2019; Wong et al., 2015).

Many research organizations have incorporated SSD literature in their reviews and established standards for evidence from studies using this methodology; these include – but are not limited to – Division 12 of the American Psychological Association (APA; Lonigan et al., 1998), Division 16 of APA (Kratochwill & Stoiber, 2002), Division for early childhood of the Council of Exceptional Children (CEC; Smith et al., 2002), and Division of research of the CEC (Horner et al., 2005). Odom et al. (2003) examined 37 studies to identify practices that are supported by the SSD literature for young children with ASD. The practices used in these studies were classified by the authors into three groups.[3] Among them, established practices are adult-directed teaching and differential reinforcement, both rooted in the traditional behavioral treatment approaches that can be traced back to the 1960s. Likewise, in Simpson's (2005) review, applied behavior analysis (ABA), discrete trial training, and pivotal response treatment are deemed to meet the standard of established practices. The report also suggests that Social Stories™ and assistive technology are promising practices.

Two more recent comprehensive review series of educational and behavioral treatment literature on EBPs were parallelly conducted by the National Autism Center (NAC, 2009; 2015) and the National Professional Development Center on Autism Spectrum Disorder (NPDC; Odom et al., 2010; Wong et al., 2015). Both works utilized systematic and rigorous criteria for evaluating interventions that are popularly used with children with ASD. The National Standards Project (NSP) developed the scientific merit rating scale (SMRS) as a means to evaluate the level of scientific merit in each selected study based on the quality of: (1) the research design, (2) measurement of the dependent variable, (3) measurement of the independent variable, (4) participant ascertainment, and (5) generalization and

[3] As different terminologies have been used across professionals to categorize practices based on the extent to which they are supported by empirical studies, three terms are adopted in this study to summarize the evidence regarding the effectiveness of a treatment according to the CEC standard categories (2014). The three terms are: (1) established practices, (2) promising practices, and (3) probably efficacious practices.

maintenance effects. On the basis of the SMRS criteria, NSP-2 (version 2) identified 14 established practices, 18 promising ones, and 13 probably efficacious practices (NAC, 2015). The NSP report has identified comprehensive behavioral treatment for young children (i.e., ABA), video modeling, pivotal response treatment, social skill package, and story-based intervention as falling into the established level of EBPs that are effective for SC/I training.

The National Professional Development Center on Autism Spectrum Disorder undertook another literature review project for identifying EBPs for children with ASD; in their review, an EBP qualified as evidence-based if it was supported by: (1) at least two high-quality RCT or quasi-experimental studies conducted by two different research groups, (2) at least five high-quality SSD studies conducted by three different research groups and involving a total of 20 participants across these studies, or (3) a combination of at least one high-quality RCT or quasi-experimental design and three high-quality SSD studies that were conducted by more than one research group (Wong et al., 2015). The results culminated in a list of 27 established EBPs, among which seven directly facilitate SC/I skills; these are: discrete trial training, pivotal response treatment, prompting, reinforcement, task analysis, video modeling, and naturalistic intervention.

The follow-up project by NPDC, the national clearinghouse for autism evidence and practice (NCAEP), is currently updating the review list and adding new ASD intervention literature published between 2012 and 2017. Moreover, the autism-focused intervention resources and modules (AFIRM) project has translated EBPs identified by Wong et al. (2015) into online learning modules. The pattern of AFIRM using modules reflects special education practitioners' strong interest in traditional ABA techniques, such as antecedent-based intervention, reinforcement, prompting, and functional behavior assessment (Sam et al., 2019).

Assistive Technology and Application-based Intervention

Technology-aided instruction and intervention (TAII), one of the 27 EBPs suggested by Wong et al. (2015), is considered to be an essential tool in supporting the acquisition of an educational goal in special education. Odom et al. (2004) defined *technology* in this context as “any electronic item, equipment, application or virtual network that is used intentionally to increase, maintain, and/or improve daily living, work, productivity, recreation, and leisure capability of individuals with ASD.” The enthusiasm for applying TAII has led to an unbridled adoption of devices with little regard for the efficacy or potential collateral effects. Therefore, this section examines the literature underscoring the use of assistive technologies (ATs) in interventions and instruction for children with ASD.

According to the Individuals with Disabilities Education Act (IDEA)’s definition, an AT device is “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability.” In the era of emergent modern technologies, the paradigm has shifted toward an increasing utilization of ATs – which have been shown to enhance skills relevant to attention span, in-seat behavior, and fine motor activities – in autism intervention practices. Some forms of those devices are designed for life-long use, including augmentative and alternative communication (AAC) devices, which can facilitate communication. Others, such as a pictorial schedule of activities to be completed during the day, including technological supplements and computer-based schedules delivered through Microsoft PowerPoint, are introduced as temporary instructional aides to modify behavioral functioning (Goldsmith & LeBlanc, 2004; Kimball et al., 2004; Rehfeldt et al., 2004). Individuals with ASD can now receive computerized instruction concerning how to decode facial expressions, practice turn-taking in the context of social interactions, and establish eye contact. Technologies are also used to help individuals with ASD improve organizational skills and keep pace with the classroom curriculum (Charlop-Christy et al., 2000; Goodwin, 2008; Ritterfeld & Weber, 2006).

High-tech AT for communication includes speech generating devices (SGDs), computer software, and tablet computer applications. An increasing body of studies on the use of SGDs to assist individuals with developmental disabilities has emerged. An SGD is a portable device that contains more than one panel or switch that, when pressed, activates pre-recorded digitized or synthesized speech output (Flores et al., 2012). Pictures and symbols on the SGD express the message or function to be performed if a specific switch or button is activated. Mechling (2011) has described the SGD as a highly portable, flexible, and easy-to-access AT device that can be used in most situations. After installing the software applications, one can use any handheld device – such as an iPad – as a speech generating tool. Kagohara et al. (2013) have suggested that SGDs can help with gaining peer acceptance and reduce AT stigmatization among individuals with disabilities, since smartphones and tablets are commonly used by most students in school settings.

Studies have demonstrated the effectiveness of SGDs in improving spoken language acquisition and communication. Desai et al. (2014) examined the effectiveness of the iPad with an AAC application, *GoTalk Now*, in teaching communication skills to a 13-year-old adolescent with cerebral palsy and autism in a school setting. Their results demonstrated an overall increase in both communication and school-related functioning skills, as well as a

13% increase in the participant's communicative behavior after the introduction of the iPad. Furthermore, Xin and Leonard (2015) conducted a multiple baseline design study to examine the effectiveness of the iPad-based SGD, *Sonoflex*, in teaching three children with autism in both classroom and recess settings. All participants were unable to present functional speech and exhibited no communicative attempts during the baseline observation. After six weeks of intervention with a least-to-most prompting hierarchy by a teacher and the introduction of the iPad as a communicative support SGD, all three participants began initiating requests, responding to questions, and making social comments in the classroom and during recess.

Proloque2Go is an application specifically developed to assist children with difficulties in speaking. It includes a large display touchscreen with big icons, offers a voice output element, and is widely supported by empirical studies in its effectiveness for teaching children with special needs to make general requests. For example, in King et al.'s (2014) study, the effectiveness of *Proloque2Go* was examined in teaching request skills to three children with ASD, with the percentage of participants' independent requests as the dependent variables. The results suggested that the participants successfully acquired the skills to ask for preferred items via the iPad, and their vocal requests increased during the training phases compared to in baseline probes. Similarly, Waddington et al. (2014) conducted a multiple baseline across participants study to examine the effectiveness of the application in teaching three children with ASD to make a general request in a clinical setting. The dependent variables were the percentage of correct responses for toy requests and "thank you" responses. All participants demonstrated improvements in performing the sequence with an unfamiliar partner during the follow-up sessions.

In addition, iPad-based SGDs can also be used to improve children's non-verbal request-making skills during toy play. Sigafoos et al. (2013) conducted a multiple baseline across participants study to examine the effectiveness of iPad-based SGDs in teaching two nonverbal children with ASD to request the continuation of toy play. Instruction mainly focused on teaching the participants to select a toy play symbol from an iPad screen when their play process was interrupted, and the intervention procedures were behavior chain interrupting, time delay, graduated guidance, and differential reinforcement. The findings suggested that both participants learned to use the iPad to make requests, and maintained the skill without prompting.

Evidence for computer-based delivery of interventions for individuals with special needs has also been improving in this line of research. The difference between computers and AAC devices is that computers do not travel with individuals, and they function as a communication modality (Grynszpan et al., 2008; Lancioni & Singh, 2014). Computers are used as modes of skill instruction to improve a child's communication but may not always accompany the individual. Ramdoss et al. (2011) has suggested that computer-assisted instruction (CAI) is a preferred medium for instruction delivery, especially for individuals with developmental disabilities, because computers typically work in a consistent and predictable way; therefore, they satisfy the preferences of individuals with ASD, who prefer routines and predictable expectations. The authors have also suggested that computers can effectively implement complex reinforcement schedules, provide and fade prompts, collect data based on responses, and give feedback to the interventionist. For instance, Hetzroni and Tannous (2004) examined the use of a CAI software program developed based on daily life and activities to improve communication skills. The findings suggested that all five participants reduced irrelevant speaking behaviors after the intervention, and most exhibited an increase in the number of communicative intentions and relevant speech. The study also indicated that children with ASD are able to transfer the newly acquired skills to natural settings for play activities.

Application-based interventions have increasingly gained attention over the past decade (Allen et al., 2016; Burton et al., 2013; Chai et al., 2014; Fletcher-Watson et al., 2016; Flores et al., 2012; Macpherson et al., 2015; Li & Wang, 2018; National Autism Center, 2009; Sansosti & Powell-Smith, 2008). In light of the ever-growing number of ABIs, it is important for practitioners to be directed toward the most effective software (Allen et al., 2016). Boyd et al. (2015) have proposed five evaluation criteria that should be considered when identifying applications for students with ASD: (1) they should be customizable to better fit the student's individual needs and preferences; (2) they should take children's fine motor abilities into consideration to ensure that they can operate the application independently or with little help from adults, so as to compensate for their communication deficits; (3) they should minimize extraneous resources and time needed to teach students to operate the application; (4) they should incorporate research-based practices that have been validated concerning effectiveness through quality studies; and (5) the cost of using an iPad device and software application needs to be considered, with the price of the application justified based on the previous criteria and product value.

Recent technological advancements have led to a shift from traditional computer-based devices to newer touchscreen devices such as smartphones, iPads, and tablets. Since the launch of the first iPad in 2010, many tablet applications have been listed for potential use in the field of developmental disability education. Studies using such applications in interventions for children with ASD have also started to emerge (Boyd et al., 2015; Burton et al., 2013; Chai et al., 2014; Clark et al., 2015; Fletcher-Watson et al., 2016; Flores et al., 2012; King et al., 2014; Lowman & Dressler, 2016). A growing body of research suggests that children with ASD can acquire social, communication, emotional, and behavioral skills with highly structured training and intervention. Prior research in the area indicates that application-based technologies may be a critical tool in improving SC/I, face recognition, adaptive behaviors, and vocational skills (Kagohara et al., 2013). An increasing number of education-oriented applications are becoming available for use in conjunction with iPads. Kasari et al. (2014) have reported that minimally verbal students with ASD can make significant and rapid gains in SC/I skills, which indicates that application-based technology plays a role in enhancing the effectiveness of the treatment. Despite the literature implying that children with ASD were able to learn appropriate SC/I skills through ABI programs, few studies have mentioned the application of those social skills to other programs. No studies have given explicit details on how to help children generalize their skills to other settings. Insufficient research exists to support the learning benefits of ABIs for SC/I skills, and decisions regarding the types of interventions to implement have become confusing and challenging for teachers attempting to meet the diverse range of students' learning needs. More studies should focus specifically on investigating ABIs with respect to social and communication improvement for children with ASD.

Applied Behavior Analysis

Applied behavior analysis (ABA) is rooted in the philosophy of modern behaviorism introduced by B.F. Skinner; its techniques are the most commonly employed intervention strategies in the special education field. Examples of ABA techniques include – but are not limited to – prompting, reinforcement, imitation, modeling, and self-monitoring. Applied behavior analysis is often employed to facilitate other forms of interventions such as video modeling and peer training (Reichow & Volkmar, 2010). Although different definitions exist, the core tenet of ABA across each interpretation is the process of systematically conducting interventions based on behavior science principles to not only improve socially significant behaviors of individuals with special needs to a meaningful degree, but also to demonstrate that the treatment approaches used have a functional relationship between a given behavioral change and an intervention (Alberto & Troutman, 2013; Baer et al., 1968).

When incorporating ABA strategies, initial assessments are particularly important, as these are predominantly based on understanding what motivations underlie the presence or absence of certain behaviors. By identifying the motivational factors of a behavior, social-skills instruction founded on ABA principles often affects behaviors by changing antecedents or consequences of the behavior. An assessment of social skills typically precedes the intervention in order to identify a specific skill impairment, as well as whether students are struggling with deficits in SC/I acquisition or performance (Gresham, 1997).

Behavior scientists who practice ABA greatly value the importance of direct observation, a clear definition of the target behavior, and systematic data recording. According to Ledford and Gast (2018), experimental control that demonstrates causal relationships between dependent and independent variables in the SSD design predominantly relies on the researchers to determine that the target behaviors to be measured are similar while still being functionally independent of one another. As an example, teaching a child to initiate a conversation versus extend a play invitation to peers are two behaviors that are considered to be functionally independent. Functional independence helps to guard against threats to internal validity, such as behavioral covariation that reflects any change in the different tiers brought about by the introduction of the intervention. Moreover, the participants and conditions utilized in the design should be functionally similar to one another, so that an intervention effect is likely to be replicated. Once these two factors are satisfied, experimental control is demonstrated through the establishment of a stable baseline, followed by at least three demonstrations of an effect across participants (Ledford & Gast 2018). Experimental control in multiple probe designs can be strengthened by clearly defined intervention conditions, establishment of the hypothesis before the start of the baseline, formative assessment, and immediate therapeutic changes in behavior when the intervention conditions begins.

In conclusion, ABA-based treatments, which include general ABA approaches and other ramifications (e.g., discrete trial training), offer strong empirical evidence to support the effectiveness of intervention programs across all the aforementioned review projects. In addition, naturalistic behavioral interventions that stem from ABA (e.g., pivotal response treatment) have also been found to provide strong evidence as established EBPs. While a variety of future research reviews may be needed to facilitate further identification of EBPs for children with ASD, a close reading of the literature reviewed in this section suggests some promising strategies that can be combined into the ABI program to meet instructional best practices: video modeling, Social Stories™ , ABA, direct instruction, and pivotal response treatment.

Pivotal Response Treatment

Based on the traditional cue-response-consequence paradigm, pivotal response treatment (PRT) is a behavioral strategy developed to address pivotal characteristics and behaviors in assisting skill acquisition and maintenance for children with ASD (Alberto & Troutman, 2013; Koegel et al., 1988). Initially referred to as the natural language paradigm, PRT is a naturalistic behavioral technique in which instructional opportunities occur in natural settings, initiated by the child's preferences, and rewarded by natural reinforcers (Corsello, 2005). Pivotal response treatment is a variation of discrete trial training (DTT) that addresses low motivation and responsivity to multiple cues through massed trials incorporated into a functional educational context. It is based on ABA principles, and it adopts a naturalistic approach that targets pivotal areas to development across communication, interaction, and other social behaviors. The core pivotal areas include but are not limited to motivation, responsivity to multiple cues, and the child's self-initiation and self-management (Lei & Ventola, 2017).

Pivotal response treatment has six motivational procedures (Koegel, 1988) that have been identified through evidence-based studies to enhance children's motivation: (1) instructional opportunities are clearly defined and appropriate to a specific task; (2) maintenance tasks are designed to incorporate new tasks; (3) tasks are selected by the student; (4) contingent reinforcement is given upon completion of a target behavior; (5) the reinforcer has a direct relationship with the desired behavior; and (6) any goal-directed attempts at the question and instruction are reinforced.

There has been an extensive body of research documenting the effectiveness of PRT in the literature, with positive findings replicated under a wide range of settings and social skills. Compared to DTT, the PRT model is more capable of facilitating self-initiated social responses, expressive language, symbolic play skills, maintenance, collateral language acquisition, and generalization gains (Arick et al., 2004; Koegel, 1988; Laski et al., 1988).

Koegel et al. (1992) demonstrated that student participants in the PRT condition have greater improvement in responding and fewer restricted or disruptive behaviors. Vismara and Lyons (2007) observed an immediate increase in joint attention initiations when employing the motivational techniques of PRT for young children with autism. Similarly, Jones et al. (2006) conducted three related studies and demonstrated the effectiveness of DTT and PRT in teaching joint attention to five children with ASD.

In addition to the above-mentioned findings in children with regard to social initiation and turn-taking, researchers have identified evidence in language and communication improvement using the PRT diagram. Laski et al. (1988) trained the parents of four children with ASD to enhance their speech ability using the natural language paradigm, and all the children displayed an increase in the frequency of verbalization across novel settings. Gillett and LeBlanc (2007) trained three parents of children with ASD to implement the natural language paradigm and not only found that the parents were able to learn to implement the procedures with high fidelity, but also observed an increase in the overall rate of vocalizations among all the student participants. Koegel et al. (2014c) identified the efficacy of employing the motivational procedures of PRT to increase social question-asking skills for three children with ASD. The participants initiated a greater number of targeted questions following the intervention and exhibited an increase in the initiation of non-targeted questions during social interaction in new settings.

Several studies have indicated the efficacy of PRT on pretend-play skills. Stahmer (1995) employed PRT to teach seven children with ASD to engage in symbolic play behaviors. All the student participants learned to perform complex and creative symbolic play actions, as well as to generalize their play across toys, settings, and play partners in most cases. Thorp et al. (1995) assessed the effectiveness of teaching sociodramatic play that employs PRT on three children with autism. Positive changes were observed in play, language, and social skills, and these changes extended across toys and settings. Lydon et al. (2011) also reported positive findings by directly comparing the effectiveness of PRT and video modeling in the acquisition and generalization of play verbalizations and actions, with evidence of greater increases as a result of PRT.

Pivotal response treatment is highly trainable; teachers, parents, and peers – whoever masters the principles and techniques of PRT – could learn to facilitate children with ASD in acquiring functional and social skills in a systematic and efficient manner. Bryson et al. (2007) documented the positive outcomes with large-scale community implementation for demonstrating PRT's effectiveness in facilitating functional verbal utterance for children with ASD. Minjarez et al. (2011) demonstrated that the parents of children with ASD can successfully learn to implement PRT with fidelity and thereby enhance their children's social communication skills. Similarly, Coolican et al. (2010) suggested that parent training in PRT can enhance the SC/I skills of children with ASD; in their study, the child participant's functional utterances increased following the training. As for examples of peer-mediated PRT implementation, Kuhn et al. (2008) evaluated the ability of peers to implement PRT with two children with ASD to increase their social interactions. Increases in opportunities to respond were observed. Similarly, Harper et al. (2008) used a multiple baseline design to investigate the effectiveness of incorporating the motivational techniques of PRT through peer-mediated practice for improving SC/I in children with autism during recess activities; they demonstrated an increase in social initiations and turn-taking.

In summary, PRT has been shown in the literature to elicit therapeutic gains in training that facilitates the spontaneous use of self-initiated social responses, expressive language, symbolic play skills, maintenance, collateral language acquisition, and generalization of newly acquired social behaviors. As the motivational techniques of PRT have been effective in addressing core symptoms of ASD as part of an intervention package (Koegel et al., 2010), in the *Qunatiandi* program, PRT is employed to stress the facilitation of children's motivation during treatment sessions, through the use of child-chosen activities that are intrinsically motivating for each participant. The structure involves the presentation of repeated behavioral trials that consists of antecedent, behavior, and consequence, while meanwhile increasing the frequency of exposure to response-reinforcement contingency to increase students' motivation throughout the sessions.

Video Modeling

The literature has long suggested that observational learning from videos could function as a positive influence on the social behavior functioning of individuals with special needs. Video technology is one of the most prevalent technologies currently used in special education, because children with ASD tend to be strong visual processors and learners (Bellini et al., 2007; Leaf, 2017; Macpherson et al., 2015; Reed et al., 2011). As a result, video-based interventions, such as video modeling and video prompting, pervade the literature as effective teaching methods for individual with developmental disabilities (Boutot & Myles, 2009; Burton et al., 2013; MacDonald et al., 2005; LeBlanc et al., 2003; Sansosti & Powell-Smith, 2008; Whalen et al., 2010). Video modeling, by definition, describes the process of having a student watch a videotape of a model performing a target behavior that needs to be imitated, after which the learner imitates the modeled behavior to learn new skills (Kroeger et al., 2007; Simpson et al., 2004). It is considered to have advantages when introducing a skill for the first time (Leaf, 2017); can be used to instruct communication skills, self-monitoring, emotional regulation, fine and/or motor skills (Lancioni & Singh, 2014); and is usually implemented in an intervention package rather than as a standalone instructional tool (Apple et al., 2005).

Social initiation skills instruction incorporating video modeling has consistently demonstrated positive effects on the SC/I behaviors of children with ASD. Nikopoulos and Keenan (2003, 2004, 2007) conducted three studies to promote social initiation in children with ASD; the first one suggests the effectiveness of video modeling in enhancing both social initiation and appropriate toy play among seven research participants. In the second study, the authors examined the effectiveness of video modeling on social initiation and play behaviors for three children with autism using a multiple baseline across subject design (Nikopoulos & Keenan, 2004). The participants watched a videotape that shows a typically developing peer engaging in simple social interactive play using a toy. The results suggested that video modeling successfully enhanced participants' social initiation and reciprocal play skills, and the effects were maintained during follow-up periods. In the third study, Nikopoulos and Keenan (2007) examined the effectiveness of video modeling in teaching complex social sequences to three children with autism in a semi-naturalistic room. The participants first watched four short videos of two people engaging in a simple sequence of activities, after which they were assessed on their ability to mimic what they saw in the videos. The results suggested that video modeling not only enhanced the social initiation skills of all participants, but also facilitated their reciprocal play engagement.

A certain number of studies have focused on general social skills such as social greeting, making eye contact, and sharing. As an example, Simpson et al. (2004) conducted a multiple probe design to examine the effectiveness of CAI-based video modeling in teaching sharing, following instructions, and social greeting. Four children with autism participated in the intervention in a special education classroom setting, and they were required to distinguish the examples from non-examples presented in video modeling. The results suggest that all of them showed rapid improvements in the desired social skills in the natural environment following the treatment condition.

Several studies have found that video modeling can help students at risk of social-play delays to catch up with their peers. D'Ateno et al. (2003) used a multiple-baseline procedure design to examine the effectiveness of video modeling in teaching complex play sequences to a preschooler with autism. The results suggest that video modeling led to the rapid acquisition of verbal and motor responses for the play sequences, and the child participant showed an increase in the number of both verbal and motor play responses. This study confirmed that video modeling can serve as an effective intervention tool for increasing social play skills. Likewise, Kroeger et al. (2007) used a quasi-experimental design to examine the effectiveness of video modeling in teaching children play skills. The participants were assigned to one of two types of intervention groups. The 13 participants in the direct teaching group used video modeling to learn play and communication skills, while the 12 children in the play group participated in unstructured play activities. The overall results suggested that children in both groups increased their play social skills, but the students in the video modeling direct teaching group made more improvements compared to the unstructured play group.

Several researchers have demonstrated the effect of video modeling on pretend play skills and their importance for children. MacDonald et al. (2005) conducted two studies to examine the effectiveness of video modeling in teaching these skills to children with autism. The first study (MacDonald et al., 2005) was conducted with a multiple probe design within participants across settings to examine the effectiveness of video modeling in enhancing thematic pretend play skills in two children with autism. The intervention package contained 17 verbalizations and 15 play actions, and was presented twice by adult teachers to the participants without further prompting or reinforcement. The results suggested that the video modeling intervention was successful, as both participants acquired the scripted verbalizations and play actions, and they also maintained the skills during follow-up sessions. In order to encourage children to engage in pretend play with typically developing peers, the second study (MacDonald et al., 2009) used a multiple probe design across settings to evaluate the effectiveness of video modeling in teaching reciprocal pretend skills to two children with autism. Each participant was paired with a typically developing partner to perform three play sets. The results suggested that both the participants and their partners acquired the sequences of scripted verbalization as well as play actions, and they all successfully maintained the performance during the follow-up sessions. Moreover, Murdock et al. (2013) examined the effectiveness of iPad play stories in enhancing pretend play skills for four young children (49–58 months) in a classroom setting. The dependent variables were the number of play dialogue utterances, such as sounds effects, structural utterances, and self-talk. The results suggested that three out of four participants demonstrated increases in the target behavior, revealing moderate and strong effects across intervention phases. The participants maintained the skills during a follow-up session three weeks later.

Compared to research focusing on social play skills, fewer studies have examined the effects of video modeling on communication and interaction skills. One example is a multiple baseline across participants design conducted by Macpherson et al. (2015) to evaluate the effectiveness of video modeling via an iPad intervention to teach verbal compliment behavior. Five children with autism were observed playing kickball with peers in a natural environment setting, and an iPad was used to present videos that taught them to encourage each other using verbal compliments. The results suggested that video modeling effectively increased verbal compliment behavior between participants, and three out of five children exhibited gains in generation probes across other activities.

In summary, video modeling has been demonstrated in the literature to increase social initiation, social play skills, perspective-taking, and communication interaction skills in children with ASD. Although prior research has reported the effectiveness of video modeling, only a few studies have specifically targeted SC/I skills (Sansosti et al., 2004). As suggested by Apple et al. (2005), video modeling is especially effective when it is followed by additional practice, prompts, and role-play activities. A noteworthy point when designing the instruction package used in the current study was to combine video modeling with role-play activities and teacher prompts, so as to maximize the learning outcomes.

Social Stories™

Social Stories™, first introduced by Carol Gray in 1993, are individualized short stories written to assist children with developmental disabilities in understanding challenging social situations through a combination of pictures, voice, and text (Barry & Burlew, 2004; Gray, 2000; Ivey et al., 2004; Sansosti et al., 2004). The main function of a Social Story™ is to provide descriptive information concerning the relevant features of a social situation, the people involved, the desired behaviors, the sequence of events, and the thoughts and feelings of others, as well as the consequences (Quill, 2000). A Social Story™ can provide a task analysis and offer suggestions for students to respond to a given social cue, and can prompt a specific order of behavioral responses or skill sets (Leaf, 2017; Sansosti, 2010). Moreover, Social Stories™ provide more explanations for interpreting and understanding what is expected in a social situation (Ivey et al., 2004), rather than directly providing anticipated action and routine instruction. Therefore, Social Stories™ can help children with ASD to not only respond to confusing social situations, but also to understand what consequences may result from a behavior and why.

Compared to the large number of studies on video modeling, literature that documents the effectiveness of Social Stories™ in improving the social skills of children with ASD has been relatively limited (Norris & Dattilo, 1999; Thiemann & Goldstein, 2001). In general, the effectiveness of Social Stories™ is usually measured through a decrease in inappropriate social behaviors, an increase in social play skills, and an increase in SC/I behaviors.

Research has demonstrated that Social Stories™ are effective in initiating social activities and sharing, as well as in reducing aggressive behaviors. Swaggart et al. (1995) combined the Social Story™ program with a traditional behavioral social skills training strategy to decrease aggression while increasing sharing behaviors for three students with autism. The intervention successfully increased the participants' appropriate behaviors, reduced behavioral excesses, and allowed for the generalization of newly acquired skills across different settings. Likewise, Norris and Dattilo (1999) conducted an AB design study to examine whether Social Stories™ could reduce inappropriate social behaviors in a student with autism. The results documented that inappropriate behavior from the student decreased by 50% after the intervention had been completed.

Several studies have found that Social Stories™ can also help children who are not good at understanding social rules or play skills to comprehend what is expected in a social situation. Barry and Burlew (2004) used a multiple baseline across participants design to examine Social Stories™ in teaching choice-making and social play skills to two children with autism. The results indicated that the intervention using Social Stories™ increased both participants’ abilities to make independent choices and to understand how to play appropriately with toys. This study also contributed empirical evidence to the effectiveness of Social Stories™ treatments for children with little or no language skills for communication. Moreover, Thiemann and Goldstein (2001) investigated the effects of combining Social Stories™, written text cues, and supplemental video feedback on the social communication skills of five children with autism. The results indicated increases in understanding and performing target social skills among the participants, and one student successfully generalized the improvements across settings. Although there was no way to determine whether Social Stories™ were the most beneficial strategy in the intervention package, it can be concluded that Social Stories™ can be included in an intervention package as an effective component, rather than as a lone instructional tool.

In summary, Social Stories™ have been demonstrated in the literature to increase social play skills, reduce inappropriate behaviors, and, more importantly, enable children to understand confusing social situations, as well as comprehend the consequences that may result from a behavior and why. Therefore, one noteworthy point when designing the instruction package used in the current study was to combine the correction staircase

(Gerber et al., 2004) approach and allow the teacher to test the student's comprehension of the learned Social Stories™, so as to maximize the learning outcomes. In addition, as Thiemann and Goldstein (2001) suggested, Social Stories™ can be implemented in combination with other intervention tools; when designing this study, the primary investigator included Social Stories™ along with video modeling in the instruction package. The unique combination of the two enabled the teacher to maintain the interest of the students and to keep them more engaged in learning about the social behaviors, which were otherwise uninteresting for them.

Direct Instruction

Direct instruction (DI) is an evidence-based teaching approach that emphasizes "well-developed and carefully planned lessons designed around small learning increments and clearly defined and prescribed teaching tasks" (National Institute for Direct Instruction, 2019). It was originally developed to improve the reading and mathematics scores of low-performing, disadvantaged primary school students (Becker & Engelmann, 1976). These findings have been replicated in teaching reading comprehension and mathematics with similar outcomes. There are eight core elements of DI, including: (1) highly regimented scripted sessions, (2) ability grouping of children, (3) repetition of teaching content, (4) flexible use of wait time, (5) use of signals, (6) choral responding, (7) fast teaching pace, and (8) mastery of preceding content before moving onto subsequent material. The DI model includes teacher modeling, prompting, and providing feedback or error correction (Banda & Hart, 2010).

Studies have demonstrated the effectiveness of DI in teaching various skills to children with developmental disabilities (Becker & Engelmann, 1976; Cadette et al., 2016), as well as in facilitating the generalization of target skills across novel settings and peers. Ganz and Flores (2009) examined the effects of a DI language program administered to elementary school age children with ASD and found a functional relation between DI and communication skills, demonstrated through the replication of skill increases across three criterion changes. The percentage of non-overlapping data was reported as at least 90 percent across participants. Around the same time, Flores and Ganz (2009) conducted another study to investigate the effects of a DI reading comprehension program for children with ASD and developmental disabilities. They extended the previous study by examining the extent to which more complex instruction can be made. The results indicated a functional relation between DI and reading comprehension skills; the target behaviors were maintained across students and conditions. Flores et al. (2013) also conducted a follow-up growth study utilizing both a DI and a language curriculum without modification to teach reading and communication skills to children with ASD and developmental disabilities. The difference in this study compared to the previous two is that the researchers implemented the curriculum exactly as prescribed. The study further supports the conclusion that DI techniques have a positive statistically significant effect on children's acquisition of the target behaviors.

In a later study in the series, Ganz and Flores (2014) used an alternation-treatment design to examine the effects of tablet-based visual scripts on communication skills in three children with autism; they demonstrated that the participants all showed improvement in verb and noun usage. Another study compared DI with DTT on language training efficacy for 13 children with autism (Flores & Ganz, 2014). The DI group received group instruction, while the DTT group received one-on-one intervention. An independent *t*-test demonstrated that DI was more effective than DTT, with a moderate effect size.

A point worth noting is that, as promising as the literature seems thus far, there is still a lack of studies that apply DI to SC/I skills treatment in children with ASD. In the *Qunatiandi* program, DI is employed in the form of the correction staircase (Gerber et al., 2004; Leafstedt et al., 2004), an important instruction phase after Social Stories™, to facilitate children's learning during treatment sessions. This study adds to the existing literature on DI in order to explore how SC/I skills will be affected, an area for which there is currently limited research.

Curriculum-based Assessment

Curriculum-based assessment (CBA) is a student-centered evaluation process that directly uses teaching materials to be learned later as the basis for assessing the degree to which the knowledge is already mastered by the students (Gickling & Havertape, 1981). Curriculum-based assessment for instructional design (CBA-ID) is a commonly presented model in the literature with a practical application in the field of special education (Curriculum-based assessment and curriculum-based management, 1990). Specifically, CBA-ID determines students' instructional needs based on their on-going performance with the existing course content in order to help teachers to determine their "window of learning" (Tucker, 1985), and to find an instructional match to improve learning effectiveness and efficiency. If a student immediately provides a correct answer to a specific question, then that knowledge is considered known information. Otherwise, the knowledge is considered unknown. The ratio of known to unknown information is later translated into decisions regarding the student's instructional and independence level (Gickling & Thompson, 1985), and an instructional match is developed when this ratio is sufficiently controlled to ensure a high level of learning success (Deno, 1987).

In the *Qunatiandi* program, CBA was employed in the baseline assessment stage, where students participated in a test by answering a series of adaptive questions on the application, which were randomly drawn from the ABI test-question bank, to further check their ability to distinguish, understand, and act out the targeted behaviors. Examples of question types include true or false, picture matching, and picture selection. Each student's test score was recorded as the baseline data for that student. The system uses these sets of CBA measurements and records students' performance samples as a portfolio assessment for making further instructional decisions.

Literature Review Summary

This chapter has presented the growing and promising evidence base that offers considerable support for children with ASD, who typically exhibit limited abilities in greetings and conversations, and who often experience delayed acquisition of nonverbal behavior cues to regulate social interaction. This review of the literature supports the theory that children with ASD can acquire SC/I skills with intervention based on a combination of scientifically validated EBPs. Treatments have been effective for many in this specific student population, and ABIs appear to be a viable strategy for future classroom intervention. More specifically, for ABA-based treatments and naturalistic behavioral interventions, strong empirical evidence supports the effectiveness of intervention programs, and several promising strategies can be combined into the ABI program to meet instructional best practices.

The primary investigator introduced a program package consisting of several components, including ABA, PRT, video modeling, Social Stories™ , and DI. Many of these techniques are primarily designed to address the intensified challenges that arise when children with ASD face severe, longstanding social and communication deficits. Although further research is required to judge whether this specific EBP package has a higher probability of success in a particular set of developmental student profiles, the primary investigator believes that the combined effect of a collection of EBPs increases the chance of validating the potential efficacy of an ABI. In order to develop intervention strategies that provide the full range of functionality required by children with ASD, one must incorporate a variety of empirically validated treatment approaches into a single intervention program. This is the theoretical foundation of the ABI program designed for and examined in the current research.

Chapter 3: Methodology

This chapter discusses the methods applied in conducting this study. It is divided into the following sections: (1) research design considerations, (2) experimental design, (3) RCT randomization, (4) pilot test, (5) participants, (6) measures, (7) ABI group characteristics, (8) settings, (9) materials, (10) pre-intervention teacher training, (11) baseline, (12) intervention procedure I: instruction, (13) intervention procedure II: guided practice, (14) dependent measures and data collection, (15) measurement of fidelity, and (16) reliability.

Research Design Considerations

A sequential explanatory mixed methods design (Creswell, 2009) was determined to be the most suitable methodological approach for gathering information and analyzing the research questions posed in this work. The main goals of the study were accomplished through discovery and interpretation of all the data received, rather than solely relying on pure analysis of the primary quantitative data. Therefore, a sequential mixed methods design was best suited to the exploratory aspect of this study. A typical sequential explanatory mixed method design incorporates the collection and analysis of quantitative data in phase one, followed by that of qualitative data in phase two. The defining characteristic of this design is that the results of the qualitative data in phase two can be explained and interpreted based on the prior results from the quantitative data collected in phase one. The two sets of data, while collected separately, are substantially connected and therefore provide a unique research methodology.

The study process in this dissertation included two phases: in phase 1, the statistical portion of the study compared the two treatment approaches using an RCT pretest-posttest research design. Student participants who received TAU are hereafter referred to as the waitlist group, while those who received the ABI program are referred to as the treatment group. Nineteen participants were examined in this phase. Four measures of functioning were utilized to compare the treatment approaches: the Social Responsiveness Scale (SRS-2) *T*-score, the autism index of the Gilliam Autism Rating Scale (GARS-3), the adaptive behavior composite (ABC) of the Vineland Adaptive Behavior Scales (Vineland-3), and the Social Communication Questionnaire (SCQ). Nonparametric tests (random permutation test and Mann-Whitney *U* test) were used to compare the treatment and waitlist groups.

In phase 2, an SSD replicated in multiple cohorts was used to collect quantitative data for analysis across baseline, intervention, maintenance, and generalization portions of the study. This phase was conducted in order to confirm and further analyze the data and results from phase 1 by obtaining detailed knowledge regarding training content, teaching experience, and effectiveness for student learning in the treatment group. Eleven participants from the treatment group were examined in this phase. The sequential yet flexible nature of the research design enabled a pragmatic approach following the development of the intervention programs, which was well suited to the exploratory aspect of the study.

Experimental Design

An RCT group design was used, in which student participants were allocated to either the ABI treatment group or the control group. The TAU in schools where the study was conducted consists of integrated classroom sessions and individual social support sessions, with students attending speech pathology training or receiving occupational therapy on a regular basis. Student participants in both arms of the study received no significant differences in ongoing educational provisions. Figure 1 illustrates the participant assignment into the two groups based on the initial screening and outlines the experimental procedure.

This study also employed a multiple probe across participants experimental design, which was replicated in several small cohorts, based on a randomized group assignment condition (Bailey & Burch, 2002; Ledford & Gast, 2018). This was used to evaluate the effectiveness of the ABI program for teaching functionally independent and non-reversible SC/I skills to children with ASD. The experimental design involved probing student participants and administering a series of social tasks to develop a stable baseline. Training for the first task (topic 1) was provided until the criterion was met, followed by the same for the second task (topic 2). For a task or a behavioral step that the student struggled with, the teacher would repeat it until it was mastered or pull it out and teach it separately. Experimental control was established by recording a stable baseline and by implementing visual analysis techniques that showed therapeutic changes in the number of correctly completed steps and showed the replication of the effects on instruction. Individual performance on the target SC/I skills improved only in the intervention condition and remained at a stable baseline level before each student received the intervention. Internal validity was maintained with the staggered introduction of the intervention across all participants in order to control for confounding variables related to maturation, habituation, and history (Campbell et al., 1963). External validity was addressed through the replication of experimental results across all the student participants. Data were collected throughout the baseline, intervention, maintenance, and generalization portions of the study.

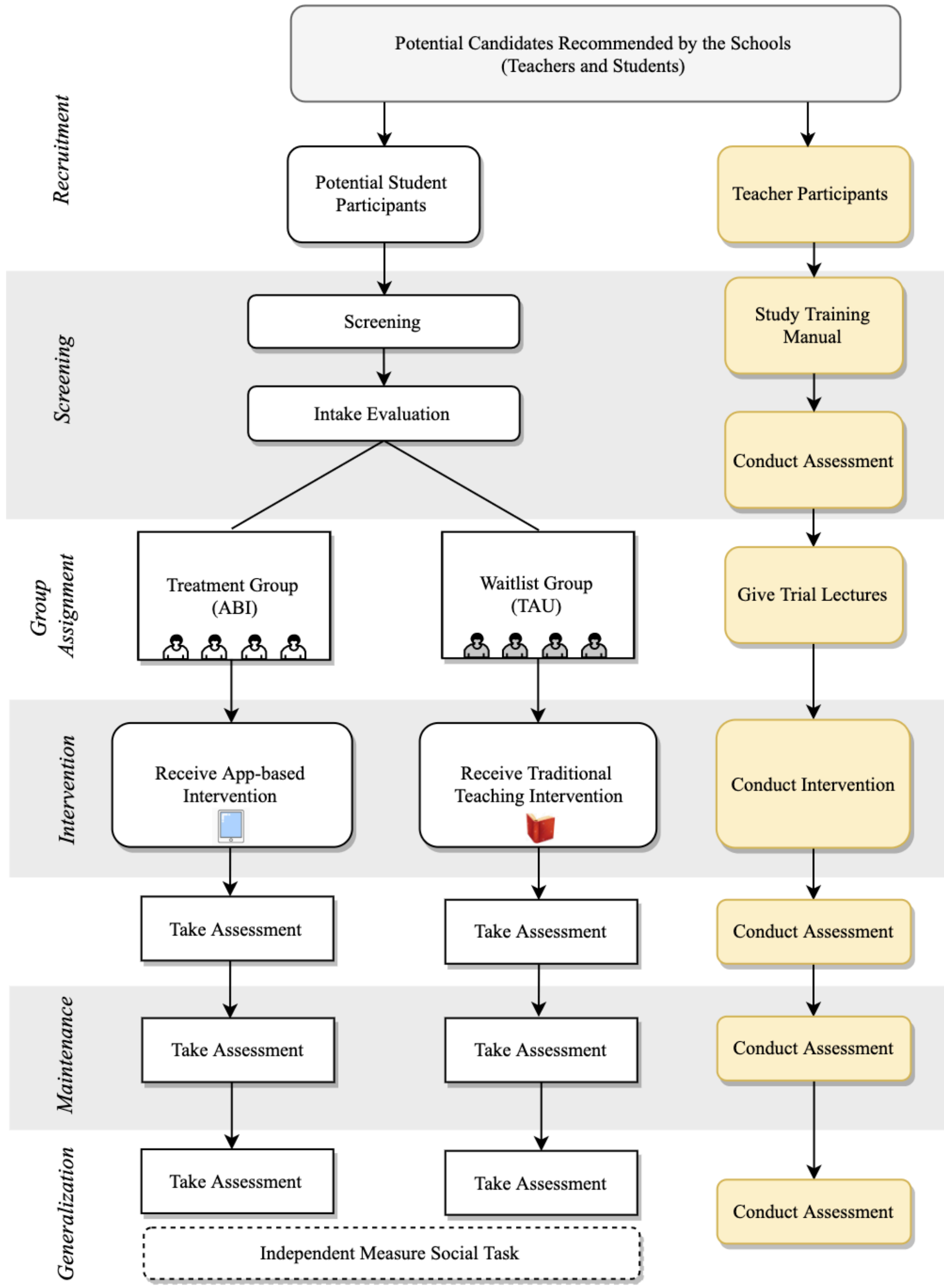

Figure 1. Diagram illustrating group assignment and experimental procedure.

Randomization

Random assignment of student participants into either the ABI (i.e., treatment condition) or the TAU group (i.e., control condition) was undertaken by the primary investigator. Each student participant was assigned an ID number. The researcher randomly assigned participants to treatment or waitlist groups by ID number using the "Random Integers" option at Random.org. A final project consort diagram is provided in Figure 1. There was a deviation from the plan, as seven of the 26 participants (27%) assigned to either condition withdrew from the study prior to the training procedure due to unforeseen logistical reasons.

It is worth noting that, since all student participants came from the same school setting, the teacher-student cohorts in the ABI group were predetermined by the school schedule, and each student was paired with a specific teacher prior to the treatment. Therefore, the primary investigator was responsible only for randomly assigning students to either the treatment or the control group, but not for assignment of teachers, as each teacher had already been paired with one or two students.

Pilot Test

The pilot study included a relatively loosely structured set of tests for researchers to explore, probe, and test some of the key parameters and procedures of the soon-to-be-run study being planned. Four preschoolers with ASD who were not involved in the later study were recruited for the pilot testing. Antecedent stimuli were tested in order to determine optimal parameters for effectiveness with the participants (Bailey & Burch, 2002). Two sessions were conducted every week, and each session lasted 30 to 45 minutes. Each participant was instructed separately, and they were all taught by the same teacher.

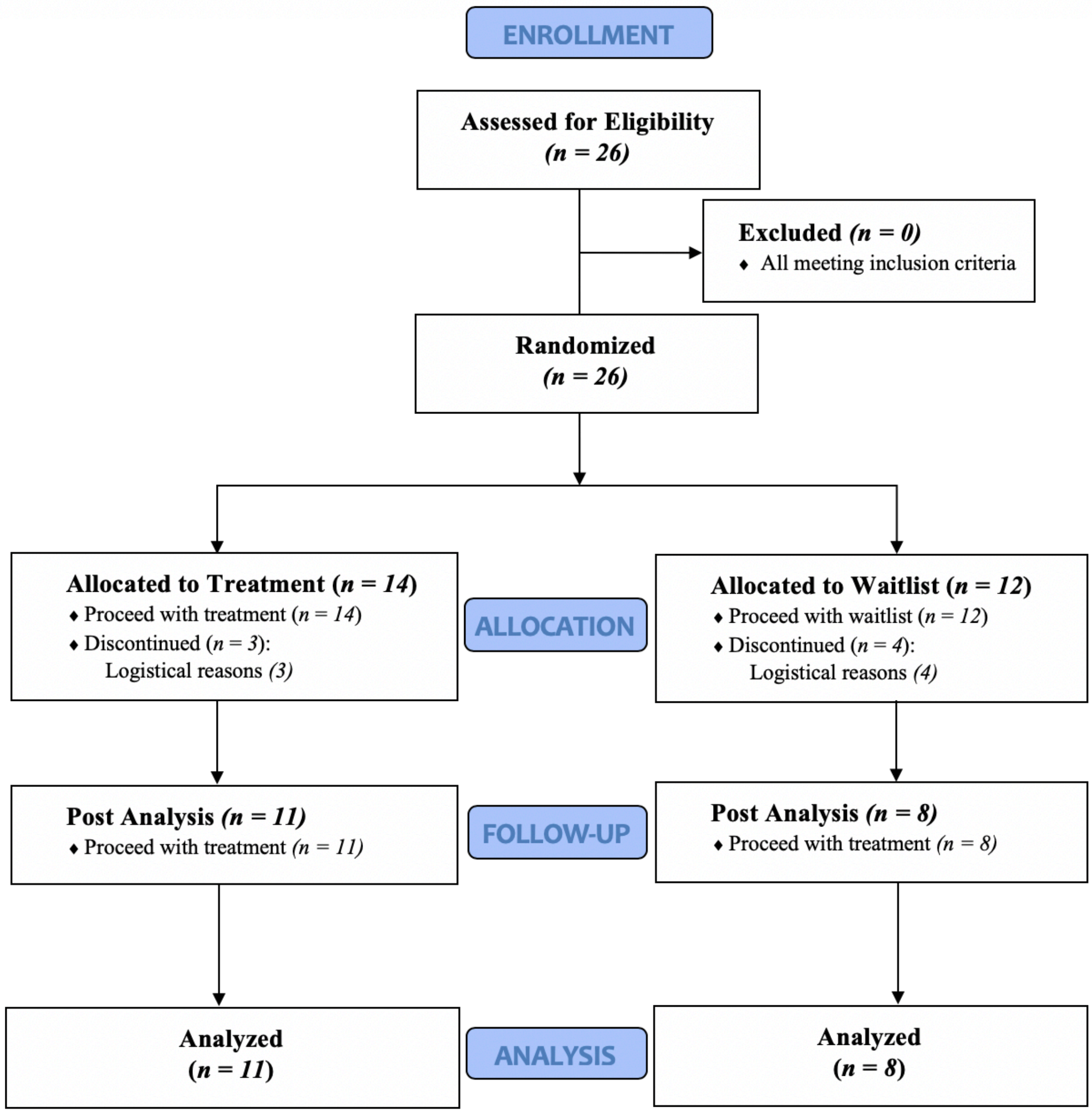

Figure 2. RCT consort diagram.

Participants

For the current study, participants were recruited during the research phases. Two special education schools were contacted during the recruitment process. The participants were recommended by their schools, and they agreed to participate in the study with written permission in accordance with the Institutional Review Board (IRB) and approval letters from the school district, the school principal, and/or the students' parents.

Teacher participants. Teachers were recruited via two main routes: some were recommended by the participating school, and selected based on teaching experience, work schedule, and other factors. Other teachers recommended themselves by expressing interest in the study, and were recruited if they met the basic eligibility requirements. The inclusion criteria were: (1) at least one semester of working experience with students with ASD, and (2) ability to commit to participating in the entire course of the study.

Student participants. The total project cohort of students that ultimately participated in the program consisted of 19 participants (five girls and 14 boys, ranging in age from 6 years 10 months to 14 years 7 months). All of them had been diagnosed as having autism by Chinese hospitals and/or outside agencies according to the diagnostic criteria outlined in the diagnostics and statistical manual, 5th edition text revision (DSM-5, American Psychiatric Association, 2013) and other Chinese diagnostic procedures. These children had been referred to special education schools for intervention services. Eleven special education teachers recommended them as potential candidates, since one of their immediate goals was to gain or improve SC/I skills. All students had experience with laptop computers, but not with handheld tablet devices. To ascertain their current level of functioning and intervene at the students' areas of needs, relative measures were administered for the social behavior ratings of the student participants in order to identify typical social skill deficits with children with ASD. An extensive exploration of the official school records was also used for gathering any additional information concerning the behavioral characteristics and training goals of the student participants.

Prerequisite skills for inclusion in this study were: (1) diagnosis of ASD based on DSM-5; (2) an autism classification based on cut-off scores of GARS-3; (3) an age between 6 and 14 years at intake; (4) visual ability to perceive videos, pictures, and characters displayed on electronic devices; (5) adequate hearing and language comprehension skills for following instructions; (6) sufficient fine motor skills for operating a tablet with one's fingers; and (7) ability to participate in a teacher-selected task for at least 15 minutes. Pseudonyms were given to all participants to protect their privacy, and no identifiable or traceable information were to be made available outside of the study.

Measures

A number of measures were used to assess baseline functioning and improvement. These included both commonly used tools in the field of ASD research – such as direct observation and direct assessment – and curriculum-based measures. These instruments were administered as outcome measures as part of the pretest and posttest design (Lopata et al., 2010; Vernon et al., 2018; Vernon et al., 2019; Wetherby et al., 2014), and testing was conducted at two time intervals to monitor progressive changes throughout the intervention.

Gilliam Autism Rating Scale (GARS-3). The GARS-3 (Gilliam, 2014) is one of the most widely used norm-referenced assessment instruments in the world that identifies individuals who may have ASD. It is composed of 58 items divided into six subscales – restrictive/repetitive behaviors, social interaction, social communication, emotional responses, cognitive style, and maladaptive speech – all of which contribute to describing observable yet measurable behaviors that may be indicative of ASD. For the GARS-3, the internal consistency reliability of the subscales exceed .85, and that of the autism indexes exceed .93. It can accurately discriminate individuals with ASD from typically developing persons with a sensitivity and specificity value of .97, and the receiver operating characteristics (ROC) analyses indicate an area under the curve (AUC) of .93. The GARS-3 is usually used as an indicator of ASD symptom severity (DSM-5 severity level), with autism index reductions associated with a decrease in observable behavioral symptoms.

Social Responsiveness Scale, 2nd Edition (SRS-2). The SRS-2 (Constantino & Gruber, 2005) is a 65-item rating scale that measures deficits in social reciprocity and SC/I associated with ASD; it yields a total score and subscale scores in social awareness, social cognition, social communication, social motivation, and stereotypic behavior associated with ASD. The SRS *T*-score has an internal consistency reliability above .90, and it correlates well with subscales of the autism diagnostic interview-revised (ADI-R), and the autism diagnostic observation schedule (ADOS). The ROC analyses of the school-age form indicate an AUC of .968, and a sensitivity and specificity value of .92 at a raw score of 62. The SRS-2 is used as a strong measure of ASD symptomatology and severity, and score reductions are associated with a decrease in observable symptoms.

Vineland Adaptive Behavior Scales, 3rd Edition (Vineland-3). The Vineland-3 (Sparrow et al., 2016) is a leading assessment instrument for diagnosing and classifying developmental delay, intellectual disabilities, and ASD. It effectively measures the adaptive behavior of individuals with ASD by providing information about adaptive performance in domains such as communication, daily living, socialization, and maladaptive behavior.

These domains are combined to generate a Vineland adaptive composite (*M* = 100, *SD* = 15), a measure of overall adaptive functioning. The Vineland-3 subscale has the following internal consistency reliabilities: communication .95, daily living skills .94, socialization .96, and adaptive behavior composite .98. The domain-level teacher form (96 core items) and the domain-level parent/caregiver form (120 core items) were adopted in the current study to assess the participants' everyday adaptive skills at home and in school.

Social Communication Questionnaire (SCQ). Originally designed as a companion measure to the ADI-R, the SCQ (Rutter et al., 2003) is one of the most researched ASD evaluation instruments that is widely used as a screening tool with established validity. Indexes of diagnostic accuracy have been shown to be especially strong in school-aged samples, the threshold score of 15 has a sensitivity value of .96 and a specificity value of .80. The SCQ is used as a strong measure of ASD symptomatology and severity, and score reductions are associated with a decrease in observable symptoms.

ABI Group Characteristics

Of the 19 eligible participants who ultimately completed this study, 11 were randomly assigned to receive the ABI program. These students were further divided into four groups, after which an SSD multiple probe design replicated across four groups was used to collect quantitative data for analyses across the baseline, intervention, maintenance, and generalization portions of this group.

Group 1. Table 1 presents the demographic information and assessment results of the three participants (child 1, child 2, and child 3) in group 1.

Child 1. Child 1 was a 14-year-old girl diagnosed with ASD severity level 2 (moderate) according to the DSM-5. She had autism indexes of 99 (percentile rank 47%), demonstrating a significant amount of autistic behavior that limited her social interactions and required substantial support in her treatment and guidance to function. Her SRS *T*-score was 87, which indicated clinically significant severe deficiencies in reciprocal social behavior leading to severe interference with everyday social interactions. Child 1 demonstrated a desire to enter and be part of a social situation but lacked the necessary skills to do so in an appropriate and effective manner. Her teacher reported that she would often make attempts to interact by placing a toy in front of her peers for attention, but she was not yet able to verbally initiate a play invitation. Moreover, she seldom recognized nonverbal cues, and she was likely to drone on about a topic despite a lack of interest from her listeners. Her peers sometimes ignored her requests, because they usually had difficulties following her lead when she mentioned subjects outside of the immediate context. During circle time, she was observed to have difficulty responding and maintaining reciprocity when probed for personal narratives. She also ignored her peers' conversation topics and requested the termination of toy exchange.

Child 2. Child 2 was an eight-year-old boy who had also been diagnosed with ASD severity level 2 (moderate) in the DSM-5. He had autism indexes of 95 (percentile rank 37%), demonstrating significant amount of autistic behavior that limited his social interactions and required substantial support in his treatment and guidance to function. His SRS *T*-score was 73, which indicates moderate deficiencies in reciprocal social behavior that are clinically significant and substantially interfere with everyday social interactions. Child 2 spoke in almost complete sentences, possessed basic reading abilities, and had a particular fascination with reading written Chinese characters out loud. Aside from these strengths, he was described as socially aloof, quiet, low in confidence, lacking eye contact, and reluctant to initiate social interaction on his own in obvious ways. His unprompted responses were mostly short and lacking in detail. However, he elaborated on his initial short responses with repeated prompts in the form of direct requests and follow-up questions. The instructional team reported that he had difficulty joining in play activities. He would spend time watching his peers play games and would also play quietly beside them. Occasionally, he peeked over at them when they played with materials that were of interest to him. He spent much of circle time exploring play materials apart from his peers.

Child 3. Child 3 was a 14-year-old boy who had been diagnosed with ASD severity level 3 (severe) based on the DSM-5. He had autism indexes of 105 (percentile rank 65%), demonstrating significant amounts of autistic behavior and requiring very substantial support in his treatment and guidance to function. His SRS *T*-score was 81, which indicated clinically significant severe deficiencies in reciprocal social behavior, social awareness, and social cognition, leading to severe interference with everyday social interactions. Child 3 seemingly enjoyed interacting with adults and peers, had a sense of sharing, and was able to make simple requests of others. He used a range of complete sentence constructions and communicated effectively in general with his school teachers. However, he had trouble paying attention to non-verbal cues, was prone to accidently interrupting peers during their activities, and could not make a request or an invitation to others politely. Both his parents and teachers indicated that he would benefit from learning how to politely initiate conversations and make requests in an appropriate manner.

Table 1

Participant demographics in Group 1

	Child 1	Child 2	Child 3
Chronological age (months)	14:3 (171)	8:5 (101)	14:1 (169)
Gender	Female	Male	Male
Social Responsiveness Scale (SRS-2)			
SRS *T*-Score	87 [b]	73 [a]	81 [b]
T-Score Range	Severe	Moderate	Severe
Social Awareness	77	62	90
Social Cognition	85	76	90
Social Communication	77	67	83
Social Motivation	78	66	69
Restricted Interests/Repetitive Behavior	90	84	90
Gilliam Autism Rating Scale (GARS-3)			
Autism Index	99 [c]	95 [c]	106 [d]
DSM-5 Severity Level	Moderate	Moderate	Severe
Overall Percentile Ranks	47	37	65
Restricted/Repetitive Behaviors	11	13	11
Social Interaction	9	9	9
Social Communication	7	8	11
Emotional Response	12	7	12
Cognitive Style	11	12	10
Maladaptive Speech	11	12	15
Vineland Adaptive Behavior Scales (Vineland-3)			
Adaptive Behavior Composite	63	67	54
Communication	72	79	60
Daily Living Skills	67	62	46
Socialization	52	62	56
Social Communication Questionnaire (SCQ)			
SCQ Total Score [e]	17	16	39

**Note:*

[a] Indicates deficiencies in reciprocal SC/I that are clinically significant and lead to substantial interference with everyday social interactions. Typical for children with ASD of moderate severity.

[b] Indicates deficiencies in reciprocal SC/I that are clinically significant and lead to severe interference with everyday social interactions. Such scores are strongly associated with a clinical diagnosis of ASD.

[c] Indicates significant amounts of autistic behavior that limit academic and social interactions.

[d] Indicates significant amounts of autistic behavior that require very substantial behavioral programming.

[e] A cutoff score of 15 or greater is an indication of a possible ASD.

Group 2. Table 2 presents the demographic information and assessment results of the three participants (child 4, child 5, and child 6) in group 2.

Child 4. Child 4 was an 8-year-old boy who had been diagnosed with ASD severity level 3 (severe) according to the DSM-5. He had autism indexes of 106 (percentile rank 65%), demonstrating a significant amount of autistic behavior and requiring very substantial support in his treatment and guidance to function. In terms of his SC/I skills, his SRS *T*-score was 64, which indicates mild deficiencies in reciprocal social behavior that are clinically significant and that lead to mild to moderate interference with everyday social interactions. Child 4 demonstrated relatively good social interaction abilities, as he could use a range of early word combinations and had expanded the functions of his communication to include not only requesting items but also commenting on simple issues. He had a strong desire to get others to interact with him, as he usually displayed excitement in showing toys or objects to others. However, his teacher noted that his ability to share experiences across contexts and individuals had not yet emerged consistently, and he was not yet able to verbally initiate a play invitation. Therefore, child 4 still needed to improve his social communication skills.

Child 5. Child 5 was a 14-year-old boy diagnosed with ASD severity level 2 (moderate) in the DSM-5. He had autism indexes of 92 (percentile rank 30%), demonstrating significant autistic behavior that limited his social interactions and required substantial support in his treatment and guidance to function. His SRS *T*-score was 76, which indicates clinically significant severe deficiencies in reciprocal social behavior that severely interfere with everyday social interactions. Child 5 had a desire to please others and had learned to anticipate his peers' actions in familiar routines and follow situational cues in classroom settings. He could use simple language to communicate a wide range of nouns and a limited range of actions words, but he could not yet combine these words to form relational meanings in phrases appropriate to his developmental level. In addition, he had difficulty monitoring the actions of others and engaging in creative and imaginative play. His teacher recognized an educational need for him to achieve greater consistency by encouraging conversation and imitation, providing repeated learning and practicing opportunities, and using supporting visual cues to break down and analyze the behavioral steps within a task.

Child 6. Child 6 was a 14-year-old girl who had been diagnosed with ASD severity level 3 (severe) based on the DSM-5. She had autism indexes of 106 (percentile rank 65%), demonstrating a significant amount of autistic behavior and requiring very substantial support in her treatment and guidance to function. Her SRS *T*-score was 90, which indicates severe deficiencies in reciprocal social behavior, social cognition, social awareness, and social communication that are clinically significant and lead to severe interference with everyday social interactions. Child 6 demonstrated a short attention span and relatively poor impulse control and was described as having a temper that would flare easily if the lesson content or format did not match her preferences. The instructional team had observed her communication skills blossom in recent months, as she became more adept at using a range of early word combinations to share her interests. Although she had an increasing willingness to express herself and play games with others, she was not yet able to maintain her focus during conversation, and she tended to redirect activities according to her preference. This had led to a rift between her and her peers, who were beginning to be put off by her tendency for changing games without telling them or considering their opinions.

Table 2

Participant demographics in Group 2

	Child 4	Child 5	Child 6
Chronological age (months)	8:11 (107)	14:2 (170)	14:7 (175)
Gender	Male	Male	Female
Social Responsiveness Scale (SRS-2)			
SRS *T*-Score	64 [a]	76 [b]	90 [b]
T-Score Range	Mild	Severe	Severe
Social Awareness	63	60	71
Social Cognition	73	78	90
Social Communication	56	75	90
Social Motivation	59	64	90
Restricted Interests/Repetitive Behavior	63	82	90
Gilliam Autism Rating Scale (GARS-3)			
Autism Index	106 [d]	95 [c]	102 [d]
DSM-5 Severity Level	Severe	Moderate	Severe
Overall Percentile Ranks	65	37	55
Restricted/Repetitive Behaviors	7	9	9
Social Interaction	3	6	10
Social Communication	10	9	11
Emotional Response	7	13	11
Cognitive Style	10	12	10
Maladaptive Speech	13	12	15
Vineland Adaptive Behavior Scales (Vineland-3)			
Adaptive Behavior Composite	54	69	56
Communication	57	70	48
Daily Living Skills	46	71	65
Socialization	61	69	48
Social Communication Questionnaire (SCQ)			
SCQ Total Score [e]	16	20	28

**Note:*

[a] Indicates deficiencies in reciprocal SC/I that are clinically significant and may lead to mild or moderate interference with everyday social interactions.

[b] Indicates deficiencies in reciprocal SC/I that are clinically significant and lead to severe interference with everyday social interactions. Such scores are strongly associated with a clinical diagnosis of ASD.

[c] Indicates significant amounts of autistic behavior that limit academic and social interactions.

[d] Indicates significant amounts of autistic behavior that require very substantial behavioral programming.

[e] A cutoff score of 15 or greater is an indication of a possible ASD.

Group 3. Table 3 presents the demographic information and assessment results of the three participants (child 7, child 8, and child 9) in group 3.

Child 7. Child 7 was a nine-year-old boy who had been diagnosed with ASD severity level 2 (moderate) according to DSM-5. He had autism indexes of 97 (percentile rank 42%), corresponding to a significant amount of autistic behavior that limited his social interactions and required substantial support in his treatment and guidance to function. His SRS *T*-score was 84, which indicates severe deficiencies in reciprocal social behavior that are clinically significant and that lead to severe interference with everyday social interactions. Child 7's expressive language had progressed remarkably in the few months prior to the study, and he could use a variety of sentence constructions to express his knowledge or opinions and comment on things (e.g., "I think he is upset because she said bad things to him"). He also demonstrated a desire to enter and take part in social situations but lacked the necessary skills to do so in an appropriate and effective manner. In addition, his ability to recognize that more information was needed when his listener had not seen an event had not yet emerged, and he needed to elaborate and explain situations more effectively to make himself understood by others.

Child 8. Child 8 was an eight-year-old boy who had been diagnosed with ASD severity level 2 (moderate) of DSM-5. He had autism indexes of 90 (percentile rank 25%), demonstrating significant amounts of autistic behaviors that limited his social interactions and required substantial support in his treatment and guidance to function. His SRS *T*-score was 79, which indicates severe deficiencies in reciprocal social behavior that are clinically significant and that severely interfere with everyday social interactions. Child 8 was an outgoing child, who described as possessing an exceptional vocabulary, a broad range of sentences structures, basic reading abilities, and a particular fascination with reading written characters out loud. His teacher reported that he wanted to make friends among his peers, and that he had become more likely to share intentions for social interaction. He was not yet inviting partners to play games or join activities, and he was not yet able to express empathy regarding a conversation partner's positive or negative experience. Both his parents and teachers indicated that he would benefit from learning how to share intentions in social interaction.

Child 9. Child 9 was a 12-year-old boy who had been diagnosed with ASD severity level 3 (severe) based on the DSM-5. He had autism indexes of 107 (percentile rank 68%), which corresponded to significant amount of autistic behaviors and required very substantial support in his treatment and guidance to function. His SRS *T*-score was 88, which indicated clinically significant severe deficiencies in reciprocal social behavior leading to severe interference with everyday social interactions. Child 9 was described as socially aloof, seemingly indifferent to other people's attention, expressing minimal pleasure when interacting with others, and reluctant to initiate social interaction on his own in obvious ways. He also demonstrated a bias toward a low state of arousal and a passive interaction style. The teacher noted that one of his objectives included noticing people and objects in the environment and seeking a variety of sensory experiences. He was beginning to seek out his peers slightly more frequently, particularly if he needed help obtaining a toy, and was working on engaging in more reciprocal interactions.

Table 3

Participant demographics in Group 3

	Child 7	Child 8	Child 9
Chronological age (months)	9:9 (117)	8:7 (103)	12:11 (155)
Gender	Male	Male	Male
Social Responsiveness Scale (SRS-2)			
SRS *T*-Score	84 [a]	79 [a]	88 [a]
T-Score Range	Severe	Severe	Severe
Social Awareness	73	73	70
Social Cognition	83	81	79
Social Communication	85	73	89
Social Motivation	64	71	85
Restricted Interests/Repetitive Behavior	89	86	89
Gilliam Autism Rating Scale (GARS-3)			
Autism Index	95 [b]	90 [b]	111 [c]
DSM-5 Severity Level	Moderate	Moderate	Severe
Overall Percentile Ranks	37	25	77
Restricted/Repetitive Behaviors	9	12	11
Social Interaction	7	5	12
Social Communication	11	5	12
Emotional Response	10	12	11
Cognitive Style	12	13	11
Maladaptive Speech	14	15	16
Vineland Adaptive Behavior Scales (Vineland-3)			
Adaptive Behavior Composite	77	71	55
Communication	76	85	55
Daily Living Skills	101	65	54
Socialization	61	66	47
Social Communication Questionnaire (SCQ)			
SCQ Total Score [d]	14	14	26

**Note:*

[a] Indicates deficiencies in reciprocal SC/I that are clinically significant and lead to severe interference with everyday social interactions. Such scores are strongly associated with a clinical diagnosis of ASD.

[b] Indicates significant amounts of autistic behavior that limit academic and social interactions.

[c] Indicates significant amounts of autistic behavior that require very substantial behavioral programming.

[d] A cutoff score of 15 or greater is an indication of a possible ASD.

Group 4. Table 4 presents the demographic information and assessment results of the two participants (child 10 and child 11) in group 4.

Child 10. Child 10 was a 12-year-old boy diagnosed with ASD severity level 3 (severe) according to the DSM-5. He had autism indexes of 114 (percentile rank 82%), demonstrating significant amount of autistic behavior and requiring very substantial support in his treatment and guidance to function. His SRS *T*-score was 90, which indicates severe deficiencies in reciprocal social behavior and social cognition that are clinically significant and lead to severe interference with everyday social interactions. Child 10 demonstrated delays in initiating conversational exchanges and appeared to have difficulty understanding the reciprocal nature of a conversation. In group activities, he had difficulty accommodating the ideas of peers and at times became distraught if not in control. His educational goals included collaborating with peers to reach a compromise, modifying language and behavior based on peers' emotional reactions, and making requests in an appropriate manner.

Child 11. Child 11 was a 12-year-old boy diagnosed with ASD severity level 3 (severe) based on the DSM-5. He had autism indexes of 114 (percentile rank 82%), which corresponded to significant autistic behavior and required very substantial support in his treatment and guidance to function. His SRS *T*-score was 79, which indicates severe deficiencies in reciprocal social behavior that are clinically significant and that lead to severe interference with everyday social interactions. Child 11 demonstrated a variety of arousal levels, and he became easily upset and needed an excessive amount of reassurance when his routine was violated. He also had difficulties conveying his emotional states and play requests in a conventional manner. In addition, he had a relatively high level of restricted and repeated behaviors.

Table 4

Participant demographics in Group 4

	Child 10	Child 11
Chronological age (months)	12:4 (148)	12:3 (147)
Gender	Male	Male
Social Responsiveness Scale (SRS-2)		
SRS *T*-Score	90 [a]	79 [a]
T-Score Range	Severe	Severe
Social Awareness	67	66
Social Cognition	90	82
Social Communication	89	73
Social Motivation	75	77
Restricted Interests/Repetitive Behavior	90	80
Gilliam Autism Rating Scale (GARS-3)		
Autism Index	116 [b]	114 [b]
DSM-5 Severity Level	Severe	Severe
Overall Percentile Ranks	86	82
Restricted/Repetitive Behaviors	12	13
Social Interaction	12	13
Social Communication	12	12
Emotional Response	13	10
Cognitive Style	11	7
Maladaptive Speech	15	13
Vineland Adaptive Behavior Scales (Vineland-3)		
Adaptive Behavior Composite	49	52
Communication	51	43
Daily Living Skills	41	54
Socialization	44	60
Social Communication Questionnaire (SCQ)		
SCQ Total Score [c]	21	31

**Note:*
[a] Indicates deficiencies in reciprocal SC/I that are clinically significant and lead to severe interference with everyday social interactions. Such scores are strongly associated with a clinical diagnosis of ASD.
[b] Indicates significant amounts of autistic behavior that require very substantial behavioral programming.
[c] A cutoff score of 15 or greater is an indication of a possible ASD.

Settings

This study was conducted over the 2019–2020 school year at a special education school in urban neighborhoods in the northern part of China. The school site represented a wide range of socio-economic statuses and cultural diversity. At least two sessions were individually conducted weekly for each student participant, and each session lasted for at least 30 minutes.

All sessions were conducted one-on-one in a small classroom. The room included a desk, two chairs, a window, and a storage wall shelf with built-in drawers containing teaching materials and toys. During each session, the student sat behind the child-sized desk facing a handheld tablet that contained the learning material. The special education teacher sat diagonally across the desk, and facilitated the baseline assessments, intervention sessions, maintenance, and generalization probes. Meanwhile, this teacher was also responsible for camera recording, preparation of the learning materials, and acting as a role-play partner in response to the student's conversation initiation.

Materials

Qunatiandi (hereafter referred to as, "ABI") is an intervention program and multidisciplinary framework that directly addresses most of the core challenges faced by children with ASD. It was specially developed for this study by the Pacific Rim Research Center affiliated with the University of California, Santa Barbara. The primary investigator of the study participated in the design and realization phases of the program. Java and an existing Android application program interface were used to develop the application to enable the incorporation of sounds, text, pictures, and videos. During the baseline, intervention, and probe sessions, a 16 GB Teclast Tpad P98 tablet running Android 4.4.2

was used to present the course content and behavioral tasks. Figure 3 shows the major screens of the ABI program used in the study.

The ABI program has seven key training domains – SC/I skills, cognition and academic skills, adaptability and regulation skills, facial expression recognition and emotion understanding skills, language skills, behavior assessment and support, and play skills – and 19 subdomains. It is organized into more than 160 targeted skills, each based on an essential skill within a learning theme.

SC/I skills constitute one of the seven major domains, and they offer students a comprehensive curriculum to learn various social skills. Each targeted social skill features its own videos and illustrated Social Stories™ in short animated episodes. The SC/I domain program utilizes EBP, teacher-mediated instruction, visual support, and an embedded adaptive training system where students can engage in interactive activities that assess their ability to identify appropriate social behaviors in various situations. The length of one set of tests ranges from 10 to 20 minutes. An automated data-collection tracking and reporting system that assesses student progress and performance was embedded into the application. This allowed researchers and teachers to be aware of each student's learning situation and procedure, and helped them to make data-based decisions in treatment planning.

Title Screen

Course Selection

Video Modeling

Guided Practice

Figure 3. Sample major screens of the ABI program used in the study.

Pre-intervention Teacher Training

Thorough teacher training is essential to the successful implementation of any behavioral intervention. Teachers require a standardized and manualized guideline that involves well-established and highly structured training stages on how children with ASD should be taught during the intervention program (Allen et al., 2016). This would provide special education practitioners with a better understanding of the criteria, technologies, and teaching approaches used in the ABI, which in turn would enable them to better focus on the implementation fidelity.

All teacher participants in the study were requested to participate in pre-intervention training sessions that taught them the requisite skills for conducting baseline assessments and interventions to ensure consistency in their teaching implementation. Training sessions mainly consisted of two parts: (1) studying a multi-component teaching manual focusing on the key elements of implementing instruction, and (2) giving a trial lecture, which was supervised by the primary investigator, on a given intervention topic.

Teacher-training materials. The training manual included a review of (1) baseline and intervention session procedures, (2) target social skills task analyses, (3) role-playing analyses with operationalized definitions of examples and non-examples of specific behaviors, (4) how to use task analysis to break a skill down into "small, sub-component steps" (Spence, 2003), (5) how to use the ABI application to deliver videos, explain Social Stories™, and assign practice tests to students, (6) how to provide corrective feedback using the correction staircase approach, and (7) how to deliver verbal prompts, physical prompts, and positive reinforcement to achieve appropriate responses from students. In addition, video demonstration and reading materials on DI, ABA, PRT, and other related topics were also available for the teachers' reference.

Trial lecture. To ensure familiarity with the instructional procedure, the teacher participants were asked to give a trial lecture to a student with ASD who was not participating in the study. Subsequently, the investigator identified what each of the teachers in the video clips was doing correctly or incorrectly and provided corrective feedback regarding the implementation of the teaching activities. If the teachers did not meet teaching fidelity, they were given corrective feedback regarding the specific components that required improvement.

Baseline

Baseline assessments were conducted in the classroom and lasted for 20 to 30 minutes. No direct instruction or prompt was delivered to any student participant. Verbal praise was allowed during testing, but not comments on accuracy. The criterion for a stable baseline was that the variability had to be no more than +/-2 behaviors for at least two consecutive sessions.

Role-play. In each role-play assessment, a teacher asked a student to finish two tasks by: (1) performing a role-play scenario with two stuffed toys, and (2) initiating a conversation and asking someone to play a game or play with a set of toys together. Role-play data on the student's self-initiation and question-asking behaviors were collected. Baseline measures were conducted at least three times by the teacher to assess the students' knowledge of acting out the target social behaviors.

Group play sessions. Group play observation is a type of naturalistic behavior observation, which is considered to be the preferred method for most social skills assessment purposes (Farmer-Dougan & Kaszuba, 1999; Spence, 2003; Walker & Severson, 1992). In the current study, each student participant was observed during a 5-minute group play session with three typically developing peers. During the session, the student participant and peers played in a small playroom. Materials that typically promote cooperation and social interaction, such as Lego models and stuffed toys, were used during the interactions. In order to increase the likelihood of student interaction during the observation, only three toy items were placed in front of the four students – i.e., at least one child had to share or invite another to play together. This design encouraged the student participant to initiate requests for toy sharing or exchange and to take turns. Furthermore, the toys were placed out of the children's reach to promote the initiation of requests throughout circle time.

Curriculum-based assessment (CBA). All student participants participated in a CBA by answering a series of adaptive questions that were randomly drawn from the ABI application's test question bank to further check their ability to distinguish, understand, and act out the targeted behaviors. Examples of types of questions include true or false, picture matching, and picture selection (detailed descriptions can be found in the Guided Practice section of Intervention Phase II). Each student's test score was recorded as that student's CBA baseline.

Intervention Phase I: Instruction

The structure and flow of the intervention phase are rooted in learning theories with a purpose to embrace the learning qualities of children with ASD. Well-documented in the literature, individuals with ASD are good at *visual thinking* (Boutot & Myles, 2009; Grandin, 1995; Sansosti & Powell-Smith, 2008; Whalen et al., 2010); they respond well to *concrete and physical exercises* rather than those that have *abstract social meaning* (Quill, 2000). When incorporating instructional strategies to the ABI program, we aimed to provide scaffolding that eases learners' cognitive load (Sweller, 1988). Therefore, the training was designed to proceed in such order – each intervention session included six components: (1) video modeling (*visual thinking*); (2) puppet role-play activities (*concrete and physical exercises*); (3) conversation partner role-play activities (*concrete and physical exercises*); (4) Social Stories™ (*visual thinking and abstract social meaning*); (5) the correction staircase (*abstract social meaning*); and (6) application-based guided practice (*concrete and physical exercises*). Each intervention session consisted of two main parts: instruction and guided practice. Figure 4 illustrates the interaction between the teacher, the application, and the student during the instructional phase. It also summarizes these steps and depicts the role of the ABI application at different stages.

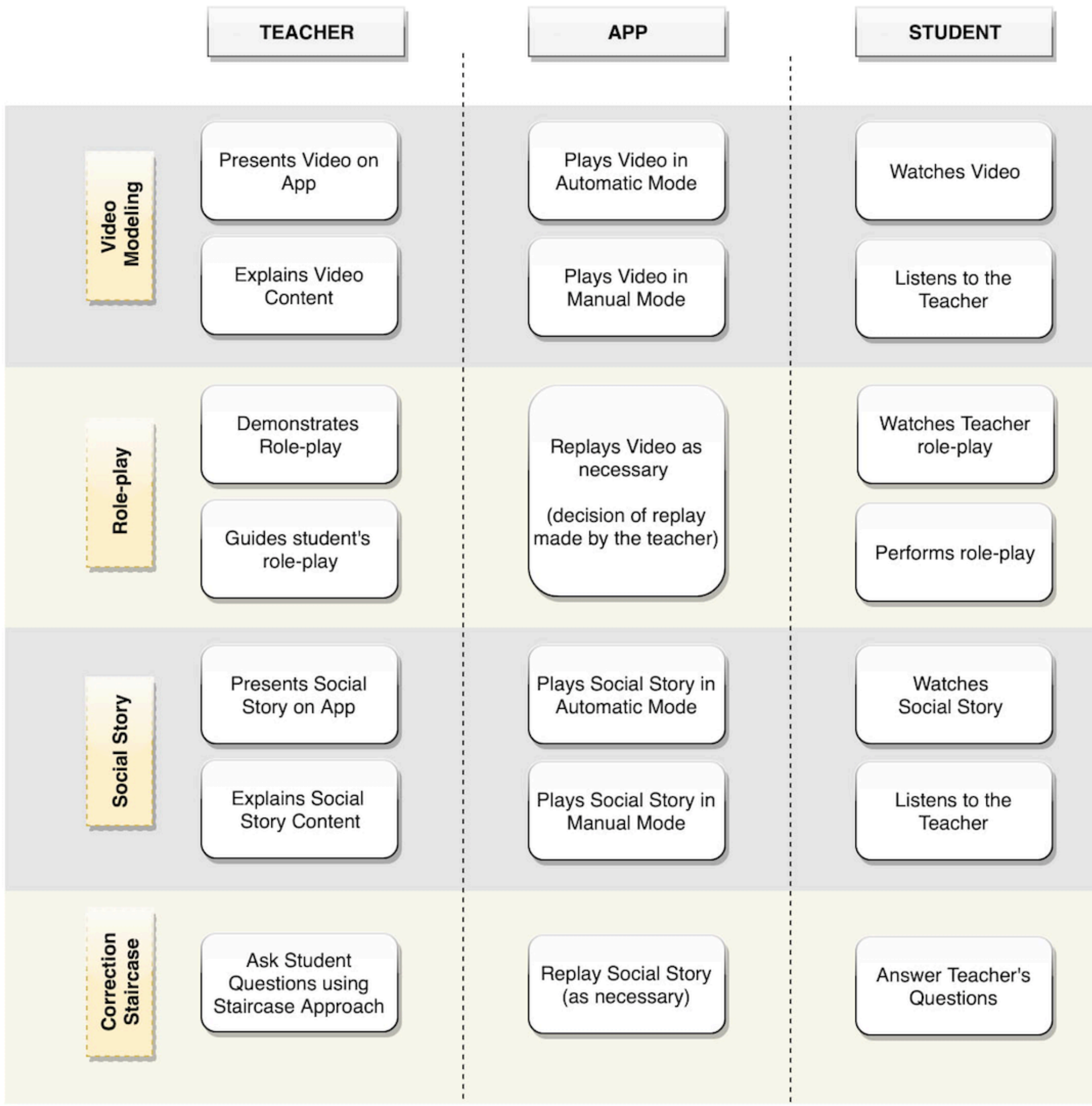

Figure 4. Teacher-application-student interaction during the instructional phase.

At the beginning of the instructional phase, the teacher guided the student in briefly reviewing classroom behavior rules and participation expectations, and then introduced the learning objectives. Each modeling video was 30 to 45 seconds in length, and the main contents were designed according to instructional suggestions from the *TeachTown* Social Skills Curriculum (2005) and *Skillstreaming* (McGinnis & Goldstein, 1997).

As it has been noted in the literature that learning is most likely to occur when a behavior is modeled by a peer of a similar age (Kroeger et al., 2007; LeBlanc et al., 2003; Spence, 2003), two typically developing peers acted as models and were videotaped performing the target behaviors in structured activities similar to the tasks that the student participants engaged in during the baseline and intervention procedures. The videos were individualized to match each student's current developmental level and individual profile of learning strengths and weakness.

All videos and stories were converted into a self-advancing presentation, which was delivered by the ABI application. There was voice-over narration for every slide, and audio instructions were read by a female native Mandarin speaker and were recorded with the tablet's built-in microphone during curriculum development. Once all the pages of a video had been covered, the teacher demonstrated how to perform the role-play activities with two puppets. She then said: "Show me how you will do the toy role play," and asked the student to repeat the role play by himself or herself. After automatically playing the video the first time, the teacher would then display the video clip page by page manually.

Following the video instructions, a brief series of role-play activities was conducted to familiarize the student with the steps in completing a behavior. Table 5 presents the intervention procedures with details on the student-teacher interactions.

Table 5

Intervention procedures in the teaching phase

Instructional module	Teacher guidance	Student behavior
Section 1 Video modeling	The teacher presents the instructive videos on the application and explains the target behavior to the student step by step.	The student watches the video and listens to the teacher's instructions.
Section 2 Puppet role-play activities	Using two stuffed toys, the teacher provides a modeling demonstration of all the behavioral steps that were presented in the video modeling section. She then invites the student to perform a role-play and provides assistance as needed.	The student observes the teacher's role-play demonstration. The student then uses two stuffed toys to present the role-play tasks.
Section 3 Conversation partner role-play activities	The teacher provides a modeling demonstration with the teaching assistant for all the behavioral steps. She then invites the student to role-play with the teaching assistant and provides prompts and assistance as needed.	The student models the teacher's demonstration: making self-introductions and inviting the teaching assistant to participate in a game activity.
Section 4 Social Stories™	The teacher presents the instructive Social Stories™ and explains the target social behavior to the student, step by step.	The student views the Social Stories™ and listens to the teacher's instructions.
Section 5 Correction staircase	The teacher asks at least five questions using the correction staircase approach to test the student's comprehension of the Social Stories™ and provides corrective feedback to the student.	The student answers the teacher's questions.
Section 6 Guided practice	The teacher invites the student to answer questions from the adaptive training system in the *Qunatiandi* application.	The student answers the questions in the application.

Puppet role-play activities. Two types of role-play exercises were included in the ABI program. The first was a role-play of the social situation described in the video section with puppets. After playing the story and video demonstrations, the teacher created opportunities for the student to practice the specific behaviors described using two role-play tasks. First, the teacher introduced a task by verbally describing the situation and target behavior. She then used two puppets to act out the situation.

For example, to introduce oneself to another person, the teacher would (1) pick two puppets from the toy box; (2) place them on the student's desk and give them names; (3) hold one puppet up on the left side of the desk and the other one on the right; (4) pretend to "walk" one puppet slowly towards the other; (5) position the two puppets facing each other, and say: "Hello, my name is Eric. Nice to meet you"; and (6) and reply (as the other puppet): "Hello, my name is Cara. Nice to meet you, too."

After the teacher's demonstration, the student was asked to complete the role-play task. General verbal prompts were delivered if the student had difficulty completing any of the behavioral steps. If a student did not follow the general verbal prompt within five seconds, a gestural prompt would be used; if he or she did not follow the gestural prompt within five seconds, the teacher would add a physical prompt by placing one hand on the student's hand (or puppet) to finish the task. Verbal praise was delivered after successful completion of each task.

Conversation partner role-play activities. Once the student had succeeded in modeling a situation using puppets, the student was designated as a role-play actor with a conversation partner. The teacher, the student, and a caregiver acted out a real-life situation, which ended with a performance of the target behavior. The student was assigned to initiate a conversation with the caregiver and was asked to play the role of a character in the situation while using the relevant skills in real life. In order to enhance the realism of the role-play, the teacher reminded the student of the responsibilities and the manners that the student was expected to practice. The student was told to follow the behavioral steps and verbally express what he or she was thinking. Meanwhile, the teacher would provide the student with help or coaching to sustain the role-play according to the behavioral steps. Verbal prompts were delivered if the student encountered any difficulties, and praise was given after successful completion of the steps.

Table 6 presents an example of the instructions used in the role-play sessions. The target behavioral skills – social greeting, introducing oneself to a new person, and inviting someone to play – were first modeled by the teacher and then carried out by the student.

Table 6

Operational definitions of on-task behavioral steps for role-playing

Behavioral steps	Student responses	Learning outcomes	Data coding
Step 1 Identify a conversation partner (or choose two puppets for role-play).	The student selects a conversation partner whom he or she plans to talk to.	The student is able to choose a person for a conversation.	(+10 points) If the student selects a person whom he or she plans to talk to, or if he or she selects two puppets allotted for the activity.
Step 2 Decide if it is a good time to start a conversation.	The student observes the conversation partner and determines his or her availability to talk. If the conversation partner seems to be busy (e.g., studying), the student should not initiate a conversation.	The student is able to determine the availability of a person and picks an appropriate time to start a conversation.	(+10 points) If the student can determine whether it is a good time to talk to the person. (If the conversation partner is busy, and the student believes it is a good time to talk, 0 points are awarded).
Step 3 Approach the person.	The student walks up to the conversation partner.	The student is able to approach the conversation partner.	(+10 points) If the student walks.
Step 4 Keep an appropriate distance.	The student maintains an appropriate distance from the conversation partner.	The student is able to keep an appropriate distance from the conversation partner.	(+10 points) If the student remains 3 to 5 feet away from the conversation partner.
Step 5 Maintain eye contact.	The student keeps eye contact with the conversation partner.	The student is able to maintain eye contact during conversations.	(+10 points) If the student can maintain at least 5 seconds of eye contact with the conversation partner.

Step 6 Greeting the conversation partner.	The student greets the conversation partner.	The student is able to greet people.	(+10 points) If the student initiates a greeting directed towards the conversation partner when he or she enters the session. A wide variety of greetings are accepted – e.g., “hi” “hello,” or “good morning.”
Step 7 Introduce yourself (e.g., “My name is…”).	The student introduces himself or herself to the conversation partner.	The student is able to make simple self-introductions to other people.	(+10 points) If the student initiates an introduction by providing his or her name and other relevant information.
Step 8 Wait for the conversation partner to tell you his or her name.	The student waits for the conversation partner to make a self-introduction.	The student is able to take turns and wait for the other person to speak.	(+10 points) If the student waits at least 5 seconds for the conversation partner to speak.
Step 9 Suggest a game or an activity to the conversation partner.	The student makes a suggestion or invites the conversation partner to join a game or an activity.	The student is able to make suggestions and invite other people to participate in a game or an activity together.	(+10 points) If the student suggests an activity and asks the conversation partner whether he or she would like to play together.
Step 10 Wait for the conversation partner to reply.	The student waits for the conversation partner’s reply.	The student is able to wait for the other person’s permission.	(+10 points) If the student waits at least 5 seconds for the conversation partner to reply.

Social Stories™. Social perception training is essential because it provides children with ASD with the ability to identify a social problem, and the understanding of how to make an adjustment to their social behavior in order to produce a successful social outcome (Barry & Burlew, 2004; Ivey et al., 2004; Spence, 2003). Therefore, the Social Stories™ section in the ABI was aimed at strengthening the students' social perception skills by teaching them to monitor, discriminate, and identify cues that regard: (1) one's own emotions and feeling, (2) the emotions, perspective, and expectations of others during an interaction, and (3) the social rules of specific situations and contexts.

Specifically, child-specific Social Stories™ were designed to target the student participants' social perception ability. The stories consist of a written script depicting a real-life situation (e.g., making a new friend) and include responses that the students were expected to make. The Social Stories™ included in the application were developed according to Carol Gray's (2000) guidelines, using descriptions of environmental and behavioral cues, directive statements, and other's thoughts and feelings. They include pictures illustrating the behavioral skills and cue components. The stories range from eight to ten pages in length. On each page, only one sentence and an accompanying scene were presented on the tablet screen, allowing the student to process one concept or one behavioral step at a time. A margin on the left side of the ABI application screen contained color-boxes that the teacher could use to circle important cues and information from the video clips. These boxes were presented not only because children with ASD tend to respond well to visual stimuli (Boutot & Myles, 2009; Sansosti & Powell-Smith, 2008; Whalen et al., 2010), but also to increase the communicative potential of the Social Stories™, making them more interactive for the students and helping them to focus on the training materials.

Correction staircase. After playing the Social Stories™ twice, the teacher would ask at least five questions about the story to check the student's comprehension. Example questions were written for each story and were included in the teaching manual for reference. If a student did not provide a correct answer or any answer in general, that student would be directed to a lower level of phrasing by the correction staircase approach.

According to Gerber et al. (2004), the correction staircase approach is based on the core intervention model grounded in DI. The approach (Gerber et al., 2004; Leafstedt et al., 2004) includes four levels of questions, in decreasing order of difficulty: (1) supply, (2) binary choice, (3) model-lead, and (4) model-imitation.

First, the teacher would generate a supply question with a brief description of the social situation (e.g., "I would like to play with that new student. What should I tell her?"), and let the student construct his or her own response. If the student was unable to respond correctly or at all, the teacher would decrease the difficulty level of the question by generating a binary choice question and let the student identify the correct option – for example: "Should I say, 'Can we play together?' or say, 'Thank you.'?" If the student answered correctly, the teacher would then increase the difficulty by once again asking the original supply question.

In contrast, if the student could not respond correctly to the binary choice question, the teacher would decrease the difficulty level further to a model-lead question. In this level of questioning, the teacher first models the correct answer, then asks the student's opinion. For example, the teacher would say: "I think we should say, 'Can we play together?'. What do you think?" Again, if the student responded correctly, the teacher would revert to the binary choice question format and continue upwards until the student could answer the original supply question.

However, if the student gave the wrong answer to the model-lead question, the teacher would continue to decrease the difficulty level to a model-imitation question. This is the easiest type of question, as the student would be prompted to imitate the teacher's answer by simply repeating what the teacher said. For example, the teacher would say: "Can we play together?" The student would be prompted until he or she successfully repeated the exact same sentence. After this, the teacher would use the next highest level of questioning, until the student reached the original supply question. Figure 5 presents an example of the correction staircase approach used in conjunction with Social Stories™.

Interactive Color-box	Sample Instructional Script	Correction Staircase Questions
- The teacher circled the handshake gesture on the screen using the color-box and explained what the gesture means. - The teacher drew an arrow pointing to the actress's eyes and explained the importance of making eye contact when introducing oneself.	- Now we will learn how to introduce yourself to a new friend. You can try to make eye contact with other people; you can also perform a handshake to show that you are a warm and friendly person. - Please repeat after me. Say: "Eye contact" and "handshake".	- Top level (supply question): "I would like to say hello to my new friend. While talking to her, where should my eyes look?" - Third level (binary choice): "Should I make eye contact with my new friend, or should I look at the floor?" - Second level (model-lead): "I think we should make eye contact with the new friend; what do you think?" - Bottom level (model-imitation): "Say, 'eye contact'."

Figure 5. An example of the staircase for the Social Stories^{TM} instruction.

Intervention Phase II: Guided Practice

After completing the instruction phase, the teacher would begin the guided practice section and invite the student to touch the screen of the directions page when ready. The main responsibility of the teacher during the guided practice section was to monitor the student's study process and provide physical or verbal prompts as necessary. The student spent most of the time interacting with the ABI application and responding to various types of questions. On each page of the adaptive test, a scene or object was shown in pictures, with a short text question and either one or four response icons at the bottom of the screen. The student had to complete three to five items correctly in each section in order to advance to the next scene. Correct answers were rewarded with a voice message saying, "great job," and an animation of the student's preference. Incorrect responses elicited a "no worries; please try again" voice clip, and the student was given a second chance to choose.

Figure 6 describes a typical guided practice exercise for a student, the interaction with the ABI application, and the role of the teacher. The diagram depicts three stages – *distinguishing*, *comprehending*, and *expressing* – and illustrates the interaction between the student and the application. It also presents the decision-making stages of the application, which enables it to decide when the student is ready for the next stage. For the first two stages, the teacher observed while the student independently interacted with the application, and the teacher provided physical or verbal prompts when necessary. During these two stages, the application determined whether to advance to the next stage based on the student's learning situation. In the final stage, the teacher actively analyzed the student's learning situation and decided whether the student had completed the task satisfactorily. If the goal was met, the guided practice phase would be terminated.

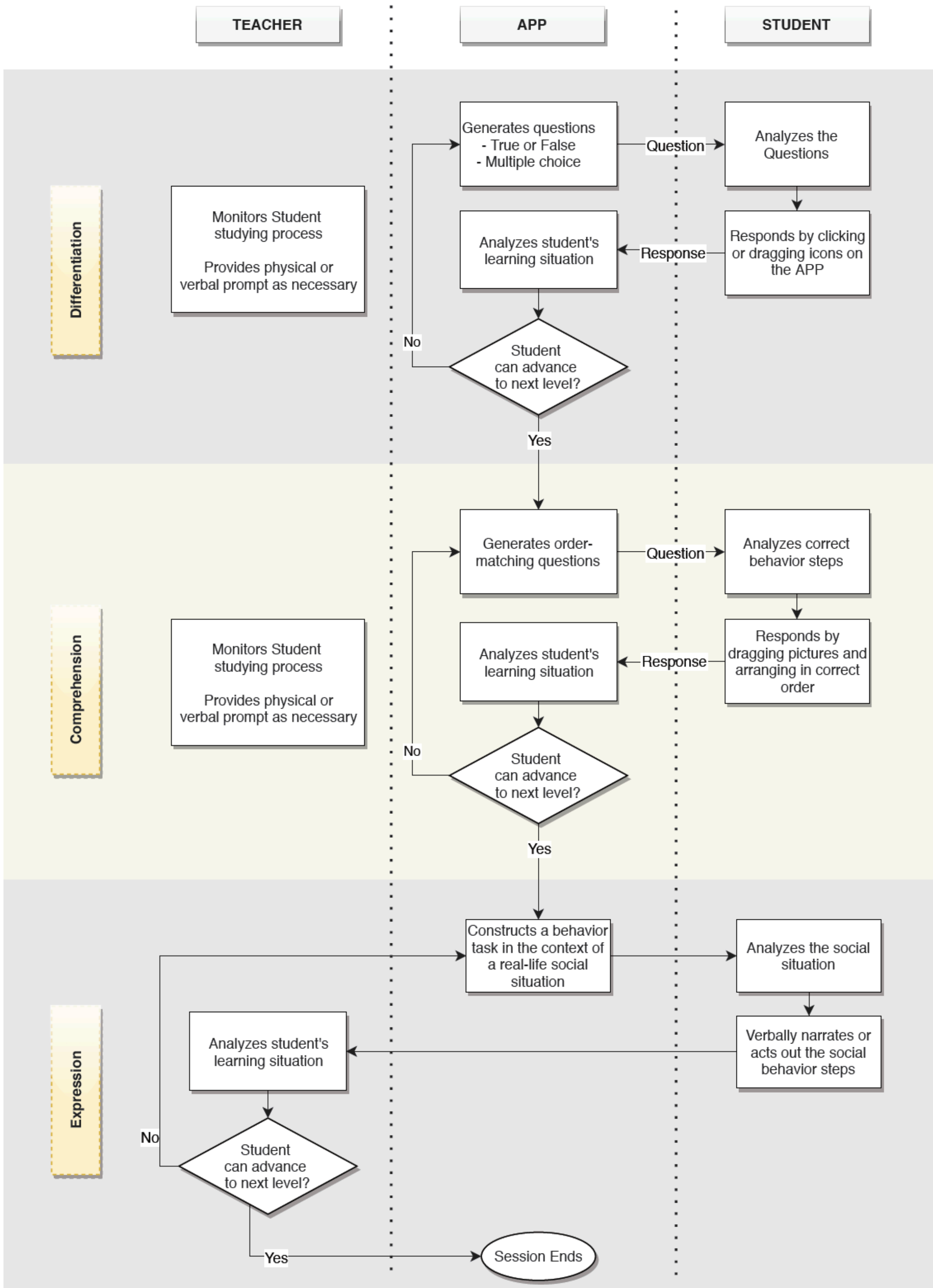

Figure 6. Teacher-application-student interaction during the guided practice phase.

During the guided practice phase, the ABI application generated and asked the students to respond to three major categories of scenario-based questions: behavior distinguishing, behavior understanding, and behavior expressing.

Behavior distinguishing. A particular challenge for children with ASD is the inability to make critical distinctions when exposed to new learning content (Arick et al., 2004). The ABI program focuses on identifying issues by presenting stimuli in a systematic manner, with planned repetition by the embedded adaptive training system. The goal is to help students identify correct or appropriate behavioral steps in a social situation. In the program, each question highlighted several steps of various behaviors; the student needed to choose the one that corresponded to the target behavior. For example, the question "Is this picture showing a correct step for making a self-introduction? Yes or No" would be accompanied by several pictures for the student to select from. For each correct answer, the application would deliver verbal praise along with a smiley face or cartoon graphic and would then proceed to the next question. All data were collected automatically by ABI.

In the ABI program, three types of questions were presented under behavioral distinguishing: (1) true or false, (2) picture matching, and (3) picture selection.

True or false. This type of question measures the student's ability to determine if a behavior depicted by the pictures is correct (or appropriate) in a specific situation. For example, the task direction might ask: "Is it an appropriate time to make a self-introduction to others?" The student would be shown a photograph of a situation in which one child was busy doing homework, and another child was wondering whether to interrupt him/her or not. The student would then be asked to determine if this behavior matched the task direction and to click on the appropriate icon at the bottom of the screen.

Picture matching. In the ABI application, picture matching follows a hierarchy from the easiest level (using identical pictures) to more complex and abstract matching tasks using representational pictures. As students advanced in the matching activities, they were able to connect a correct behavioral step (e.g., shaking hands) to pictures that also represented a correct behavioral step (e.g., making eye contact when talking). Students were provided with the scaffolding needed to develop their skills in discriminating target behavioral steps through the use of a progression of picture matching activities based on ABA techniques. There are three types of picture matching questions based on the number of possible choices (two to four). For example, in a three-picture matching question, the first screen contains four images. A prompt picture starting with the target behavior is placed in the top row, and three possible choices are placed horizontally across the bottom of the screen. After the task direction was delivered by the application, the student would identify the correct choice by dragging one bottom-row picture to match the top-row one.

Picture selection. As with the picture matching questions, the ABI application also has three types of picture selection questions based on the number of possible choices (two to four). The difference in the picture selection question task is the absence of the prompt picture in the top row of the screen, which had provided a hint for the student in the picture matching task. Therefore, the students had to select from the possible choices based solely on their own judgment. In addition, the choices for each question were randomly ordered from a large pool of pictures, hence students were unlikely to see the same picture screen in many runs through the adaptive testing sessions.

Behavior understanding. This is the second category of questions presented by the ABI application during the guided practice. Sequencing is one skill that contributes to a student's ability to comprehend what they have learned (Arick et al., 2004). It refers to the identification of the components of a story (i.e., beginning, middle, and end), as well as the ability to retell the event in a given context following the order in which the component parts occurred. The ability to sequence events in a text is a key comprehension strategy. Teaching students with ASD to understand the importance of the ordering of events deepens their comprehension and enables them to retell a narrative in a manageable way. When children begin to tell stories, their ability to form a plot depends on their understanding that the events happened in a fixed order.

In the behavior understanding questions, the ABI application presented a series of picture sequencing activities and asked the students to arrange three or four pictures in a logical order depicting the beginning, middle, and the end of an event in order to build their sequencing skills with regard to a target behavior. The goal was to help students understand and identify the correct sequence of conducting a behavior and to provide an opportunity for them to demonstrate and reinforce their recollection of a behavioral task. Each question included several pictures that represented the steps taken in order to complete a task, and the student needed to complete a series of picture sequencing tasks. An example set of instructions is as follows: "Karen wants to introduce herself to a new classmate. Please arrange the order of the following four steps in order to help her to finish the task."

Behavior expressing. This is the last category of questions presented during the guided practice phase. Unlike the first two categories, this type of practice requires the teacher's participation and judgment to assess the student's learning level. The student was given a real-life situation by the ABI application and asked to complete the task either by verbally describing the behavioral steps or by acting out the steps. The teacher used the application's embedded camera/video function to record the student's performance. As the final step of the intervention, the teacher then determined whether to provide further assistance or instruction, or to end the session for that day.

Dependent Measures and Data Collection

The purpose of dependent measures and data collection was to help the researcher and the teachers in making individualized training decisions for the student participants. Each lesson in the ABI application provided a system to collect appropriate data for ongoing decision-making and a summary of students' progress.

Guided practice. The target behavior was defined as the receptive clicking or dragging of the correct icons on the tablet screen that corresponded to the target skills (e.g., social greeting, self-introduction, and invitation for others to play). This ensured that the student was in fact making distinct choices among the various behaviors. The dependent variable is the percentage of correct receptive identification responses for the target skill during each session.

Three potential responses were automatically recorded by the ABI application during training. (1) 'Correct' indicates that the student clicked or dragged the correct answer within five seconds after the task directions were delivered. The criterion to move on to the next level of questions was whether the participant had selected the correct answers three consecutive times. (2) 'Incorrect' means that the student clicked or dragged the wrong answer within five seconds after the task directions were given. (3) 'No response' means that the student did not touch or failed to touch any correct or incorrect answer within five seconds after the task directions were delivered.

Role-play activities. For real-people role-play sessions, a target social interaction was defined as: (1) verbal, physical, or gestural initiation and response to the conversation partner; (2) social greetings, self-introduction, and use of appropriate social vocabulary to invite the conversation partner to join a play activity; and (3) physical gestures such as walking towards the conversation partner and making eye contact. Operational definitions were developed, and two graduate student researchers watched the video clips and documented examples and non-examples of the behaviors according to the definition of each behavioral step.

Scores were based on the type of response, with the following codes used: (1) independent response, (2) verbally prompted, and (3) physically assisted. An independent response was defined as the completion of a role-playing task without any external verbal prompts or physical assistance from the teacher. The teacher gave verbal prompts when the student did not respond to the task within five seconds. Physical assistance was provided when the participant did not respond to verbal prompts after five seconds.

Measurement of Fidelity

Video clips of experiment sessions, which include baseline collection, intervention, maintenance, and generalization probes for each student participant, were reviewed and scored for teaching implementation fidelity. The teachers' adherence to the teaching protocol was monitored through a teaching implementation fidelity checklist (Table 7) created by the primary investigator. The checklist outlines the major components to ensure that each teacher conducted and implemented all intervention sessions according to the teaching manual. Teachers were observed and scored so that they would be able to implement the intervention with at least 80% procedural fidelity during the selected probes.

Table 7

Teaching implementation fidelity checklist

Category	Description	Score			
Class preparation and evaluation					
Equipment	Tablets with the required application	N/A	0	1	2
	Video recording equipment	N/A	0	1	2
	Several stuffed toys/puppets	N/A	0	1	2
Classroom	Visual and aural distractions are minimized	N/A	0	1	2
	Intervention sessions consistently occur in designated areas	N/A	0	1	2
Evaluation	Select appropriate tests (probes) from the ABI application's question bank for the student	N/A	0	1	2
	Implement curriculum-based assessment (CBA)	N/A	0	1	2
	Make instructional decisions based on the types of disabilities, level of severity, and results from the CBA and other measures	N/A	0	1	2
Teaching methodologies					
Task Analysis	Determine a target task for the student to perform	N/A	0	1	2
	Break the task down into smaller steps	N/A	0	1	2
	Decide what order to teach the steps in	N/A	0	1	2
	Teach one step until the student masters it	N/A	0	1	2
	Add each step into a chain until the task is completed	N/A	0	1	2
Staircase	Generate supply questions	N/A	0	1	2
	Generate binary choice questions when necessary	N/A	0	1	2
	Generate model-lead questions when necessary	N/A	0	1	2
	Generate model-imitation questions when necessary	N/A	0	1	2
	Prompt the student at a lower level of phrasing and provide corrective feedback	N/A	0	1	2
	Prompt the student at a higher level of phrasing	N/A	0	1	2
Prompts	Full physical prompt	N/A	0	1	2
	Partial physical prompt	N/A	0	1	2
	Gestural prompt	N/A	0	1	2
	Positional prompt	N/A	0	1	2

	Visual prompt	N/A	0	1	2
	Full verbal prompt	N/A	0	1	2
	Phonemic prompt	N/A	0	1	2
Reinforcement	Praise and non-verbal communication	N/A	0	1	2
	Tangibles (e.g., stickers)	N/A	0	1	2
	Activities and privileges (e.g., playing a game)	N/A	0	1	2
	Application-based reinforcement (e.g., cartoon)	N/A	0	1	2
Teaching procedure					
Introductions	Review rules and expectations of classroom participation	N/A	0	1	2
	Auto-play videos twice	N/A	0	1	2
	Demonstrate puppet role-play	N/A	0	1	2
	Direct the student to imitate puppet role-play, and provide performance feedback and assistance	N/A	0	1	2
	Cooperate with a conversation partner for human role-play demonstration	N/A	0	1	2
	Direct the student to imitate human role-play, and provide performance feedback and assistance	N/A	0	1	2
	Manually play the video, pausing when necessary, and explain key behavioral steps to the student	N/A	0	1	2
Social Stories™	Auto-play the social story twice	N/A	0	1	2
	Manually play the social story and use the interactive color-box to emphasize specific behaviors, gestures, and facial expressions	N/A	0	1	2
	Explain the content of the social story, environmental and behavioral cues, and responses that the student is expected to make	N/A	0	1	2
	Use the correction staircase approach at the end of the social story to check the student's understanding	N/A	0	1	2
Guided practices					
	Explain and direct the student to finish the guided practice sessions	N/A	0	1	2
	Teach the hand movements (e.g., dragging an item on the screen) used to operate the application	N/A	0	1	2
	Facilitate the student's practice with the ABI application and provide prompts when necessary	N/A	0	1	2

*Scoring key: implemented = 2; partially implemented = 1; did not implement = 0; not applicable = N/A.

Reliability

Coded data was collected by a special education master's student in a university in China who acted as an assistant for the project; she (the assistant) served as the contact person between the partner school in China and the primary investigator in the US. She was responsible for making logistical arrangements, monitoring teachers' intervention procedures and progress, and ensuring the treatment quality of the ABI program. To ensure scoring reliability, approximately 25% of experiment tapes were viewed and scored by two graduate researchers who are naïve to the hypotheses of this study. The reliability-check sessions were first randomly selected from the baseline assessments, interventions, and follow-up probes, and then presented to both researchers in a random order to control for observer drift. The researchers participated in a video analysis, following the observation and scoring procedures based on the dependent variable description. Observations were conducted by both researchers to measure the reliability of the number of student attempts, conversation initiations, role-play performances, and teaching procedures.

An observation agreement was reached when both researchers recorded an occurrence or a non-occurrence in the same interval for each data probe. Inter-observer agreement (IOA) was then calculated for each variable by dividing the number of agreements by the total number of agreements plus disagreements and multiplying the results by 100. The IOA ranged from 82% to 100% (M = 89%) for child 1, 80% to 100% (M = 94%) for child 2, 87% to 100% (M = 93%) for child 3, 80% to 100% (M = 94%) for child 4, 82% to 100% (M = 89%) for child 5, 74% to 100% (M = 89%) for child 6, 80% to 100% (M = 94%) for child 7, 74% to 100% (M = 89%) for child 8, 67% to 100% (M = 93%) for child 9, 87% to 100% (M = 93%) for child 10, and 74% to 100% (M = 88%) for child 11.

Chapter 4: Results

This chapter begins by presenting the statistical results, which are divided into: (1) sample descriptive statistics, (2) dependent variables and choice of analysis, and (3) tests of hypotheses: between-group comparisons for both treatment and waitlist groups. The chapter closes with a demonstration of the SSD multiple probe design results for analysis across baseline, intervention, maintenance, and generalization portions of the study.

Sample Descriptive Statistics

The statistical portion of the study compared the two treatment approaches using an RCT pretest-posttest research design. Participants who received the TAU treatment were subsequently referred to as the waitlist group, while participants who received the ABI program were referred to as the treatment group. Nineteen participants were examined in this study. The quantitative results section begins with a description of the sample and tests used to determine if the randomly assigned groups were equivalent. There are alternative ways of analyzing data from research designs like the ones used in this study, and this chapter goes on to explain the choice of permutation tests and Mann-Whitney *U* tests that avoid the violation of statistical assumptions that are associated with ANCOVA approach, and that have been selected for use in this study because of the small sample size available for analysis. The discussion of the results then turns to the outcomes of the nonparametric analyses used to compare the treatment and waitlist groups. All statistical analyses were performed using MATLAB (version 9.5; MATLAB, 2018) and IBM SPSS (version 26; IBM Corp, 2019) with the exception of measures of effect strength for Mann-Whitney *U* analyses which were performed using G*Power (version 3.1.9.2; Faul et al., 2007).

Eight student participants comprised the waitlist group, consisting of three females (37.5% of the waitlist group) and five males (62.5% of the waitlist group). Ages of participants in the waitlist group ranged from 82 to 143 months with a mean of 120.38 months (*SD* = 23.18). Eleven participants were assigned to the treatment group, consisting of two females (18.2% of the treatment group and nine males (81.8% of the treatment group). Ages of participants in the treatment group ranged from 101 months to 175 months with a mean of 142.09 months (*SD* = 29.54). Participants in the treatment group received between 3 and 11 sessions on topic 1 with a mean of 6.45 sessions (*SD* = 2.70), between 3 and 6 sessions on topic 2 with a mean of 4.45 (*SD* = 1.04), and between 6 and 16 total sessions with a mean of 10.91 sessions (*SD* = 3.42).

It should be noted here that one participant in the treatment group (Case ID = 1) displayed an extremely unusual combination of Vineland-3 ABC pretest and posttest scores. This bivariate outlier was assessed using the Mahalanobis distance statistic (*D*) which was evaluated for significance against the chi-square distribution. With $df = 2$ (the number of variables used in calculating *D*), the obtained value of $D = 11.36$ reached significance at $p < .005$. As will be discussed later, this statistically aberrant combination of Vineland-3 pretest and posttest scores caused the participant to fail one of the subsequent tests of the statistical assumptions for the analysis to be used in comparing treatment and waitlist groups on the Vineland-3. The participant's scores were deleted and were not used in the analysis of that variable. Consequently, in the analysis of Vineland-3 data, there were 8 students in the waitlist group and only 10 participants in the treatment group.

Group equivalence at pretest. The groups were compared on their pretest characteristics to evaluate the success of the random assignment process in establishing equivalent groups. The groups did not differ significantly in their gender composition, χ^2(1, N = 19) = 0.89, p = .345, nor was there a significant difference in the mean ages of the groups, t(17) = 1.72, p = .103 (two-tailed). Table 8 provides descriptive statistics at pretest and posttest for each group on the study's dependent variables – SRS-2 T-score, GARS-3 Autism Index, Vineland-3 ABC, and SCQ total score. Differences at posttest will be discussed later with the focus here on pretest differences that might suggest a failure of the randomization process to establish equivalent groups. Two-tailed independent-samples t-tests showed that the groups did not differ significantly at pretest on SRS-2 T-scores, t(17) = 0.77, p = .456, GARS-3 Autism Indexes, t(17) = 0.25, p = .809, or SCQ total scores, t(17) = 0.87, p = .395. However, the treatment group (with the outlier discussed above having been deleted) scored significantly higher than the waitlist group on pretest Vineland-3 ABC, t(16) = 2.89, p = .011, indicating that the random assignment of participants to groups was not completely successful in creating equivalent groups.

Table 8

Descriptive statistics for dependent measures

	Waitlist Group (*n* = 8)				Treatment Group (*n* = 11*)			
	Pretest		Posttest		Pretest		Posttest	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
SRS-2	83.75	7.36	79.63	10.24	81.00	8.01	68.91	8.95
GARS-3	103.75	11.13	90.38	16.15	102.64	8.65	76.18	9.23
Vineland-3	45.88	13.27	59.63	16.83	61.30	9.39	72.90	17.84
SCQ	25.13	7.16	22.25	7.36	22.00	8.08	13.45	6.99

**Note:* there were 11 participants in the treatment group except on the Vineland-3 variable, for which there were only valid data from 10 cases at both pretest and posttest.

Dependent Variables and Choice of Analysis

On the SRS-2, GARS-3, and SCQ instruments, higher scores indicate lower functioning and lower scores indicate higher functioning. This pattern is reversed on the Vineland-3 where higher scores reflect higher functioning and lower scores reflect lower functioning. Table 8 provides descriptive statistics for the dependent variables at pretest and posttest for the waitlist and treatment groups. The use of four dependent variables would normally suggest a univariate approach (e.g., ANCOVA) to comparing the treatment and waitlist groups. After testing a substantial number of statistical assumptions associated with the one-way between-subject ANCOVA, violations were found on (1) normally distributed residuals of SRS-2, and (2) homogeneity of regression slopes of GARS-3 and SCQ. Violations of these assumptions may distort the exact significance levels that are output when the statistically adjusted posttest scores are compared between groups. In addition, the relatively small sample size that was available for analysis in this study precluded the effective use of this procedure. Two nonparametric statistical tests were used to compare the randomly assigned treatment and waitlist groups at pretest and posttest on each of the four outcome measures. These two tests were a random permutation test (also known as a Monte Carlo permutation test or an approximate permutation test) and the Mann-Whitney *U* test (also known as the Wilcoxon Rank-sum test). The independent variable in all analyses was *Groups*, with two levels defined by the treatment group, which received ABI, and the waitlist group which received TAU. Dependent variables in the analyses were the scores on the SRS-2 *T*-test, GARS-3 Autism Index, Vineland-3 ABC, and SCQ total score.

The random permutation test and the Mann-Whitney *U* test are two widely recognized nonparametric procedures in the behavioral and biological sciences that have been popularly embraced by researchers comparing two groups of observations in situations where parametric alternatives were unavailable due to deviation from assumptions (Campos et al., 2015; Edgington, 1969; Fay & Proschan, 2010; Kasuya, 2001; Mann & Whitney, 1947; Nachar, 2008). They are ideal for analyzing quantitative data that do not satisfy statistical assumptions underlying parametric tests (Collingridge, 2013), especially for small samples of subjects (fewer than 20 participants). The test statistic of the random permutation test is the difference between the average of the posttest scores and the average of the pretest scores for each of the four assessments. The Mann-Whitney U combines data from both groups, ranks the n raw scores from the lowest (ranked = 1) to the highest (ranked = n), and then evaluates the statistical significance of the difference between the mean ranks of the two groups.

Tests of Hypotheses Using Random Permutation Tests

For each random permutation test, posttest and pretest scores for a given measure were randomly assigned to either the waitlist group or the treatment group and the test statistic was calculated based on this permutation of the data. This permutation procedure was repeated 10,000 times by a custom MATLAB script, and the resulting test statistic values were tabulated and used to construct the null sampling distribution against which the observed value of the test statistic was compared. After the null sampling distributions was constructed, a one-tailed test of the null hypothesis was performed by mapping the observed value of the test statistic onto the corresponding sampling distributions and determining the fraction of the sampling distribution that rests between the observed value of the test statistic and the end of the tail. When analyzed with the random permutation tests, two of the four measures yielded statistically significant results in favor of the ABI treatment over TAU in improving the SC/I skills of the participants.

SRS-2 Data. Data on the SRS-2 demonstrated a mean change in performance between post- and pretests of -4.13 ± 3.77 SEM compared to -12.09 ± 2.24 SEM for TAU, $p = .038$ (one-tailed).

GARS-3 Data. Data on the GARS-3 demonstrated a mean change in performance between post- and pretests of -13.38 ± 4.40 SEM compared to -26.45 ± 4.26 SEM for TAU, $p = .030$ (one-tailed).

Vineland-3 Data. Data on the Vineland-3 demonstrated a mean change in performance between post- and pretests of 13.75 ± 4.11 SEM compared to 11.60 ± 3.20 SEM for TAU, $p = .397$ (one-tailed).

SCQ Data. Data on the SCQ demonstrated a mean change in performance between post- and pretests of -2.88 ± 2.39 SEM compared to -8.54 ± 3.82 SEM for TAU, $p = .136$ (one-tailed).

Tests of Hypotheses Using Mann-Whitney *U* Tests

When analyzed with the Mann-Whitney *U* tests, three of the four measures yielded statistically significant results in favor of the ABI treatment over TAU in improving the SC/I skills of the participants.

SRS-2 Data. Data on the SRS-2 from participants of the TAU and ABI groups at pretest and posttest are summarized in Figure 7 – a scatterplot in which the pretest scores are represented along the horizontal axis, and posttest scores are represented along the vertical axis. Individuals whose conjoint pretest and posttest scores are plotted above the diagonal line showed increases (declines in functioning) from pretest to posttest. Those plotted below the line showed decreases (improved functioning) from pretest to posttest. Those plotted on the diagonal showed no change from pretest to posttest. Among treatment group participants, all 11 (100%) showed decreases in scores from pretest to posttest (improved functioning). Among the eight waitlist group participants, three (37.5%) scored lower (improved functioning), three (37.5%) scored higher (decreased functioning), and two (25%) showed no change from pretest to posttest.

Pretest comparison. The between-group difference between the waitlist group (*M* = 83.75, *SD* = 7.36, mean rank = 11.25) and the treatment group (*M* = 81.00, *SD* = 8.01, mean rank = 9.09) was small and not statistically significant, *U* = 34.00, *z* = 0.83, *p* = .221 (one-tailed). The groups can be considered to have been equivalent on the SRS-2 at pretest making a posttest comparison readily interpretable.

Posttest comparison. At posttest, the difference between the waitlist group (*M* = 79.63, *SD* = 10.24, mean rank = 13.19) and the treatment group (*M* = 68.91, *SD* = 8.95, mean rank = 7.68) was larger than the pretest difference and statistically significant, *U* = 18.50, *z* = 2.11, *p* = .017 (one-tailed). It was concluded that the treatment group functioned at a significantly higher level than the waitlist group at posttest, as measured by the SRS-2. Cohen's measure of effect strength *dz* = 1.11 indicated that the posttest treatment effect was quite strong. Figure 8 provides a graphic summary of SRS-2 means at pretest and posttest as a function of group membership.

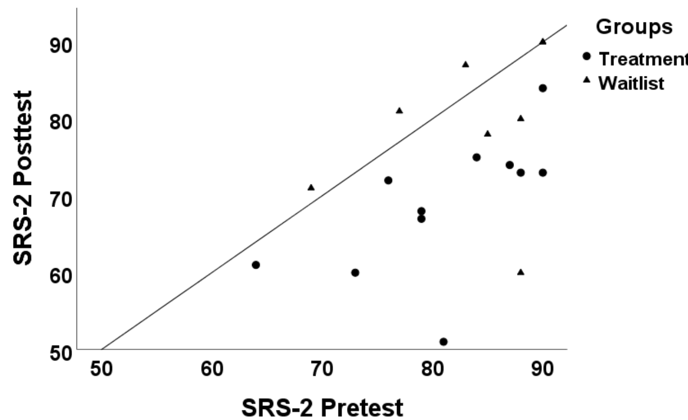

Figure 7. Scatterplot of individual scores on the SRS-2 at pretest (horizontal axis) and posttest (vertical axis) for participants in the treatment and waitlist groups.

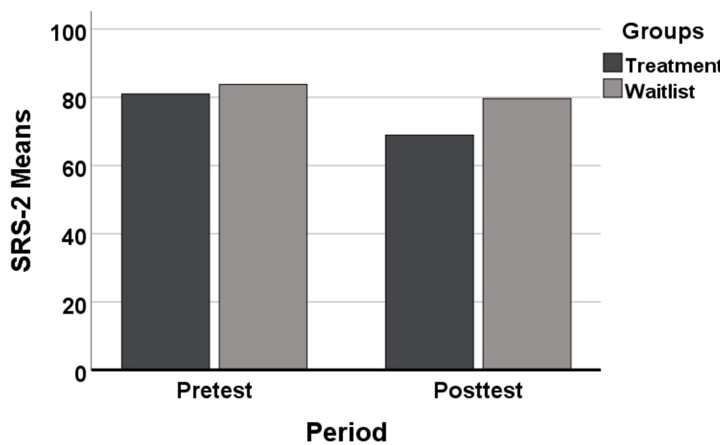

Figure 8. SRS-2 means at pretest and posttest for the treatment and waitlist groups.

GARS-3 Data. Data on the GARS-3 from individual members of the waitlist and treatment groups at pretest and posttest are summarized in Figure 9 – a scatterplot in which pretest scores are represented along the horizontal axis and posttest scores are represented along the vertical axis. Individuals whose conjoint pretest and posttest scores are plotted above the diagonal line showed increases (declines in functioning) from pretest to posttest. Those plotted below the line showed decreases (improved functioning) from pretest to posttest. Those plotted on the diagonal showed no change from pretest to posttest. Among 11 treatment group participants, all 11 (100%) showed decreases in scores from pretest to posttest (improved functioning). All eight (100%) waitlist group participants also scored lower (improved functioning) at posttest than pretest.

Pretest comparison. The between-group difference between the waitlist group (M = 103.75, SD = 11.13, mean rank = 10.63) and the treatment group (M = 102.64, SD = 8.65, mean rank = 9.55) was small and not statistically significant, U = 39.00, z = 0.42, p = .359 (one-tailed). The groups can be considered to have been equivalent on the GARS-3 at pretest making a posttest comparison readily interpretable.

Posttest comparison. At posttest, the difference between the waitlist group (M = 90.38, SD = 16.15, mean rank = 10.63) and the treatment group (M = 102.64, SD = 8.65, mean rank = 9.55) was larger than at pretest and was statistically significant, U = 16.50, z = 2.28, p = .010 (one-tailed). It was concluded that the treatment group functioned at a significantly higher level than the waitlist group at posttest, as measured by the GARS-3. Cohen's measure of effect strength dz = 1.08 indicated a strong treatment effect at posttest. Figure 10 provides a graphic summary of GARS-3 means at pretest and posttest as a function of group membership.

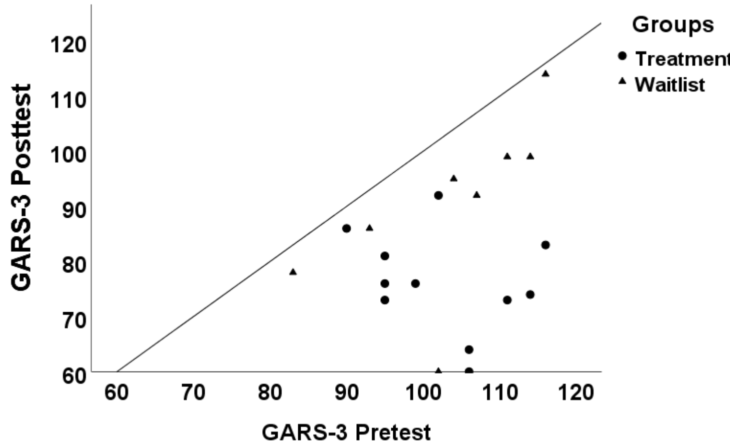

Figure 9. Scatterplot of individual scores on the GARS-3 at pretest (horizontal axis) and posttest (vertical axis) for participants in the treatment and waitlist groups.

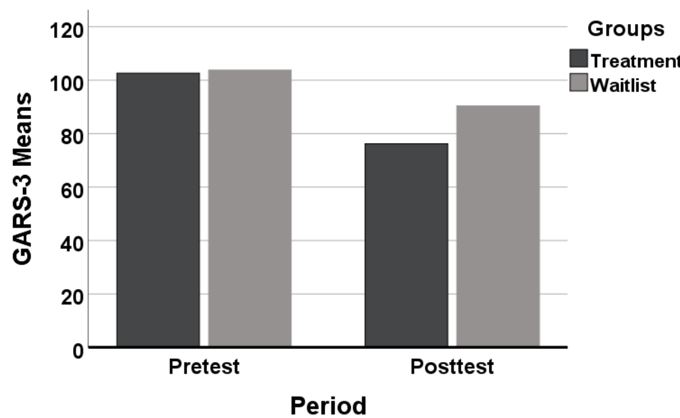

Figure 10. GARS-3 means at pretest and posttest for the treatment and waitlist groups.

Vineland-3 Data. Data on the Vineland-3 from individual members of the waitlist and treatment groups at pretest and posttest are summarized in Figure 11 – a scatterplot in which pretest scores are represented along the horizontal axis and posttest scores are represented along the vertical axis. Individuals whose conjoint pretest and posttest scores are plotted above the diagonal line showed increases (improvements in functioning) from pretest to posttest. Those plotted below the line showed decreases (decreased functioning) from pretest to posttest. Those plotted on the diagonal showed no change from pretest to posttest. Among the 10 treatment group participants for whom Vineland-3 data were available, 9 (90%) showed increases in scores from pretest to posttest (improved functioning) and one (10%) showed no change from pretest to posttest. Six of the eight waitlist participants (75%) scored higher (improved functioning) at posttest than pretest, and two (25%) scored lower (decreased functioning) at posttest than pretest.

Pretest comparison. The between-group difference between the waitlist control group (M = 45.88, SD = 13.27, mean rank = 6.50) and the treatment group (M = 61.30, SD = 9.39, mean rank = 11.90) was small and not statistically significant, U = 16.00, z = 2.14, p = .017 (one-tailed). It was concluded that the treatment group was significantly higher functioning than the waitlist control group even at pretest. This fact needs to be taken into consideration when evaluating the posttest difference between the groups.

Posttest comparison. At posttest, the difference between the waitlist group (M = 59.63, SD = 16.83, mean rank = 7.31) and the treatment group (M = 72.90, SD = 17.84, mean rank = 11.25) still favored the treatment group, but was no longer statistically significant, U = 22.50, z = 1.56, p = .061 (one-tailed). Figure 12 provides a graphic summary of Vineland-3 means at pretest and posttest as a function of group membership.

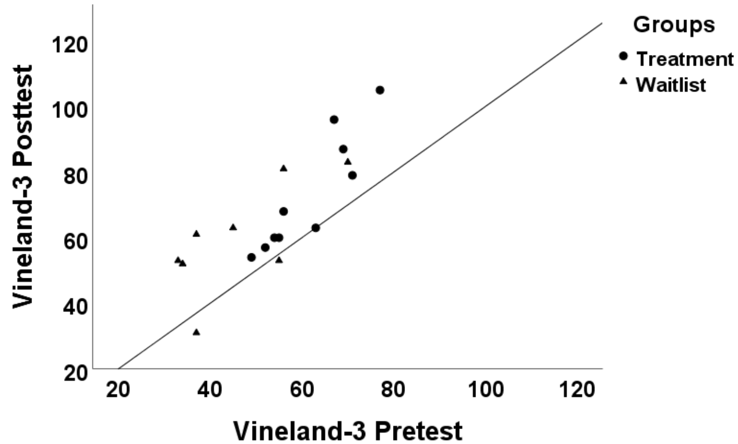

Figure 11. Scatterplot of individual scores on the Vineland-3 at pretest (horizontal axis) and posttest (vertical axis) for participants in the treatment and waitlist groups.

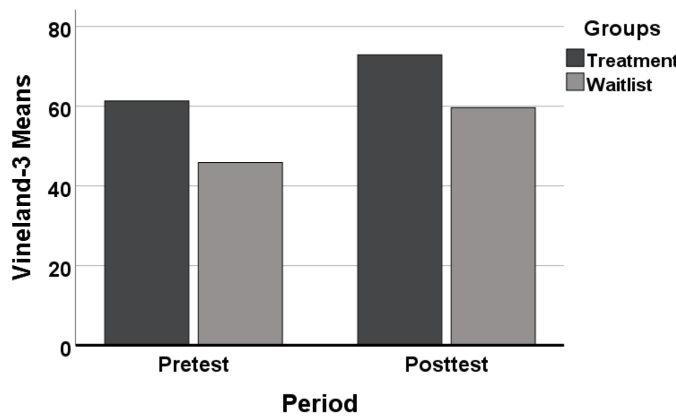

Figure 12. Vineland-3 means at pretest and posttest for the treatment and waitlist groups.

SCQ Data. Data on the SCQ from individual members of the waitlist and treatment groups at pretest and posttest are summarized in Figure 13. Individuals whose conjoint pretest and posttest scores are plotted above the diagonal line showed increases (declines in functioning) from pretest to posttest. Those plotted below the line showed decreases (improved functioning) from pretest to posttest. Among 11 treatment group participants, eight (72.7%) showed decreases in scores (improved functioning) and three (27.3%) showed increases in scores (decreased functioning). Among the eight waitlist group participants, six (75%) showed decreased scores (improved functioning) from pretest to posttest, and two (25%) showed increases (decreased functioning). It should be noted that two of the treatment group participants showed equal score decreases from pretest to posttest and consequently do not appear as separate plotted points beneath the diagonal in Figure 13.

Pretest comparison. The between-group difference between the waitlist group (M = 25.13, SD = 7.16, mean rank = 11.63) and the treatment group (M = 22.00, SD = 8.08, mean rank = 8.82) was small and not statistically significant, U = 22.50, z = 1.56, p = .061 (one-tailed). The groups can be considered to have been fairly equivalent on the SCQ at pretest making a posttest comparison more readily interpretable.

Posttest comparison. At posttest, the difference between the waitlist group (M = 22.25, SD = 7.36, mean rank = 13.50) and the treatment group (M = 13.45, SD = 6.99, mean rank = 7.45) was larger than it was at pretest and was statistically significant, U = 16.00, z = 2.32, p = .010 (one-tailed). It was concluded that the treatment group functioned at a significantly higher level than the waitlist group at posttest, as measured by the SCQ. Cohen's measure of effect strength dz = 1.23 indicated a strong treatment effect at posttest. Figure 14 provides a graphic summary of SCQ means at pretest and posttest.

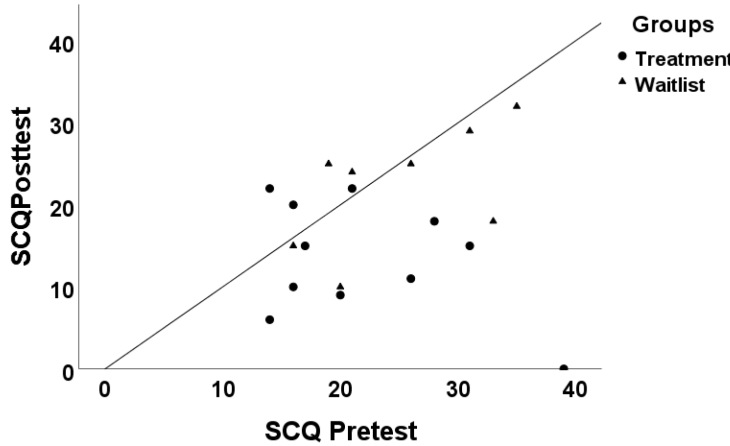

Figure 13. Scatterplot of individual scores on the SCQ at pretest (horizontal axis) and posttest (vertical axis) for participants in the treatment and waitlist groups.

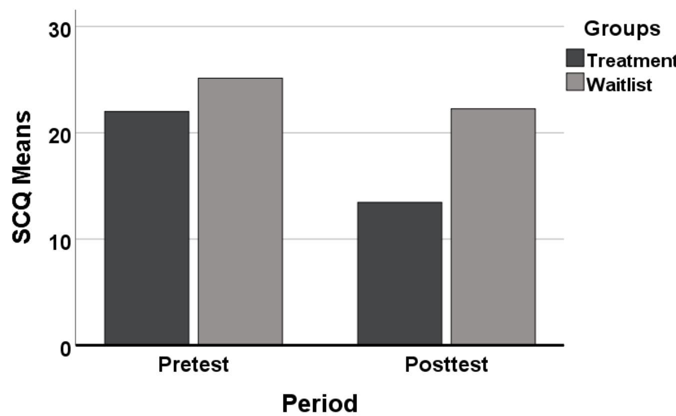

Figure 14. SCQ means at pretest and posttest for the treatment and waitlist groups.

Multiple Probe Design

The SSD portion of the study specifically examined the data of the 11 participants who received the ABI program. The treatment was introduced in a staggered manner when the student's performance displayed a decelerating or a stable trend at the baseline (Ledford & Gast, 2018). Data analysis reveals a functional relationship between intervention and accuracy of responses for all participants. The y-axis represents the percentage of correct responses given by each student during guided practice sessions; the x-axis represents the chronological intervention sessions of data collection. As 80% accuracy (spontaneous or independent response, with no prompt) was used as the learning criterion for moving to the next level in the social learning intervention program (Arick et al., 2004), the passing criterion for advancing to the second learning topic in this study was set to 80% accuracy over at least one weekly scoring period. Visual inspection of data supports the effectiveness of ABI in teaching SC/I skills to young students with ASD, and most of the newly learned skills were generalized and maintained after the treatment condition.

Group 1. Figure 15 presents data on the mean percentage of correct responses from each student in this group. All three participants demonstrated an increase in the percentage of correctness of discriminating target behavioral steps during their guided practice sessions.

Child 1. During baseline, child 1 was highly focused on answering questions and occasionally chose the correct answers. The direction of her baseline response trend indicated a mid-level performance (39.8–45%) in the average performance of the test results (M = 41.6%). It should be noted that she was confused by the format of the ABI program in the first session and tended to click randomly to try different functions of the application, which caused her test performance to drop to 33.3%. In session 2, her level of correct responses increased markedly to 83.3%, and she successfully remained in the same range in the following sessions and demonstrated a mean of 83.25% correct responses before moving on to the second target behavior (topic 2). Child 1 moved to the second topic in session 6 with a starting correct response rate of 77.8%, and her responses reached 100% in session 7, stabilizing at the ceiling level (100%) in sessions 8, 9, and 10. Improvements maintained during a follow-up session were at a similar level to the scores from the final intervention sessions. Child 1 upheld high levels of accuracy two weeks later on 100% of the probes. Generalization probes taken two weeks after the completion of the intervention phase showed that her improvement in target social behaviors had become generalized not only to an unfamiliar adult (80%), but also to a new peer (70%).

Child 2. The general trend of child 2's baseline response trend is negative, which indicates a low-level performance (17–35.5%). In session 1, his correct responses went up slightly above his baseline range at 49.4% and remained at a similar range in the following two sessions (46.8–56.3%). Visual analysis reveals a more obvious change in level and an upward trend after the introduction of his fourth intervention: during session 4, his correct responses had increased to 71.9%. His correct responses continued to improve, with 77.6% in session 5 and 92.6% in session 6. Starting from the second topic intervention in session 7, however, he displayed a sudden drop in correct responses (22.8%) due to a lack of familiarity with the new content (topic 2). He steadily improved starting with session 8 and demonstrated a mean of 64.6% correct responses throughout the rest of the treatment sessions. Child 2 maintained an accuracy level of 68% after two-week maintenance. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors was generalized to an unfamiliar adult (100%), as well as to a new peer (60%).

Child 3. Child 3's percentage of correct responses ranged from 33.3–45% at the baseline, which represents a low to medium level of performance (*M* = 37.8%). When the intervention commenced, the levels immediately increased, and the percentage of correct responses reached ceiling levels (100%) in session 6. He showed the same learning pattern as child 2 and experienced a drop in the first session of the second target behavior training, followed by a substantial increase to 92.6% in the second session; he then maintained a ceiling level performance range (97.1–100%), demonstrating a mean of 98.9% correct responses throughout the rest of the five sessions for topic 2. The graph shows a steep, increasing trend with high stability once the second session of intervention commenced. Similar to child 1, child 3 also upheld high levels of accuracy two weeks later for 100% of the probes. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors had become generalized not only to an unfamiliar adult (80%), but also to a new peer (60%).

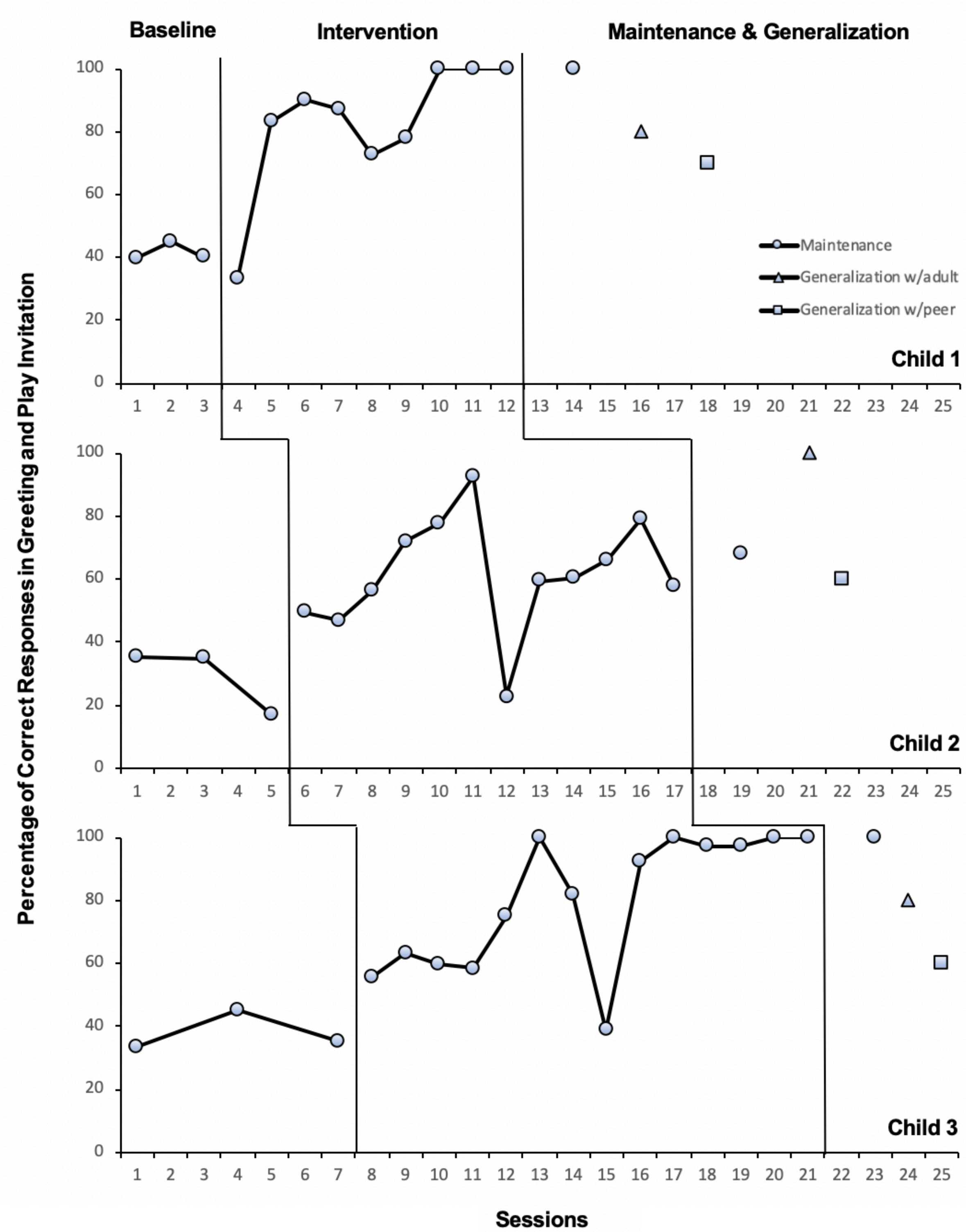

Figure 15. Percentage of correct responses from Group 1.

Group 2. Figure 16 presents data on the mean percentage of correct responses from each student in this group. All three participants demonstrated an increase in the percentage of correct responses to the discriminating target behavioral steps during their guided practice sessions.

Child 4. During the baseline session, he was highly focused on answering questions and occasionally chose the correct answers. The direction of child 4's baseline responses indicates a low level performance (17–30%) in the average performance of his test results (M = 21.7%). After session 1, his level of correct responses increased to 35.4%, remained in the same range during the second intervention (33.3%), and then steadily increased to 41.3% in session 3 and 56.4% in session 4. During sessions 5 to 8, he reached the passing score range (75.9–83.3%) and demonstrated a mean of 79.3% correct responses. He then moved onto the second topic, displaying a sudden drop in correct responses in sessions 9 and 10 (32% and 25.8%, respectively) due to a lack of familiarity with the new content. He had a substantial increase to 97.1% in session 11 and maintained a ceiling level score of 96.6 in session 12. Child 4 maintained a performance of 94.2% accuracy after a two-week maintenance period. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors had become generalized not only to an unfamiliar adult (100%), but also to a new peer (80%).

Child 5. Child 5's percentage of correct responses ranged from 30–62.3% at the baseline, which indicates a mid-level of performance (M = 45.8%). Visual analysis reveals a sudden upward trend after introducing the intervention. After session 1, his correct responses increased to 94.3%. He gave 84.4% correct responses in session 2 and reached ceiling level (100%) in session 3. He demonstrated a mean of 92.9% correct responses throughout the treatment sessions for topic 1. He then moved on to the second topic in session 4 and displayed a small drop in correct responses (71%), remaining in the same range in sessions 5 and 6 (65.8% and 70%, respectively), before exhibiting an increase to 93.3% in the last session. Improvements maintained during follow-ups were at a similar level to the scores obtained in the intervention sessions. Child 5 upheld high levels of accuracy two weeks later on 89.3% of probes. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors had become generalized not only to an unfamiliar adult (80%), but also to a new peer (80%).

Child 6. Child 6 demonstrated a stable, low level with a zero-acceleration trend during initial baseline conditions (M = 28.8%). At the baseline, she appeared to be afraid of making mistakes in the adaptive tests, as she consistently tried to cover her eyes and frequently sought help from the teacher in answering the questions. The introduction of the intervention resulted in an increase in the percentage of correct responses. In session 1, she exhibited 86.8% correct responses before a small decline in session 2 (61.6%), and then her performance bounced back to 85% in session 3 and reached the passing criterion. She moved on to topic 2 in session 4, and her correct responses ranged from 67.8% to 94.9%, with a mean of 83.62% correct responses throughout the rest of the treatment sessions. Child 6 upheld high levels of accuracy two weeks later on 89.4% of the probes. However, generalization probes taken two weeks after the completion of the intervention phase showed that her improvement in target social behaviors failed to generalize to both an unfamiliar adult (40%) and to a new peer (40%).

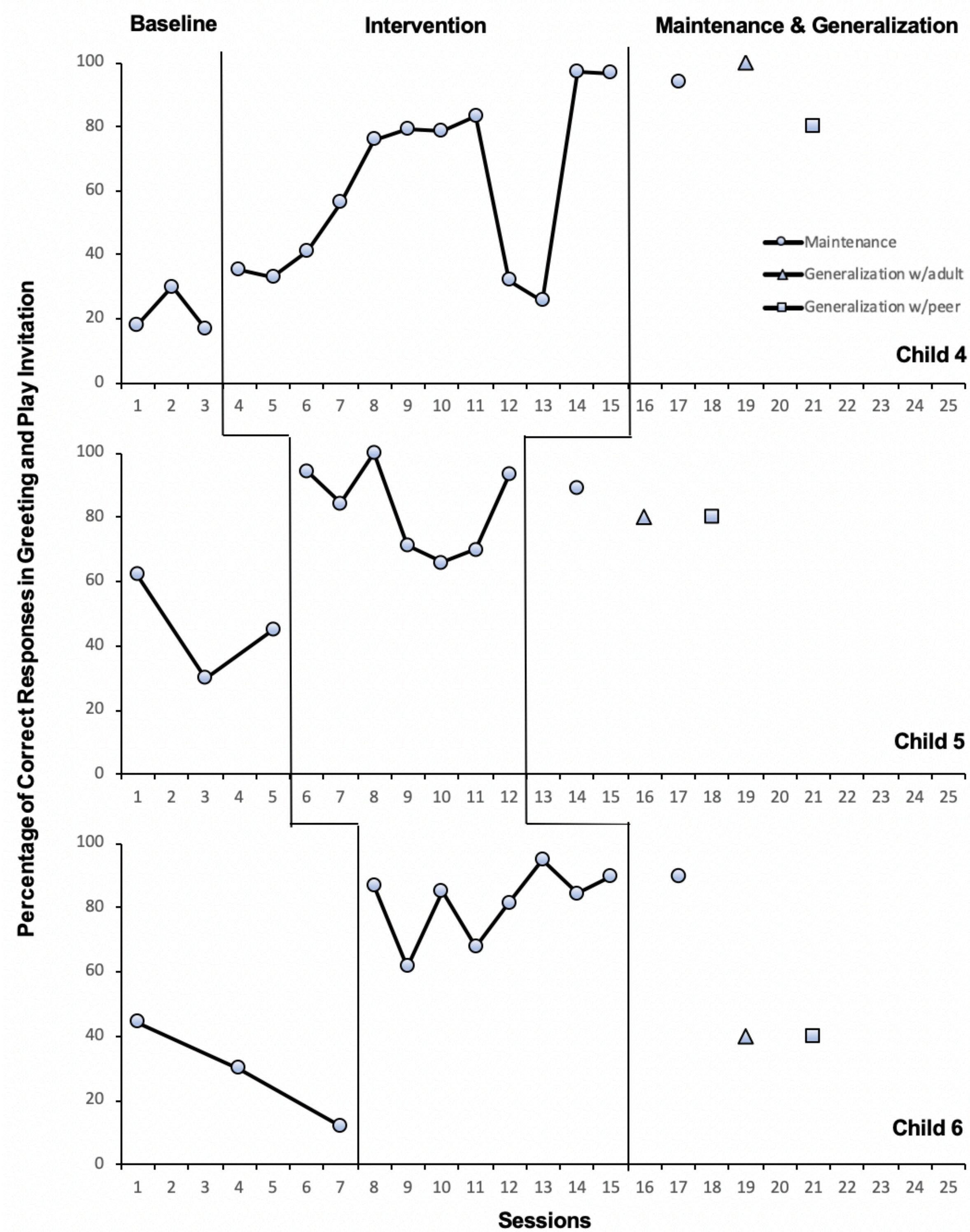

Figure 16. Percentage of correct responses from Group 2.

Group 3. Figure 17 presents data on the mean percentage of correct responses provided by each student in this group. All three participants demonstrated an increase in the percentage of correct responses to the discriminating target behavioral steps during their guided practice sessions.

Child 7. The direction of child 7's baseline response indicates a low-level performance (7–45.8%) in his test results on average (29.2%). Visual analysis reveals a sudden change in level (64.9%) in session 1; he maintained in the same range (62.7%) during session 2, followed by an upward trend in the third session (90%). Although his performance is generally stable, he did experience minor score drops in sessions 4, 5, and 9 (72.9%, 71.6%, and 62.5%, respectively). He achieved peak performance (94.4%) in session 10, then moved onto the second topic in session 11. As with many participants in the treatment group, he showed a similar learning pattern and experienced a drop in the first session of the second target behavior training, reaching ceiling level in session 14. His correct responses ranged from 66.7% to 94.3%, and he demonstrated a mean of 79.25% correct responses throughout the rest of the treatment sessions. At the end of all the sessions, child 7 successfully performed target behaviors for 90.8% of the preset opportunities. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors had become generalized not only to an unfamiliar adult (80%), but also to a new peer (80%).

Child 8. Child 8's percentage of correct responses ranged from 35–45.5% at the baseline, which indicates a low to medium level of performance (M = 36.8%). His performance trend and level stabilities were established over three consecutive days. When the intervention session was introduced, the correctness rate of his test performance was in the same range as the baseline in session 1 (41.6%), and then he had a small increase (56%) in session 2. During the first two sessions, the teacher noticed that he seemed to randomly select a picture of choice after not paying attention to the task directions. At the beginning of session 3, the researcher modified the intervention procedures by implementing an attention management system (AMS) to improve child 8's attention to the task. Specifically, the teacher would remind him of the following three steps before the ABI application presented any questions: (1) describe each picture's content, (2) decide which one is correct and why, and (3) choose the correct one. His performance jumped to 66.7% after the implementation of the AMS. To further identify whether the AMS was responsible for the behavior change in the dependent variable in session 7, a reversal design was introduced by removing the AMS in session 8 – child 8's performance dropped to 39.4%. Before session 10, the teacher remodified the intervention procedure by requesting that child 8 proactively apply the AMS himself. Surprisingly, child 8 started describing the picture content proactively, and his correct responses rose from 27.7% to 80.5% in session 10 before the treatment session ended. At the end of all the sessions, child 8 successfully performed target behaviors for 61.8% of the preset opportunities. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors had become generalized not only to an unfamiliar adult (100%), but also to a new peer (70%).

Child 9. Child 9's percentage of correct responses ranged from 14–36.7% at the baseline, which indicates a low level of performance (*M* = 26.9%). After session 1, his correct responses percentage increased to 45.2%. Visual analysis revealed a sudden change in level and an upward trend after the introduction the second intervention session. His correct responses reached ceiling level (90%) in session 2 and remained in the same range for the rest of the sessions. He demonstrated a mean of 82.7% correct responses throughout the full treatment period. Child 9 upheld high levels of accuracy two weeks later on 94.4% of the probes. However, generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors failed to generalize to both an unfamiliar adult (50%) and to a new peer (50%).

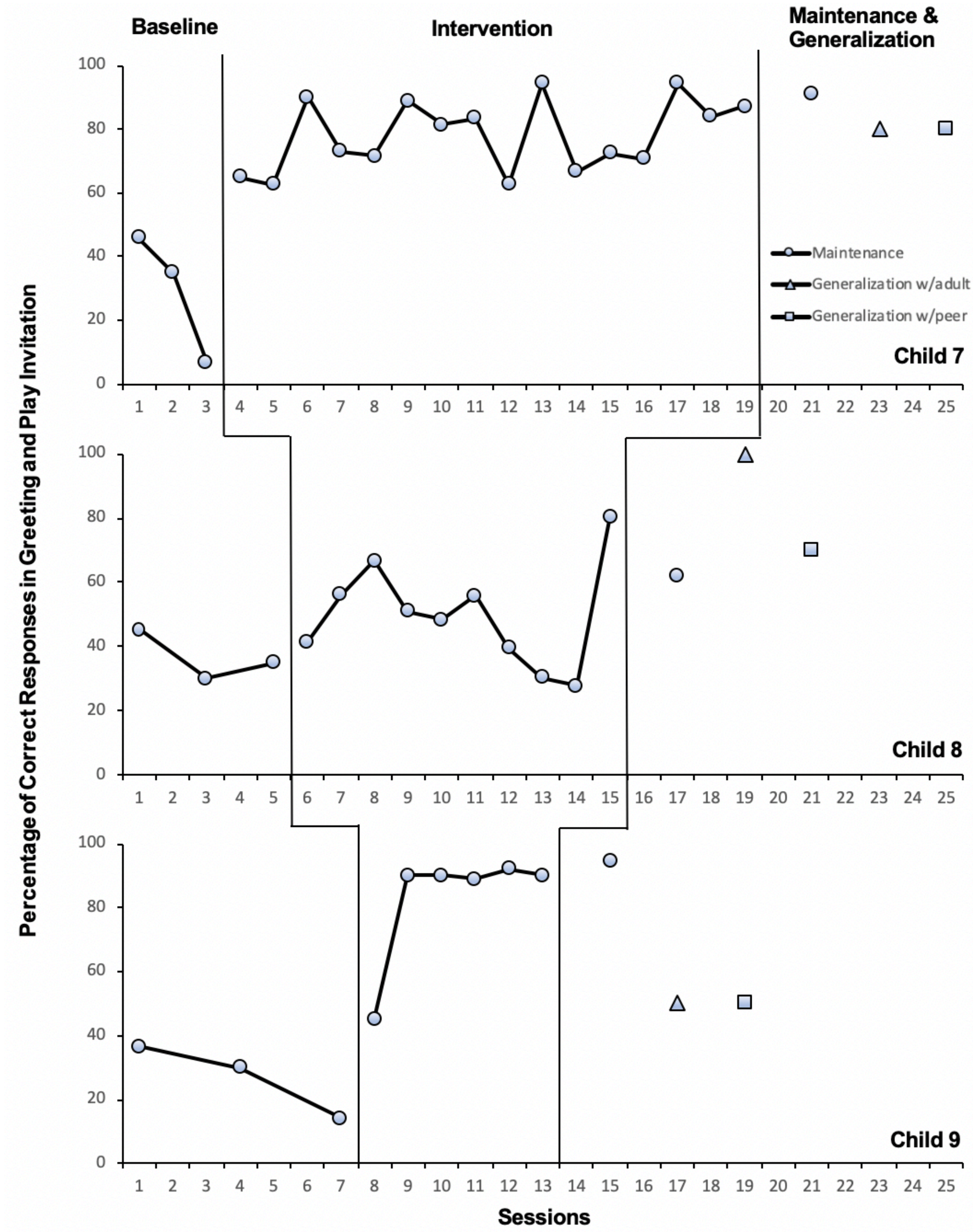

Figure 17. Percentage of correct responses from Group 3.

Group 4. Figure 18 presents data on the mean percentage of correct responses from each student in this group. Both participants demonstrated an increase in the percentage of correctness for the discriminating target behavioral steps during their guided practice sessions.

Child 10. The direction of child 10's baseline response indicates low-level performance (range: 12–39.4%, *M* = 23.8%). As shown in the graph, child 10's performance was somewhat inconsistent; he exhibited noncompliant behaviors during sessions, and his percentage of correct responses was variable during much of the intervention phase. After session 1, his level of correct responses increased remarkedly to 66.7%, and continued to increase to 91.7% in session 2, then fell to 67.1% in session 3, followed by another increase to 91.7% in session 4. He achieved maximal performance (100%) in session 7, then moved onto the second topic in session 12. Child 10 demonstrated a mean of correct responses of 78.5% throughout the eight sessions for topic 1. He exhibited 83% correct responses on average in sessions 9 through 16 of topic 2, with performance ranging from 66.7% to 100%. Child 10 upheld high levels of accuracy two weeks later on 83.3% of the probes. However, generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors failed to generalize to both an unfamiliar adult (50%) and to a new peer (50%).

Child 11. Child 11's percentage of correct responses ranged from 14–56.6% at the baseline, which indicates a mid-level of performance (*M* = 33.5%). Visual analysis reveals a sudden change in level and an upward trend after the introduction of the intervention. After session 1, his correct responses increased to 91%. His correct-response rate was 83.3% in session 2, 89.1% in session 3, and eventually reached ceiling level (100%) in session 6. He demonstrated a mean of 91.9% correct responses throughout the treatment sessions for topic 1. He then moved on to the second topic in session 8 (87.4%) and displayed a small drop in correct responses during session 9 (69.2%), before obtaining a performance of 86.1% in the last session. Improvements maintained during follow-ups were at a similar level to his scores during the intervention sessions. Child 11 upheld high levels of accuracy two weeks later on 92.3% of the probes. Generalization probes taken two weeks after the completion of the intervention phase showed that his improvement in target social behaviors successfully generalized to an unfamiliar adult and to a new peer, but only by a very small margin (60% and 60%, respectively).

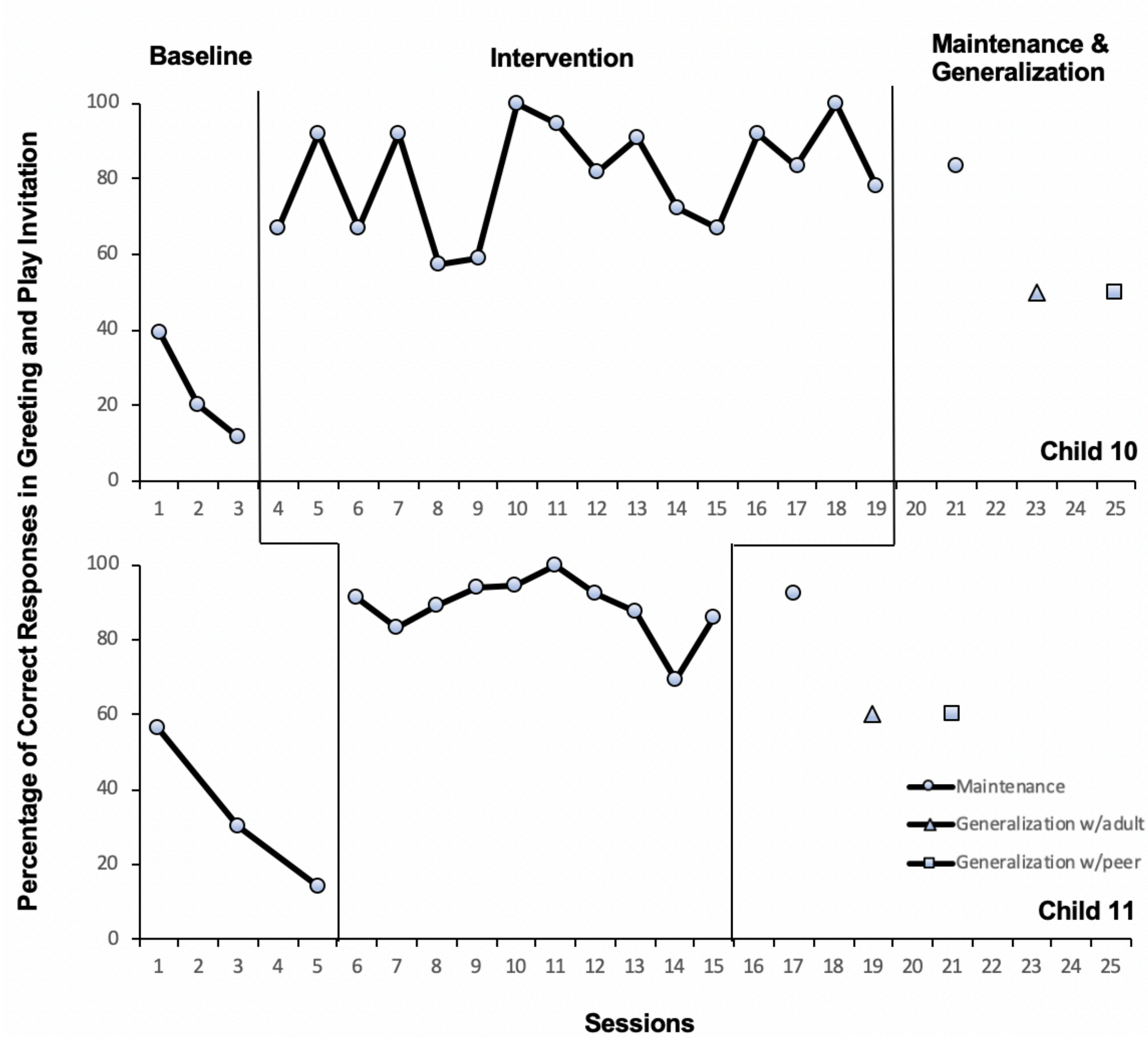

Figure 18. Percentage of correct responses from Group 4.

Social Validity

Several measures were collected to obtain social validity information.

Student Happiness Rating. During the intervention sessions, an observational rating of the level of happiness exhibited by the students was adapted from similar scales used by Koegel et al. (2009). Rating scores were collected during the first 10 minutes of each video-recorded probe, using a 6-point Likert scale numbered from 0 to 5. Scores ranging from 0–1 indicate low levels of happiness, 2–3 indicate moderate levels, and 4–5 indicate high levels of happiness (Table 9).

Social validity was also assessed through a parent-completed questionnaire and an informal teacher interview that evaluated both parents' and teachers' satisfaction with the goals, procedures, and outcomes of the study (Burton, 2013). Survey and interview data were analyzed through content analysis (Mayring, 2004). The findings indicated that all the teachers agreed that learning these target social behaviors was a developmentally appropriate goal for all student participants. The teachers also expressed their wish to incorporate the ABI program as a central activity to assist other students with similar conditions.

Table 9

Student happiness rating

Low Happiness Level (0–1)	Moderate Happiness Level (2–3)	High Happiness Level (4–5)
- Student appears to be sad, angry, frustrated, and or stops answering questions on the application.	- Student seems neutral overall during the intervention, neither particularly happy nor unhappy.	- Student engages in answering questions in the adaptive training system on the application.
- Student spends much time looking around and not attending to the task.	- Student may frown or smile occasionally.	- Student appears to be happy during intervention.
- Student does not appear to be happy overall during the intervention. - Score 0 or 1 depending on the extent of low enjoyment.	- Score 2 or 3 depending on the extent of moderate happiness.	- Score 4 or 5 depending on the extent of high enjoyment.

Chapter 5: Discussion

The present study was designed to examine the effectiveness of an ABI program that consisted of video modeling and Social Stories™ combined into an adaptive training system so as to teach children with ASD social greeting, self-introduction, and play-initiation skills. The general purpose of the study was supplemented by the following research questions: (1) Is there a treatment effect from using the ABI program that incorporates several common EBPs and the adaptive training system to teach SC/I skills to children with ASD? How much of a treatment effect does the ABI have compared to the TAU condition? (2) Will the ABI program be effective in increasing target social skills for each participant in the cohorts? (3) If the ABI cohorts are able to acquire the target behaviors, will they maintain and generalize their skills across time, settings, stimuli, responses, and individuals? (4) What are the teachers' perceptions (such as intervention practicality and cost-effectiveness) of the technology-based intervention for their students' SC/I performance?

Statistical Findings

The statistical portion of the study compared the efficacy of the ABI program received by a treatment group consisting of 11 children with ASD versus a waitlist group consisting of eight similar participants who received TAU. Four measures of functioning were utilized to compare the treatment approaches: the SRS-2 *T*-score, GARS-3 Autism Index, Vineland-3 ABC, and SCQ. Student participants were randomly assigned to groups; statistical comparisons of the groups based on gender, age, and pretest scores on the SRS-2, GARS-3, and SCQ indicated that the randomization process was fairly effective in creating equivalent groups. The groups did differ significantly, though, on Vineland-3 pretest scores with the treatment group showing superior functioning to the control group even at pretest.

In the analysis of SRS-2 data, there was near equivalence between the treatment and waitlist groups at pretest, but at posttest the treatment group's scores were significantly lower on average than the waitlist group, $U = 18.50$, $z = 2.11$, $p = .017$ (one-tailed). This finding supports the conclusion that the ABI was significantly more effective than TAU in improving functioning. In order for a between-group difference to reach statistical significance with samples as small as those used in this study, an effect must be quite strong. Cohen's measure of effect strength $dz = 1.11$ did indeed indicate a strong treatment effect in the posttest comparison of groups.

In the analysis of GARS-3 data, there was near equivalence between the treatment and waitlist groups at pretest, but at posttest the treatment group's scores were significantly lower on average than the waitlist group, $U = 16.50$, $z = 2.28$, $p = .010$ (one-tailed). This finding supports the conclusion that the ABI was significantly more effective than TAU in improving functioning. In order for a between-group difference to reach statistical significance with samples as small as those used in this study, an effect must be quite strong. Cohen's measure of effect strength $dz = 1.08$ did indeed indicate a strong treatment effect in the posttest comparison of groups.

The analysis of Vineland-3 failed to support the advantage of ABI over TAU that was seen in the other outcome measures. There was no significant difference between the waitlist and treatment groups at posttest, $U = 22.50$, $z = 1.56$, $p = .061$ (one-tailed).

In the analysis of SCQ data, there was fair equivalence between the treatment and waitlist groups at pretest, but at posttest the treatment group's scores were significantly lower on average than the waitlist group, $U = 16.00$, $z = 2.32$, $p = .010$ (one-tailed). This finding supports the conclusion that the ABI was significantly more effective than TAU in improving functioning. In order for a between-group difference to reach statistical significance with samples as small as those used in this study, an effect must be quite strong. Cohen's measure of effect strength *dz* = 1.23 did indeed indicate a strong treatment effect in the posttest comparison of groups.

It should be noted that two of the four measures used in this study were found to reveal statistically significant differences in outcomes in favor of the ABI treatment using two different nonparametric statistical tests. This independent corroboration increases the confidence of those results, that the ABI treatment significantly boosts student SC/I skills when compared to TAU.

Single-subject Design Findings

The SSD portion of the study specifically examined the data of the 11 participants who received the ABI program. Data analysis reveals a functional relationship between intervention and accuracy of responses for all participants. The percentage of correct responses in the adaptive training system and of correct behavioral steps completed in role-play activities indicated remarkable improvement in students' performances after the intervention was implemented. Overall, the participants in the treatment group improved their social greeting, self-introduction, and play-initiation skills through the ABI program. Procedural reliability, interobserver agreement, and effectiveness data demonstrated that the procedures and the teacher participants succeeded in teaching SC/I target skills to the 11 children with ASD. Experimental control was strengthened by the replication of the independent variable across cohorts and participants. These findings extend the evidence for the use of the ABI program in teaching SC/I skills to individuals with ASD.

Target Behavior Acquisition. During the baseline condition, six participants (children 2, 4, 6, 7, 9, and 10) showed a low level and five (children 1, 3, 5, 8, and 11) demonstrated a medium level of correct responses rate in target behaviors. Upon the introduction of the ABI program, nine out of 11 participants (children 2, 3, 4, 5, 6, 7, 9, 10, and 11) immediately revealed a noticeable or very obvious change in levels and achieved a mean of 65.5% correct responses during their first session. Among them, three participants (children 5, 6, and 11, with 94.3%, 86.8%, and 91% correct responses, respectively) reached the passing criterion level within just one session, which suggests that the ABI program has a fast and immediate effect in changing students' behaviors. Five participants (children 1, 2, 3, 10, and 11; after sessions 7, 6, 3, 7, and 6, respectively) reached a 100% correct-response rate during the ABI treatment, with a mean number of 5.8 sessions to reach this level. Children 4 and 3 had the largest gains – 75.4% and 62.2%, respectively – in improvement rate through target behavior training, and they were able to conduct most of the target behaviors independently across partners. The results of the SSD study demonstrated the ABI program's utility as a highly efficient aide to instruct SC/I skills. The increased learning opportunities provided could lead to self-efficacy and better educational outcomes for the students throughout their lives.

Despite several positive results, two participants (children 1 and 8) appear to have had a relatively delayed change in level and trend, as their teachers administered at least two sessions before there was a noticeable improvement. Within child 1, the teacher noted that she tended to click randomly in order to explore different functions of the application in the first session, which directly caused her test performance to drop to 33.3%. As for child 8, during the first two sessions, the teacher noticed that he seemed to select a picture at random after receiving the task instructions without paying much attention.

One possible explanation for the above-mentioned phenomenon may be the following: The interactive format of the ABI application may be overstimulating to some students, causing them to focus on playing with different buttons out of curiosity rather than practice answering the questions. For students such as child 1, and for those who exhibited noncompliant behaviors or seldom engaged in reciprocal interactions during role-play sessions, teachers may consider using the application as a reward to encourage learning by suggesting that if students behave well during practicing activities, they will be rewarded with extra play time with the ABI. This would also be consistent with Koegel et al.'s (2009) findings that children with ASD are capable of exhibiting appropriate behaviors if they are motivated. Therefore, in the future, when teachers perform interventions with a similar type of student who enjoys playing with a tablet, they can use tablet play as a reward and encourage the student to effectively learn role-play and other main activities.

Another explanation for the phenomenon can be summarized as follows: for child 8 and other participants who had difficulty paying attention, teachers may consider adopting an attention management system. From the beginning of session 3 onward in the study, the teacher reminded child 8 of the following three steps before the application presented any questions: (1) describe the contents of each picture, (2) decide which one is correct and why, and (3) choose the correct one. The results demonstrated that child 8's performance jumped to 66.7% after the implementation of this strategy. Before session 10, the teacher began asking child 8 to proactively apply the strategy himself; he grasped the ability to describe the picture contents on his own, and his correct responses rose from 27.7% to 80.5% in session 10 before the treatment session ended.

Target Behavior Maintenance. The results indicated that the newly learned social skills could be successfully maintained after an extended period of time. Nine out of 11 participants remained at very high accuracy levels during the maintenance probes (range: 83.3–100%, $M = 92.6\%$), where they demonstrated a stable or increasing trend in the target behaviors compared to the intervention sessions. Among them, children 1 and 3 successfully leveraged 100% of the available opportunities during conversation partner role-play maintenance sessions. Although two participants (children 2 and 8) failed to meet the passing criterion (at 68% and 61.8%, respectively) in the maintenance probes, they nonetheless significantly improved compared to their baseline performances (29.1% and 36.8%, respectively).

Nevertheless, there may be concerns with high variability in the intervention conditions that may have influenced the maintenance data, especially when sessions were postponed or cancelled. Due to logistical reasons, child 2 had to postpone the second target behavior training sessions for several days after he had just passed the training criteria for his first learning topic. It is hypothesized that postponing preplanned intervention sessions may have weakened the learning effects, as he may have forgotten some key concepts in the interim, thereby leading to diminished performance.

Target Behavior Generalization. One of the purposes of this study was to investigate students' abilities to generalize their learned skills across conversation partners who were neither targeted by the program nor familiar with the students. Generalization probes taken two weeks after the completion of the intervention showed that most of the participants (seven out of 11 participants) generalized the newly learned skills to their new partners – an adult and a typically developing peer. The goal of assigning new partners was to ask students to apply their newly learned skills and invite their partner to play a game.

In general, participants perform better when interacting with adult conversation partners rather than peers. All students successfully generalized the pre-set probes, remaining at higher accuracy levels in interaction probes with an adult (range: 40–100%, *M* = 74.5%) than with a peer (range: 40–80%, *M* = 63.6%). Three out of 11 participants (children 2, 4, and 8) demonstrated 100% accuracy during interactions with the adult. Interestingly, child 2 demonstrated generalization differences depending on whether the conversation partner was an adult or a peer. When initiating a self-introduction and play request with an adult, he successfully completed all of the tasks. However, he only partially completed the same set of tasks (60%) with a peer even after sufficient encouragement from the teacher. One assumption is that the teacher instruction format familiarized child 2 with applying the newly acquired skills to and interacting with adults, which translating into a level of social comfort and corresponding higher task completion rate when engaging in generalization assessments with adults rather than peers later on. It is unclear whether adding a few peer-mediated sessions would increase child 2's generalization performance with peers than was achieved in the current study. Future research is required to provide scientific evidence regarding the effects of peer-mediated sessions on the ABI program.

There may be concerns with variability in the intervention conditions attributable to a change of instructors due to the availability of student or teacher participants. After child 2 returned from his absence for subsequent sessions, the previously assigned teacher was unavailable for those time slots, so the teacher for the other group taught him for a few sessions. Changes in interventionists may be a source of high variability in data collection. While switching or changing teachers during the intervention phase increased the variability of students' performance, it arguably improves the generalization of targeted social skills (Davis et al., 2018). Anecdotal observation indicated that the lead teacher's sessions were associated with an upward trend in the data, due to child 1's greater willingness to participate in and cooperate with the training sessions. Therefore, it is still unclear whether the change in personnel may have caused any differences in students' learning outcomes and the generalizability thereof.

In addition, it is worth noting that student participants who showed the best efficiency results within the fewest intervention sessions may have arguably had the poorest long-term maintenance performance data (Davis et al., 2018; de Marchena et al., 2015). In the current study, although children 6 and 9 learned the targeted SC/I skills with great efficiency (in eight and six sessions, respectively) and attained a very high level performance (range: 92.2–94.9%) in the learning sessions, they may not necessarily have had the highest maintenance data. Since they received the least total number of instructional sessions in a short period of time, they also had fewer opportunities to practice their new skills compared to the other participants. Unfortunately, due to the school's administrative schedules, it was not possible to collect more maintenance data or conduct more generalization tests to verify this conjecture. However, it would be worthwhile for future research to investigate whether increasing intervention sessions would result in better treatment maintenance for a high learning efficiency student as in the abovementioned cases.

While the current study displayed an overall powerful generalizability across settings, it is noteworthy that four of the 11 students in the ABI group (children 6, 9, 10, and

11) failed to generalize the target behaviors to new conversation partners. Corresponding to this issue, earlier studies have suggested five dimensions (i.e., high extraversion, agreeableness, conscientiousness, openness, and lower neuroticism) that may be associated with successful learning outcomes in children with ASD (Pervin & John, 1999; Schriber et al., 2014) and have raised the possibility that personality traits may be one explanatory mechanism. A close inspection of the data from the current study revealed a trend: student participants with certain personality trait indicators received a less satisfactory generalization result than others. There is likely a dynamic relationship between generalized performance and certain personality traits: for instance, children who were weaker generalizers tended to have poor impulse control (e.g., child 6), flare easily when the lesson content or format did not match personal preferences (e.g., children 6 and 11), and exhibit a higher percentage of non-compliant behaviors (e.g., child 10). In addition, students who demonstrate a bias toward a low state of arousal and a passive interaction style may also exhibit diminished generalization performance. An example is child 9, who was described as socially aloof, seemingly indifferent to other people's attention, expressing minimal pleasure when interacting with others, and reluctant to initiate social interaction on his own in obvious ways. The aforementioned personal trait indicators represent an initial step toward unpacking some of the difficulties in SC/I skill generalization for children with ASD, a noted phenomenon in the field. This hypothesis elicits a call for more studies in this area.

As described in the results section, child 10 exhibited noncompliant behaviors, and his percentage of correct responses was variable during much of the intervention phase. Although he mastered most of the behavioral steps during treatment, he refused to initiate interaction with someone he was not interested in, therefore, his generalization performances were lower (40% of correct responses for both conversation partners) than those in the training sessions. This case may indicate that children with ASD can be selective about their conversation partner, and their generalization performance may be unpredictable and subject to change. Therefore, in situations similar to child 10's case, it may be clinically beneficial to add a few more generalization probes for a more accurate result.

Qualitative Findings

Implementation of qualitative research methods provided detailed descriptions of varying perspectives, increasing the possibility of establishing recommendations for future practice. Data from the teachers' interviews suggested that the ABI program supported student learning through effective scaffolding, and the level of support was gradually reduced as gains in behavior developed. Adaptive scaffolds embedded into the ABI application enabled adjustments to be made during student interactions to enhance learning success, especially in providing readily available multimodal prompts and supports to suit the student's current level. Interview data was analyzed and synthesized through content analysis (Mayring, 2004), after which five major themes were condensed (Table 10) under the scope of the adapted Boyd et al.'s (2015) tablet application evaluation rubric. The teachers reported improvements in their students' skills in day-to-day interaction and shown interest in the students' participation in additional intervention sessions in the future. The findings provided insight into the experience of assisting SC/I development for children with ASD through the ABI program, which reflected the teachers' satisfaction with the goals, procedures, and outcomes of the treatment.

Table 10

Teacher participant perceptions of the ABI

Criteria	Exceeds Expectations	Meets Expectations
Customizable	- Choice of authentic photograph and/or other types of pictures provided in the guided practice sections. - The app collects data on student language use. - ABI can serve as motivation or a reward for positive behaviors, such as the completion of a task. - The built-in features of the app help support children with ASD at all levels and abilities.	- Ability to change color, font, and sound of buttons. - Optimizes the user experience by adding specialized layouts for different screen sizes and bitmap images for common screen densities. **Suggestion:** Gear to support different language levels by adding specific versions of the voice-over narration that contain customized language for different students.
Motor Skills	- Prevents accidental selections by students. - Audio is easy to hear. - Videos and images help students to grasp invisible rules.	- Low physical effort is required to operate the app. **Suggestion:** Provide a flexible user interface that adapts to different screen configurations.
Minimize Extraneous Resources/Time	- Easy to teach students to use the app. - Teaching manual with suggestions included. - Data collection through the adaptive system is immediate and accurate, and requires no training of school staff.	- Students can use the app with minimal adult assistance. - The benefits of using ABI appear quickly. - Learning content is generalizable across SC/I goals.
Research Basis	- Evidence-based sources provided (e.g., ABA, PRT). - Helps students to practice retelling personal narratives that offer opportunities to demonstrate language organization, while making the embedded video modeling examples meaningful. - Teaches social rules through Social Stories™ and correction staircase to help students understand how to apply those rules.	- The ABI program has been researched and shown to be effective through at least one controlled SSD study.
Cost-Effectiveness	- Price of ABI is justified based on the value of the product. - Instruction delivery is consistent and predictable to be individualized to meet student's preferences in the classroom.	

Limitations

Although the study results were promising and appealing, there are unexplored variables that may limit the effectiveness of this program. Further studies are needed to replicate the experimental effects and strengthen the external validity of the findings.

One limitation involved the sample size and the characteristics of the participants. Although the initial sample size of 26 children with ASD is reasonably large relative to the available literature, the unexpected drop-outs unfortunately shrank the sample size to 19. While ample results can still be yielded through analyses, the available sample of participants who received the ABI treatment was small to provide adequate statistical power for correlational analyses. According to the project contact person in China, the drop-outs were purely due to unforeseen logistical reasons; (1) after participating in the eligibility screening, the second partner school decided to withdraw because the administration foresaw that it would be unable to meet the experimental schedule and deadline before the end of the fall semester, and (2) the school realized that it would be unable to provide sufficient iPads for all of their students for intervention use.

In addition, the characteristics of the participant sample may have been unbalanced – the students were mostly male (five girls and 14 boys). Ensuring a better gender balance in future studies can increase the generalizability of the findings. Caution should also be taken in generalizing the research findings across students, settings, and severity of disabilities; the generalizability of this intervention's effects for students with other developmental disabilities – such as cerebral palsy, intellectual disabilities, and Down syndrome – is unknown.

Another limitation derived from the fact that three students (specifically, children 7, 10, and 11) in the ABI group may require additional baseline measurements, as their scores clearly fall into decreasing trends. Although the current study has already measured three baseline probes – which aligns with the convention in behavioral science that a minimum of three baseline data points are required to establish dependent measures stability – it would be beneficial to add one or two more probes until baseline stability is fully obtained. Due to miscommunications with the point of contact – as well as the partner school's extremely tight schedule, especially at the end of the semester – it was unfortunately impossible to extend more baseline probes before the intervention started. Nevertheless, the primary investigator considers this issue to be a minor limitation, as the target behavior reflected in the dependent measure is expected to improve as a result of the ABI program, which agrees with Byiers et al.'s (2012) claim that "a decreasing trend during baselines does not pose a significant problem" in SSD research.

Furthermore, the baseline data indicated that some participants, especially child 5, already had some of the behaviors in his repertoire prior to intervention – he could perform the desired behaviors during role-play sessions at medium levels (range: 45–62.3%) commensurate with the criterion of the target behaviors. This may decrease the potential of the study to demonstrate large improvements in children's social behavior changes. Fortunately, in the cases of children 2 and 4, their initial role-play performance during all baseline sessions was low (range: 17–35.5%), which indicated the effectiveness of the intervention to some extent.

Another potential limitation pertains to the limited data available to make definitive claims with regard to SC/I intervention, maintenance, and generalization. Restrictions such as school schedules, availability of teachers, health conditions of students, and the time needed to obtain authorization to conduct research were major factors in deciding to conduct a relatively short instruction program. Maintenance data were collected two weeks after the intervention was completed. Consequently, it is difficult to conclude that each participant would have maintained the new skills after an extended period of time.

In addition, a lack of qualitative data and SSD data required the researcher to limit the scope of the follow-up analysis. The worldwide COVID-19 pandemic has produced unprecedented operational challenges, which included the cessation of collection of in-depth qualitative interview data and SSD follow-up data beginning on January 17, 2020. This is the date when the partner school in China went on its annual winter break, during which time all data collection must stop as a matter of standard practice. While this winter break was scheduled to end on February 16, 2020, the pandemic situation by that time had caused all normal school functions to stop, essentially resulting in extended mass closures of schools throughout China. As such, teachers were not able to provide additional information regarding the treatment or maintenance, as they have not seen their students since January 18. Therefore, a temporary halt to thorough qualitative data and follow-up SSD data collection was implemented. This halt was still in place through the time of submission of this work (June 2020). To partially overcome this limitation, the primary investigator applied the adapted Boyd et al.'s (2015) evaluation rubric with teachers' feedback to strengthen the findings as much as possible. As such, future studies are warranted once an in-depth qualitative exploration is possible.

Future Directions

Given the lack of literature on a comprehensive application-based training program to improve the SC/I skills of students with ASD, the current study provides an important contribution to the field. There are many avenues for future research on such types of interventions.

Further studies on the effectiveness of the application-based instruction program for children with ASD should replicate the present study with more verified and better-controlled research procedures, especially with large sample sizes. More evidenced-based rigorous investigations, especially those incorporating conditions and randomized group assignment of participants to compare the effects of different treatment approaches, should be considered. This would ensure a systematic and scientific comparison of the students' learning outcomes between ABI and TAU.

The majority of SC/I intervention programs in the field have focused on short-term treatment effects (McConnell, 2002). Although follow-up data were collected in the current study, future research should further examine the long-term treatment effects to better understand participants' skill maintenance and generalization. This is especially important for children with ASD, as studies have noted that they often do not successfully maintain or generalize behaviors (Arick et al., 2004; Koegel et al., 2012; Sansosti, 2010). It is presently unclear how long the intervention effects would last without booster sessions. If long-term follow up data continue to be collected once the intervention has ended, it may be possible to assess whether the gains have been maintained over time. Therefore, a longitudinal study may be merited to further examine the variables and to understand how the participants maintain and generalize their learned skills over time.

Research could be done to evaluate the ABI in transition-age youth to examine if preparing incoming elementary school students with ASD could place them into a different social developmental trajectory. Therefore, it may be worthwhile to conduct a longitudinal study that follows student participants from early childhood (around age four) up to their transition into early elementary school age (around age seven). Gaining SC/I skills early on could potentially offer children with ASD increased opportunities to build and maintain meaningful social relationships throughout their early education before they begin elementary school. The premise of this point is that years of practice could build fluency in the SC/I skills needed for their transitions into elementary schools and therefore improve their social competence and well-being. An intervention could be a key component to a successful transition plan for preschoolers with ASD.

In addition, since this program was conducted by special education professionals in structured classroom settings, future research is required to delineate the extent to which benefits can be achieved in less-controlled settings (e.g., at home or in a park), via group instruction formats, and with implementation of instruction by different types of instructors, especially by non-professionals such as parents and peers. While there is evidence for the successful use of parent-directed, peer-mediated, and paraprofessional-delivered interventions for children with ASD (Davis et al., 2018; Kagohara et al., 2013; Koegel et al., 2012; Koegel et al., 2014b), more research is needed, particularly in determining whether parents and peers can deliver the ABI program with fidelity. It is hypothesized that altering instructors, instructional patterns, and settings could have long-term effects and other potential outcomes. Considering that parents have been reported as the primary driving force behind ABI use in ASD – they tend to adopt a trial-and-error system of intervention for their children (Christon et al., 2010; Clark et al., 2015) – it is especially important to provide them with additional training and support on the appropriate use of the intervention. In this way, parents can play a role during training sessions to "serve as antecedent cues for use of social skill behavior" (Spence, 2003) and to prompt, model, and reinforce more appropriate social responses from their children.

More research is needed to identify the characteristics of individuals who would best benefit from this intervention program. Variables such as developmental age, receptive language level, conversational speech level, imitation ability, and fine as well as gross motor skills have all been attributed to students' learning outcomes. A next step in this programmatic line of research is to examine these variables and the resulting impact of student behaviors and learning outcomes. Future research should also investigate the intervention's effects on children with developmental disabilities who demonstrate pragmatic impairment, such as those with cerebral palsy, intellectual disabilities, and Down syndrome.

Additional research endeavors should also examine how intervention density affects various instructional variables, such as treatment frequency and length of intervention (duration of one session in minutes, number of sessions per week, or total length of intervention in weeks). This is because some advanced SC/I skills may require more frequent sessions or longer instructional sessions to bring a student up to an adequate proficiency level in terms of targeted behaviors. Spence (2003) noted that months, rather than weeks, may be required to ensure the adequate duration of training for certain young children to bring about significant improvements in their social functioning. Therefore, it may be clinically relevant that increasing or decreasing the duration or frequency of an intervention phase may result in more treatment benefits, greater treatment maintenance, or better generalization of improvements.

Conclusion

This study examined the treatment effectiveness of an ABI program which incorporates several widely recognized EBPs embedded into an adaptive training system in directly addressing the core social skill challenges faced by children with ASD. The research expanded the current body of studies by incorporating puppet role-play, conversation partner role-play with video modeling, Social Stories^{TM}, and opportunities for students to answer questions through the correction staircase approach into the program.

A sequential explanatory mixed methods design was adopted, and this divided the research into two phases. The statistical portion of the study compared the two treatment approaches using an RCT pretest-posttest design. Participants who received TAU are subsequently referred to as the waitlist group, while those who received ABI are referred to as the treatment group. Nineteen participants were examined in this phase. Four measures of functioning – SRS-2 *T*-score, GARS-3 Autism Index, Vineland-3 ABC, and SCQ – were utilized to compare the treatment approaches. Nonparametric tests were used to compare the treatments; the results demonstrated that participants who received ABI were functioning at a significantly higher level at posttest than those who received TAU.

A multiple probe across participant design replicated in four groups in phase two was used to collect quantitative data for analysis across baseline, intervention, maintenance, and generalization portions of the study. Eleven participants from the treatment group were examined, and they significantly improved their social greeting, self-introduction, and play initiation skills through ABI. The effectiveness of the intervention was evaluated based on student engagement and performance in discriminating, understanding, expressing the target behaviors through their role-play and adaptive training sessions. Procedural reliability, interobserver agreement, and effectiveness data demonstrated that the procedures and the teachers were successful in imparting the target SC/I skills. Experimental control was strengthened by the replication of the independent variable across cohorts and participants. The SSD graph showed that nine out of 11 participants remained at very high accuracy levels in the maintenance probes (range: 83.3–100%, $M = 92.6\%$), where they demonstrated stable or upward trends in the target behaviors compared to the intervention sessions. Generalization probes taken two weeks after the completion of the intervention showed that most of the participants generalized the learned skills to new conversation partners, and the participants performed better when interacting with new adults than with novel peers. The pattern showed that all participants successfully generalized the pre-set probes, remaining at higher accuracy levels in interaction probes with adults (range: 40–100%, $M = 74.5\%$), than with peers (range: 40–80%, $M = 63.6\%$).

If this type of instruction proves to be effective over time and can result in improved SC/I behaviors in individuals, the instruction program may become one of the major instructional approaches for children with ASD. This study was a first attempt to implement an application-based instruction program that incorporates multiple evidence-based intervention approaches. The investigator hopes that this study will call to the attention of special education practitioners and instructional technologists the possibilities of designing interventions using advanced technologies to teach children with ASD.

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Appendices

Appendix A

Literature Review Summary Table

Author(s)	Design and Intervention Components	Participants and Setting	Dependent Measures	Treatment Effect(s)
Bellini et al. (2007)	Multiple baseline design; Video self-modeling to increase social engagement	*N* = 2 (ASD); Ages: 4–5; Did not identify ethnicity; Child intervention in a preschool classroom setting	Unprompted social engagement with peers (active participation in an activity or play sequence with a peer involving shared toys, objects, and play items)	Video self-modeling led to rapid and substantial increases in unprompted social engagement with peers for both participants.
Charlop-Christy et al. (2003)	Multiple baseline design; Video modeling to teach perspective taking	*N* = 3 (ASD); Ages: 6–8; Did not identify ethnicity; Child intervention	The number of correct response (control question, memory question) for each task, either verbal or nonverbal	All participants demonstrated full understanding of the control question during baseline and were able to locate the object's current location.
D'Ateno et al. (2003)	Multiple baseline design; Video modeling to teach complex play sequences	*N* = 1 (Autism); Age: 3; Did not identify ethnicity; Child intervention in an autism treatment center setting	The number of scripted and unscripted verbal statements and the number of modeled and not-modeled motor responses	Video modeling led to the rapid acquisition of both verbal and motor responses for all play sequences and an increase in the number of both verbal and motor play responses.

Flores et al. (2012)	Single-subject design; iPad with an AAC application versus picture cards to teach communication skills	*N* = 5 (ASD and ID); Ages: 8–11; Did not identify ethnicity; Child intervention in a university-sponsored summer program setting	The frequency of communication behaviors (iPad: touch the picture on the screen; Picture cards: point to a card, give to teacher or remove to Velcro)	Mixed results: communication behaviors either increased when using the iPad or remained the same as when using picture cards.
Grynszpan et al. (2008)	Pre-posttest design; CAI software to check human-computer interaction and to examine its effectiveness in improving communication abilities	*N* = 10 (Autism); Ages: clinical group average: 12.10; typical group average: 9.7; Did not identify ethnicity; Child intervention in a school setting	Total duration of scenarios either passed or failed (TDS), and the number of clicks on an utterance for displaying the associated facial expression (NC).	Participants tended to perform less satisfactorily compared to normally developed peers when a software interface looks complicated, as they lack the ability to organize multimodal information resources.
Hetzroni & Tannous (2004)	Multiple baseline design across settings; CAI software program that was developed based on daily life and activities to improve communication skills	*N* = 5 (Autism); Ages: 7.8–12.5; Arabic speakers; Child intervention in a school setting	Number of sentences using delayed echolalia, using immediate echolalia, using irrelevant speech, using relevant speech, and number of child initiations	All participants reduced the behavior of delayed or irrelevant talk after intervention; most of them increased the number of communicative intentions and relevant talk.

King et al. (2014)	Single-subject multiple probe design; iPad with "*Proloquo2Go*" to teach acquisition of requesting skills	*N* = 3 (ASD); Ages: 3–5; Did not identify ethnicity; Child intervention in a hallway of the school setting	The percent of participant's independent requesting	Participants acquired skills to request preferred items using iPad, vocal requesting increased during training phases in comparison to baseline probes.
Kroeger et al. (2007)	Quasi-experimental design; Video modeling teaching group versus play activities group in teaching social skills	*N* = 13 (VM); *N* = 12 (play); Ages: 4–6; 9 Caucasians, 4 African Americans in VM group; Child intervention in an unstructured play setting	The frequency, duration, and nature (positive or negative) of the videotaped social interactions for each child during two 30-min. segments	Both groups increased pro-social behaviors, but the video-modeling direct teaching group made more gains in social skills than participants in play activities group.
LeBlanc et al. (2003)	Multiple baseline design across two tasks; Video modeling to teach perspective-taking skills	*N* = 3 (Autism); Ages: 7–13; Did not identify ethnicity; Child intervention in a classroom setting	The frequency of perspective taking in tasks	Although video modeling and reinforcement were effective overall, it had limited generalization in this study because only two out of three participants passed an untrained task.
MacDonald et al. (2005)	Multiple probe design within participants across setting; Video modeling to teach thematic pretend play skills	*N* = 2 (Autism); Ages: 4–7; Did not identify ethnicity; Child intervention in a classroom setting	The number of scripted verbalizations and play actions	Video modeling intervention was successful as both participants acquired the scripted verbalizations and play actions; they also maintained the skills during follow-up sessions.

MacDonald et al. (2009)	Multiple probe design across settings; Video modeling to teach reciprocal pretend skills with peers	*N* = 2 (Autism) 2 pairs of children; Ages: 5–7; Did not identify ethnicity; Child intervention in a classroom setting	Scripted verbalizations, play actions, unscripted verbalizations, unscripted play actions, cooperative play, and reciprocal verbal interaction chains	Both participants and their partners acquired the sequences of scripted verbalization as well as play actions, and they all successfully maintained the performance during follow-up sessions.
MacDuff et al. (2007)	Multiple probe design across participants; audiotaped scripts to increase the frequency of bids for joint attention responses	*N* = 3 (Autism); Ages: 3–5; Did not identify ethnicity; Child intervention in a hallway and a classroom	A single word or phrase, or an approximation to a word or phrase that pertained to an object in the immediate environment	All participants acquired this skill to make bids for joint attention without scripts and maintained the skill with untrained toys and settings.
Macpherson et al. (2015)	Multiple baseline design; Portable video modeling technology to increase compliment behaviors	*N* = 5 (ASD); Ages: 9–11; Did not identify ethnicity; Child intervention on a large lawn near a behavioral treatment center	Verbal compliments and compliment gestures	Participants demonstrated more than one compliment per opportunity and 4 of 5 participants demonstrated extensive response variation, however they seldom made compliment gestures.
Murdock et al. (2013)	Multiple baseline design; iPad play story to increase pretend play skills	*N* = 4 (ASD); Age: 49–58 months; Did not identify ethnicity; Child intervention in a classroom setting	The number of play dialogue (PD) utterances (sound effects, structural utterances, self-talk)	3 of 4 participants demonstrated increases in the target behavior revealing moderate and strong effects across intervention phases. Effects were largely maintained during a 3-week follow-up condition.

Nikopoulos & Keenan (2003)	Multiple treatment design; Video modeling in promoting social initiation	*N* = 7 (Autism); Ages: 5–9; Did not identify ethnicity; Child intervention in a classroom setting	Latency to social initiation, time spent in appropriate play	Suggested the effectiveness of video modeling to enhance both social initiation and appropriate toy play in all seven participants.
Nikopoulos & Keenan (2004)	Multiple baseline across subjects design; Video modeling on social initiation and play behaviors	*N* = 3 (Autism); Ages: 7–9; Did not identify ethnicity; Child intervention in a classroom setting	Latency to social initiation and the total duration of reciprocal play	Participants' social initiation and reciprocal play skills were successfully enhanced by video modeling and the effects were maintained in follow-up periods.
Nikopoulos & Keenan (2007)	Multiple baseline across subjects design; Video modeling on instructing complex social sequences	*N* = 3 (Autism); Ages: 6.5–7.5; Did not identify ethnicity; Child intervention in a semi-naturalistic room setting	Social initiation, reciprocal play, imitative response, object engagement, other behaviors	Video modeling not only enhanced social initiation skills of all participants, but also facilitated reciprocal play engagement.
Sigafoos et al. (2013)	Multiple baseline across participants design; Teach participants to request the continuation of toy play using iPad	*N* = 2 (Autism); Ages: 4–5; Did not identify ethnicity; Child intervention in a university clinical room setting	The cumulative number for each response (i.e., reaching, hitting, and correct iPad-based requesting	Both participants learned to use the iPad to request and maintained the skill without prompting. Acquisition of iPad-based requesting was associated with decreases in reaching and aggressive behavior.
Simpson et al. (2004)	Multiple probe design; CAI embedded video to improve social skills	*N* = 4 (Autism); Ages: 5–6; Did not identify ethnicity; Child intervention in a special education classroom setting	Complying with teacher direction, greeting others, sharing materials	All participants showed rapid improvements in targeted social skills in the natural environment.

Tetreault & Lerman (2010)	Multiple baseline across scripts design; Using point-of-view video modeling to teach participants to engage in both eye contact and vocal behavior	*N* = 3 (ASD); Ages: 4–8; Did not identify ethnicity; Child intervention in a small room at a day treatment center	Five specific exchanges of eye contact and vocal behavior (e.g., looks up from the toy, looks at the conversant, and greetings)	The combination of video presentation and reinforcement of target behavior proved successful for increasing the social behavior of two participants, prompts were necessary to achieve acquisition for a third.
Waddington et al. (2014)	Multiple baseline across participants design; iPad-based SGD to teach participant to make a general request	*N* = 3 (ASD); Ages: 7–10; Did not identify ethnicity; Child intervention in a university-based clinic room setting	Percentage of correct responses for participants for Step 1 (general toy request), Step 2 (specific toy request), and Step 3 (thank you response)	All participants showed improvement in performing the communication sequence. This improvement was maintained with an unfamiliar communication partner and during the follow-up sessions.
Wert & Neisworth (2003)	Multiple baseline design; Video self-modeling of teaching spontaneous requesting	*N* = 4 (ASD); Ages: 3–6; Did not identify ethnicity; Child intervention in a school setting	The frequency of spontaneous requesting	Video self-modeling led to a large increase in requesting behavior in all four participants.

Appendix B

Teacher Consent Form for Participating in the Research Study

Purpose

I understand that I am being asked to participate in a research study. The purpose of the study is to use an application-based intervention to investigate if the use of the intervention program improves the social communication and interaction skills of my student(s).

Procedure

I understand that if I decide to participate in the study, I will first select potential student participants according to the subject inclusion criteria, and then distribute an information package to all of the potential participants' parents. I will also return the signed parent consent forms to the researcher, then provide the parents' and students' contact information to the researcher.

I understand the researchers will proceed by collecting observational data while my student is learning from the application. This is to establish a baseline, before implementing intervention. I also understand that during the intervention process, the researchers will define target behaviors, provide video models and social stories to teach the target social skills, and then provide adaptive questions for my student(s) to practice.

I understand that all intervention sessions (which may include me assisting my student(s)) will be video recorded for analysis by the researcher.

I understand that the project timeline will range from 6–12 weeks. The duration of the intervention state will be 2–4 times per week for 4–6 weeks. Each session will last approximately 30 to 45 minutes. I also understand that 2–4 weeks after the intervention is completed, maintenance and generalization data will be collected.

I understand that I will be interviewed as part of the project, and I am willing to participate in that.

Benefits

I understand that the purpose and potential benefits of my participation in this study may be an improvement in the social communication and interaction skill of my student(s), although this is not guaranteed.

Confidentiality

I understand that the data collected by the researchers will not be linked to my identity in any way. Data collection sheets created by the researchers will not include any identifiable information connected to me. All data and information including the video recordings will be stored safely in UCSB Box. I also understand that the confidentiality of all data collected will be maintained, and no information will be distributed other than to the researcher and principal investigator.

Right to Refuse or Withdraw

I understand that I may refuse to participate and still receive any benefits my student(s) would receive if they were not in the study. I may change my mind about being in the study and stop my participation after the study has started.

Questions

I understand that if I have any questions about this research project, I can contact Dr. Mian Wang at mwang@education.ucsb.edu. I also understand that if I have any questions regarding my rights and participation as a research subject. I can contact the Human Subjects Committee at hsc@research.ucsb.edu.

PARTICIPATION IN RESEARCH IS VOLUNTARY. MY SIGNATURE BELOW WILL INDICATE I HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THIS STUDY DESCRIBED ABOVE. I WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

____

Signature of Participant or Legal Representative

____

Date

Appendix C

Letter to Parents of the Potential Student Participants

Dear student parent(s) or guardian(s),

I am writing to seek the participation of your child in a research study. The purpose of the study is to use an application-based intervention program (*Qunatiandi Autism Intervention System*) to investigate if the use of the application improves social communication and interaction skills of children with autism spectrum disorders (ASD). By participating in this study, your child may benefit from acquiring or improving social communication and interaction skills and generalize them into his/her daily life. After the research is completed, you will be asked to fill out a questionnaire about your child's improvement or changes in his/her everyday behavior after the use the application.

I would appreciate if you would permit your child to participate in this project, as it will contribute to furthering our knowledge of social communication and interaction skills of children with ASD. If you are interested in the study, please sign the enclosed parental permission form for your child to participate, and return it to the school teacher by (insert date).

Appendix D

Parental Permission Form for Participating in the Research Study

I agree to allow my child, ______________, to participate in a research study titled, "Examining the Effects of Application-based Instruction on Social Communication and Interaction Skills in Chinese Children with Autism Spectrum Disorders." I understand that the purpose of the study is to use an application-based intervention (*Qunatiandi Autism Intervention System)* to investigate if the use of the program improves the social communication and interaction skills of my child. I understand that the study will last for 9 to 12 weeks. Each session will last 30 to 45 minutes, and the intervention will take place during free time and will not interfere with daily classroom instruction. I understand that all intervention sessions will be video recorded for analysis, and any individually identifiable information collected about my child will be kept confidential. I understand that my child's participation is voluntary, which means I do not have to allow my child to be in this study if I do not want to. My child can also refuse to participate or stop taking part at any time without penalty or loss of benefits to which s/he is otherwise entitled.

PARTICIPATION IN RESEARCH IS VOLUNTARY. MY SIGNATURE BELOW WILL INDICATE I HAVE DECIDED TO ALLOW MY CHILD TO PARTICIPATE AS A RESEARCH SUBJECT IN THIS STUDY DESCRIBED ABOVE. I WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

____

Signature of Parent

____

Date

Appendix E

Transcript for Not Meeting Research Selection Criteria

Date:

Dear student parent(s) or guardian(s),

I am writing to you regarding the result of your child's participation in the screening session for selection in our research project, *Qunatiandi Autism Intervention System*, at your school site for students with autism spectrum disorders. I regret to inform you that your child has not been selected for participation in the research study. I would like to express my sincere gratitude to you and thank you for agreeing to let your child participate in the screening process. I wish you the best of luck for your child's future education endeavors.

Appendix F

Social Validity Questionnaire for Student Parent(s) or Guardian(s)

Please circle a number to indicate your agreement or disagreement with the statements below regarding this study.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	**2**	**3**	**4**	**5**

A. I believe my child has enjoyed learning from the *Qunatiandi* application.

1 2 3 4 5

B. I have observed improvements of my child's skills in day-to-day interaction at home.

1 2 3 4 5

C. I have received positive feedback from teachers on the improvement of my child's skills in day-to-day interaction at school.

1 2 3 4 5

D. I would be interested in my child's participation in additional intervention sessions in the future.

1 2 3 4 5

E. I will recommend this type of intervention to friends and family for their children with disabilities.

1 2 3 4 5

F. I believe that overall my child's social communication and interaction skills have improved through this intervention program.

1 2 3 4 5