

Effectiveness of Smart ABA in Teaching Reading Skills to Children with Autism

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Received : 21 October 2025
 Revised : 21 June 2026
 Accepted : 16 July 2026
 DOI : 10.26822/iejee.2026.460

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Abstract

Autism Spectrum Disorder is a neurodevelopmental disorder that appears before the age of three, marked by persistent deficits in communication, social interaction, and learning abilities. Reading is an essential skill for children with Autism Spectrum Disorder (ASD), supporting their academic and daily functioning. This study examined the effectiveness of Smart Applied Behavior Analysis (Smart ABA) in teaching foundational reading skills to children with ASD. Five nonverbal children under five years old participated in a structured intervention integrating Smart Discrete Trial Training and Smart Discrimination Training across five tasks focused on uppercase vowel recognition (A, O, U, E, I). The mastery criterion was set at ≥80% accuracy for three consecutive sessions. Results showed that all participants achieved reading mastery within an average of 46 sessions (approximately two weeks) and demonstrated consistent retention during generalization. Smart ABA improved reading acquisition, attention, and compliance, and provided measurable evidence of learning stability. Beyond empirical outcomes, Smart ABA contributes methodologically through explicit time-based tracking of mastery and aligns with Sustainable Development Goal (SDG) 4 by promoting inclusive and quality education for all children.

Keywords:

Autism Spectrum Disorder; Smart ABA; Reading uppercase vowels; Therapist reliability and assessment; SDGs

Introduction

Autism spectrum disorder (ASD) is a severe neurodevelopmental disorder. It often appears in early childhood and is characterized by core symptoms: repetitive, stereotyped behavior patterns and impairments in social communication and social interaction (American Psychiatric Association, 2022). In addition, children with Autism Spectrum Disorder (ASD) frequently encounter significant barriers during the early stages of reading acquisition. These challenges include difficulties in visual letter discrimination, letter-sound association, and maintaining focus during structured learning activities (Arciuli & Bailey, 2021). Although some children are capable of recognizing basic letters, many fail to consistently associate letters with their corresponding phonemes (Solis et al., 2016). Reading performance also tends to decline when



www.iejee.com
 ISSN: 1307-9298

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learning stimuli change or become more complex (Randi et al., 2010). Moreover, deficits in attention and weak stimulus control are strongly correlated with low literacy performance among children with ASD (Henderson et al., 2022; Ke et al., 2023; Tsuji et al., 2024; Westerveld et al., 2021). Therefore, an instructional approach that integrates systematic structure, effective teaching techniques, and quantifiable, transparent measurement is essential to address these challenges.

Applied Behavior Analysis (ABA) has long been recognized as an effective therapeutic and instructional method for children with ASD. ABA emphasizes structured behavioral principles such as reinforcement, stimulus control, and repeated practice to support skill acquisition and behavioral adaptation. These principles have been successfully applied to improve various domains, including communication, social interaction, and academic readiness (Coburn et al., 2022; Du et al., 2024; Makrygianni et al., 2023; Sandbank et al., 2024). However, the application of ABA in reading instruction for children with ASD is still not consistently implemented through structured and measurable procedures (Arciuli & Bailey, 2021; Whalon et al., 2009). As a result, the integration of phonemic awareness, decoding, and fluency often varies across intervention settings.

Empirical evidence supports the effectiveness of Applied Behavior Analysis (ABA) in improving reading-related skills among children with ASD. Singh et al. (2017) confirmed the effectiveness of Behavior Skills Training in enhancing reading comprehension up to 80% after 12 sessions, while Solis et al. (2016) reported comprehension gains of 73-83% following a two-week ABA-based intervention. Bekmurat and Autayeva (2023) found significant lexical improvement after nine months of adapted ABA therapy that combined discrete-trial and functional communication training. Reisener et al. (2014) observed marked increases in oral reading fluency after 30 sessions using stimulus-control-based procedures such as Repeated Reading. These findings indicate that ABA can support reading development. However, several important limitations remain. Most studies do not clearly describe systematic teaching procedures, standardized instructional sequences, or the duration required to achieve mastery. In addition, the learning process is often not reported in a way that allows replication across settings.

Addressing this methodological gap, Smart Applied Behavior Analysis (Smart ABA) was developed as an extension of ABA (Anwar et al., 2022). It integrates systematic procedures, consistent teaching methods, and transparent quantitative measurement to define clear learning stages and timelines for reading mastery, as described in previous Smart ABA studies (Arneliza et

al., 2026). Smart ABA also introduces a structured two-on-one instructional model to improve consistency and engagement during instruction. This study aims to examine the application and effectiveness of Smart ABA in teaching early reading skills to children with ASD. It also explores its contribution to the Sustainable Development Goals (SDGs), particularly Goal 4, which promotes quality and inclusive education.

The study focuses on early reading as a foundational literacy skill. While prior studies have established the general efficacy of ABA in enhancing academic performance, few studies have provided detailed and measurable instructional procedures for early reading in children with ASD. In contrast, Smart ABA offers a systematic instructional framework, consistent teaching practices across therapists, and quantifiable, transparent evaluation metrics. The study also examines performance consistency across sessions and maintenance phases. This study contributes to the literature by providing a structured, measurable, and replicable instructional model for early reading. Detailed procedures are presented in the Methods section.

Accordingly, the following research questions guided this study:

1. How can a systematic and measurable reading instruction model for children with ASD be developed using Smart ABA?
2. How effective is Smart ABA in improving early reading skills among children with ASD?
3. To what extent are reading skills maintained following the implementation of Smart ABA?

Method

Research Design

This study employed a developmental research approach combined with limited implementation to examine the initial effectiveness of the Smart ABA framework in teaching early vowel reading to children with Autism Spectrum Disorder (ASD). The development phase involved designing a structured instructional model based on the Smart ABA Model, which emphasizes systematic procedures, sequential learning, and transparent measurement. The model was developed through collaborative processes and refined to ensure practical applicability in real therapy settings. This approach aligns with developmental research that focuses on model design, feasibility, and initial impact on users (Richey & Klein, 2007). The effectiveness in this study is positioned as an early indicator of functional application.

Following the development phase, a Single Subject Research (SSR) A-B design with maintenance and mastery criterion was implemented to observe changes in participants' reading performance through repeated measurement (Kazdin, 1982). The study consisted of a baseline phase (A), an intervention phase (B), and a maintenance phase to assess skill stability. Baseline was defined as an initial performance documentation phase within a structured mastery-based framework, rather than a no-assistance condition. Initial prompt procedures were applied based on Smart ABA decision rules due to the absence of prerequisite skills. The intervention emphasized continuous and progressive learning, where instruction was not withdrawn for experimental purposes, in line with ethical considerations in pediatric intervention research (Lepola et al., 2024; Matsui et al., 2021).

Participants and setting

This study involved five children with ASD under the age of five (three boys and two girls). Based on medical assessments, parent reports, and the initial Smart ABA evaluation, all participants were categorized as nonverbal. Participants were selected based on the following inclusion criteria: (1) a confirmed diagnosis of Autism Spectrum Disorder (ASD), (2) classified as nonverbal, defined as the inability to produce meaningful spoken words, and (3) not receiving other concurrent behavioral interventions during the study period. The intervention began with a basic curriculum consisting of fifteen learning activities. Parents provided written informed consent to participate in the study and were allowed to observe therapy sessions through individual closed-circuit television (CCTV) monitors installed outside the therapy room.

Development and Procedures

The development of Smart ABA was carried out through a focus group discussion involving three therapists, one supervisor, one program director, and one consultant. The team collaboratively designed a systematic instructional framework to teach reading skills to children with ASD, ensuring that it was practical, accessible, and applicable for therapists, parents, and other professionals. The Smart ABA Model is also designed to ensure that learning takes place in an enjoyable and engaging atmosphere for children, supported by warm interaction, responsive communication, and enthusiastic reinforcement. The Smart ABA approach adopts an intensive model aligned with the principles of Early Intensive Behavioral Intervention (Matson et al., 2012; Sandbank et al., 2024). Session frequency was age adjusted: four sessions per day for children under five years old, five sessions for ages 5-10, and six sessions for children above 10. All sessions were conducted by certified Smart ABA therapists trained in structured literacy-

based behavioral instruction (Arneliza et al., 2025).

Unlike conventional ABA's one-to-one format (Gelkop et al., 2015; Wood et al., 2021), Smart ABA implements a two-to-one instructional model in which one participant is supported by two trained therapists. Both therapists had completed approximately three months of structured training and internship. During each session, the therapists alternated roles as therapist and therapist assistant (TA). The therapist was responsible for delivering instructions, guiding the learning process, and preparing session reports. The therapist assistant (TA) supported session preparation, delivered prompts when needed, recorded all participant responses using trial-by-trial procedures, calculated total scores, and plotted data into graphs. This structured role division was designed to maintain child engagement, ensure systematic data recording, and minimize inter-rater bias during the intervention.

The instructional framework and assessment tools were evaluated for readability by seven therapists, all of whom reported that the procedures were easy to understand. Next, four educational and psychological experts and three autism therapy practitioners rated the clarity of the content, ease of use, and appropriateness of the language using a five-point scale. The results were analyzed using Aiken's V coefficient (Aiken, 1985). The implementation followed a continuous and sequential learning process. After participants mastered the imitation of the vowel sound "A," the program progressed directly to reading the corresponding uppercase letter "A" and continued sequentially to subsequent vowel targets. In this study, after approximately 2 to 3 months from the start of the Smart ABA program, participants began to demonstrate the ability to imitate vowel sounds. Instruction was then immediately advanced to reading tasks using uppercase letter cards. This structured progression reflects the hierarchical and continuous nature of the Smart ABA learning model, in which instruction is not interrupted once a skill is acquired. All therapy sessions were conducted in an individual therapy room with a structured environment designed to minimize distractions and support consistent learning implementation.

Data Collection Techniques and Measurement

All participant responses were systematically recorded by the therapist assistant (TA) using standardized Smart Measurement and Evaluation (Smart ME) protocols (Arneliza et al., 2026). Role rotation between therapist and assistant served as an inter-rater reliability control to minimize scoring bias. Each response was coded following Smart DTT procedures (Anwar et al., 2022) and plotted in real-time graphs for continuous monitoring by parents, therapists, and consultants. Data collection was conducted consistently across both daily and maintenance programs to ensure

accuracy and continuity. Any signs of stagnation or decline were reviewed during weekly team meetings with the consultant, program director, and supervisor, who provided corrective recommendations. All data were securely stored and reviewed under ethical supervision to ensure confidentiality, data integrity, and compliance with research standards.

Internal Validity

To ensure internal validity, this study adhered to the principles outlined by Shadish, Cook, and Campbell (2002). First, all participants had a confirmed diagnosis of ASD by a certified pediatric specialist. Second, no additional interventions were introduced during the study apart from the Smart ABA program. Third, participants followed a medically supervised diet free of casein, gluten, sugar, chemical additives, and high-phenol fruits or vegetables and were not exposed to electronic devices or television. Fourth, each child was supported by three trained therapists who alternated across four daily sessions (Sunday to Friday). The involvement of qualified ABA practitioners is critical to maintaining both safety and therapeutic effectiveness (Clark & Wilder, 2024; Ragulan et al., 2023). Data recording was performed in real time by assistant therapists, and any issues were reviewed in weekly meetings with the supervisor and consultant. Fifth, all sessions were conducted in a distraction-free, soundproof therapy room equipped with CCTV and external monitors for parental observation.

Data analysis

Visual analysis is the primary method for interpreting data in Single-Subject Research (SSR) (Dowdy et al., 2022; Ninci et al., 2015). This approach facilitates the identification of behavioral change patterns and supports systematic and quantitative evaluation of the relationship between the independent variable (Smart ABA) and the dependent variable (reading ability in children with ASD) (Blair & Ledford, 2022; Lane & Gast, 2014; Wolfe et al., 2019).

Ethical Considerations

All research procedures adhered to institutional ethical standards and regulations and were approved Research Ethics Committee of Universitas Muslim Indonesia (Approval No. 589/A). by the Research Ethics Committee of Universitas (Approval No.) Written informed consent was obtained from all participants' parents prior to data collection, and all personal identities were protected in accordance with strict confidentiality principles.

Results

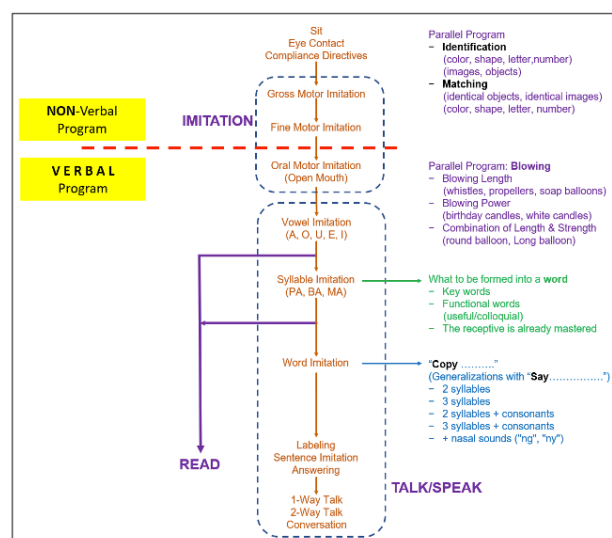
The total Aiken's V value was 0.96 ($p < 0.01$), indicating that all items were valid and the overall structure

statistically reliable. Thus, the systematic design and teaching framework for reading in children with ASD, along with its quantified assessment, were validated. The development of a reading instruction procedure for children with Autism Spectrum Disorder (ASD) resulted in a conceptual model entitled Systematic Approach to Teaching Reading in ASD Using Smart ABA, which emphasizes a structured, sequential, and quantitatively measurable learning framework. The model integrates Smart Discrete Trial Training (Smart DTT) and Smart Discrimination Training (Smart DT) (Sutadi et al., 2026) across progressive stages of reading instruction, beginning with uppercase vowel recognition (A, O, U, E, I). Each stage includes a transparent mastery criterion ($\geq 80\%$ for three consecutive sessions under a dropout system) and a time-based evaluation mechanism that enables objective and continuous monitoring of the child's developmental progress.

Model Conceptualization

The development of the systematic Teaching Speaking and Reading approach using Smart ABA is illustrated in Figure 1 below:

Figure 1.
Systematic Approach to Teaching Speaking and Reading in ASD Using Smart ABA

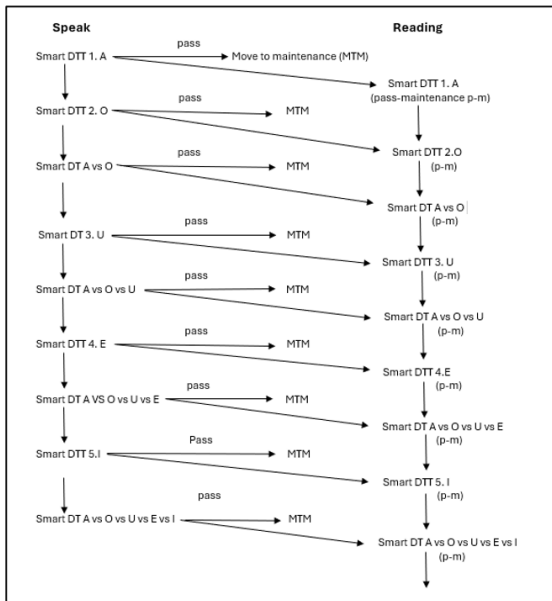


The Smart ABA stages begin with an attending-skills/compliance program, including sitting calmly, making eye contact, and following verbal instructions. Programs are organized in blocks of five activities and run in parallel with gross motor imitation exercises and 15 other programs, implemented in both daily and maintenance sessions. After mastering seven gross motor imitation activities, children proceed to fine motor imitation; after mastering seven fine motor imitation activities, they continue with oral motor imitation (only opening the mouth). In parallel, children are gradually trained to blow using various media,

including balloons, whistles, straws, paper pinwheels, and others. After completing the oral motor imitation program, daily sessions continued with Smart DTT Activity 1 (imitating the vowel 'A'). The systematics of teaching reading to children with ASD can be seen in Figure 2 below.

Figure 2.

Systematic Approach to Teaching Reading in ASD Using Smart ABA



The Smart ABA reading program is designed to be hierarchical, parallel, and measurable, following the mastery of vowel imitation skills as the main prerequisite before introducing uppercase vowel reading. This prerequisite also applies to syllables and words. Instruction is delivered through two primary formats: Smart Discrete Trial Training (Smart DTT), used to teach the imitation of a single sound or letter in each activity; and Smart Discrimination Training (Smart DT), used to train discrimination between two or more sounds or letters presented simultaneously.

The mastery criterion is defined as achieving $\geq 80\%$ accuracy across three consecutive sessions, applying a dropout system. The program consists of five main activities: reading uppercase vowels A, O, U, E, and I. The fundamental principle of Smart ABA is that children can only proceed to the reading phase once they have mastered imitation of the corresponding vowel or syllable.

Activity 1. Vowel "A"

The program begins with Smart DTT Activity 1 (imitating the sound "A"). Upon reaching the mastery criterion, the sound "A" is transferred to maintenance. In parallel, the child begins Smart DTT Reading Activity 1 (reading uppercase vowel "A"). After meeting the mastery criterion, reading activity "A" is also moved to maintenance to ensure retention.

Activity 2. Vowel "O"

The next stage is Smart DTT Activity 2 (imitating the sound "O"). Once the child achieves mastery, the sound "O" is placed in maintenance alongside "A." Smart DT (A vs. O) is then introduced to strengthen auditory discrimination. After meeting the criterion, the activity is moved to maintenance, and the previous imitation tasks ("A" and "O") in maintenance are discontinued. In the reading program, after the child masters uppercase vowel "A," they proceed to Smart DTT Reading Activity 2 ("O"). After meeting the mastery criterion, it is moved to maintenance in parallel with "A." Smart DT Reading (A vs. O) follows to train visual discrimination between the two letters. Upon mastery, reading activities "A" and "O" in maintenance are discontinued.

Activity 3. Vowel "U"

The next phase is Smart DTT Activity 3 (imitating the sound "U"). After mastery, the sound "U" is placed in maintenance, followed by Smart DT (A vs. O vs. U) to strengthen three-sound discrimination. Upon meeting the criterion, it is moved to maintenance, and the "U" imitation task in maintenance is discontinued. In parallel, the child proceeds to Smart DTT Reading Activity 3 (uppercase vowel "U"). After reaching the criterion, Smart DT Reading (A vs. O vs. U) is conducted to increase visual and auditory discrimination complexity. When mastery is achieved, the reading activity "U" is moved to maintenance, and earlier maintenance activities are discontinued.

Activity 4. Vowel "E"

This stage begins with Smart DTT Activity 4 (imitating the sound "E"). After achieving mastery, the sound "E" is moved to maintenance, followed by Smart DT (A vs. O vs. U vs. E) to train four-sound discrimination. Once the mastery criterion is met, the activity is transferred to maintenance, and the "E" imitation task in maintenance is discontinued. In parallel, the child participates in Smart DTT Reading Activity 4 (uppercase vowel "E"). After meeting the criterion, reading "E" is placed in maintenance and run concurrently with other vowels. Smart DT Reading (A vs. O vs. U vs. E) is then introduced to reinforce visual discrimination of four vowels. After mastery, reading activity "E" and the previous combinations in maintenance are discontinued.

Activity 5. Vowel "I" (Block I Integration)

The final phase involves Smart DTT Activity 5 (imitating the sound "I"). Upon meeting the mastery criterion, the sound "I" is moved to maintenance, followed by Smart DT (A vs. O vs. U vs. E vs. I) known as Smart DT Block I to integrate all vowel sounds. After mastery, the activity is transferred to maintenance, and all previous imitation

tasks are concluded. In parallel, the child undertakes Smart DTT Reading Activity 5 (uppercase vowel "I"). Once mastery is achieved, the reading activity "I" is moved to maintenance, followed by Smart DT Reading (A vs. O vs. U vs. E vs. I) or Block I Reading to ensure complete integration of auditory and visual discrimination skills. After meeting the criterion, this activity is transferred to maintenance, and all previous reading tasks are terminated.

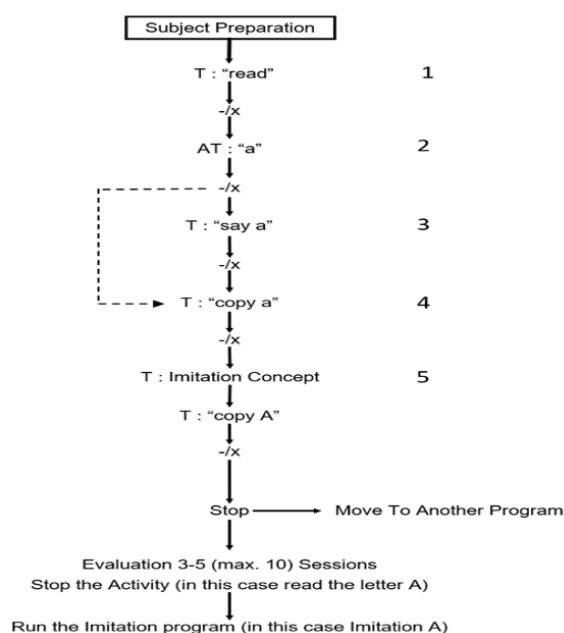
Maintenance and Generalization Phase

The maintenance program is implemented regularly to ensure retention and stability of acquired skills. The mastery criterion for the maintenance phase is defined as achieving 80% of total sessions with a score above 80%, conducted over 4–6 weeks. In this study, each participant was supported by three therapists; thus, the mastery criterion was calculated as: 3 therapists × 6 weeks = 18 sessions × 80% = 15 sessions (meaning the child passes if they achieve ≥15 out of 18 sessions with >80% accuracy). After all Smart DT combinations (both imitation and reading) reach the mastery criteria, children proceed to the generalization phase at home. Parents, who have received brief training from Smart ABA therapists, continue parallel sessions.

Escalation Prompt

In a reading program, if the child does not respond, remains silent, makes mistakes, or is off-task, the therapist and therapy assistant can implement the Smart Escalation Prompt technique (tiered prompting). The structure of the Escalation Prompt is illustrated in Figure 3 below.

Figure 3:
Standard Operating Procedure for Implementing Smart Escalation Prompt



In Figure 3, T is the therapist, and AT is the therapist's assistant. In Figure 31, it starts with preparing the child, then the therapist gives verbal program instructions by labeling (e.g. "What color?"; "What is this?") or reading (e.g. "read") or answering questions (e.g. "What is your name?"). In the example above, the program reads the letter card A with the instruction "read" with the expected response from the child, namely the child answers "a".

The requirement for this program/activity to read the letter A is that the child has been able to imitate "a". If the child does not respond correctly (in this case marked with -/x, i.e. a silent or incorrect response), the therapist's assistant sitting behind the child prompts from the back of the child's side by saying "a" in a rather quiet voice that is quite audible to the child. If the child still responds silently or incorrectly (-/x), then the prompt is taken over by the therapist, with the therapist saying "say a" if the child has previously generalized from "copy a" to "say a" in the say drill program.

However, if there has never been a generalization of "copy a" with "Say a", then the therapist immediately gives the prompt "copy a". If the child continues to respond silently or incorrectly (-/x), the therapist implements the concept of imitation. The concept of imitation is to restore the child's understanding of the concept of imitation, with the therapist giving instructions to imitate gross and/or fine motor movements, 3-5 movements that the therapist is sure the child is capable of, so that it runs smoothly, does not stutter, then the therapist again gives instructions to "imitate A" with the mention of "A" expressively. If the child still responds silently or incorrectly (-/x), then the drilling is stopped and then moved to another program in the child's individual curriculum. If the child responds off-task, the child is prepared again, sat down, and paid attention, if needed.

Next, an evaluation is conducted for 3-5 sessions, a maximum of 10 sessions, in which if there is no improvement in ability, then the program/activity of reading the letter A is stopped, to re-run the program/activity of imitation A. This shows that the child's ability to imitate A has decreased. After the child's imitation ability reaches the graduation criteria, the program is run again (the example above is the letter A card reading program). What if in the Smart EP series the child responds correctly, namely following the prompt given? The value given is P (not the +/plus sign) because the child responds correctly in a series of prompts. Next, the Smart DTT series is carried out again, which starts again from preparing the child if necessary to be given instructions to label/read/answer, which in the example above is reading the letter A card.

Measurement and Evaluation

All participant responses were meticulously recorded by the assistant therapist following standardized Smart ABA assessment procedures. The rotation of roles between therapist and assistant functioned as an inter-rater reliability control to minimize scoring bias. Each response was coded according to Smart DTT procedures (Anwar et al., 2022) and visualized in real-time graphs, allowing parents, therapists, and consultants to monitor each child's progress and promptly adjust interventions in cases of stagnation or regression. Additional observations were conducted by the supervisor and consultant, both directly in the therapy room and through CCTV recordings.

Each child's response was categorized as silent (-), incorrect (X), off-task (O), partially correct (P+), or correct (+). Correct responses produced after direct prompting from the assistant on the third instruction were coded as P. Approximate responses in the verbal imitation program were coded as A (approximation), while responses in labeling and question-answering tasks were marked with a plus sign (+). The assistant therapist calculated session scores using the formula: $\text{Score} = (\text{Correct Response} / \text{Opportunity}) \times 100\%$, where CR represents the number of correct responses and OP the number of response opportunities (excluding P). Mastery was defined as achieving $\geq 80\%$ for three consecutive sessions under a dropout system (Arneliza et al., 2026). Each session consisted of three to five instructional cycles, two-instruction, or single-instruction depending on the child's performance and consultant recommendations. An example of Smart ABA recording and scoring is presented in Table 1.

Table 1.
Response Recording and Scoring

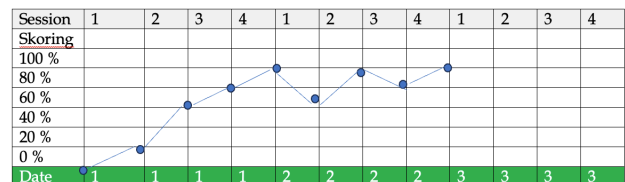
		TRIAL										TOTAL		
Date	Session	1	2	3	4	5	6	7	8	9	10	Op	C R	Score
1	1	X	X	P	X	X	P	X	X	P	X	10	0	0%
		X	P	X	X	P								
1	2	X	X	P	X	X	P	-	O	P	X	15	3	20%
		X	P	X	P	X	X	P	+	+	+			
1	3	-	X	P	+	+	P	-	+	+	P+	13	8	61%
		+	+	+	+									
1	4	+	+	O	+	+	+	+				7	6	85%
2	1	+	+	+	+	+						5	5	100%
2	2	X	+	+	X	+	+	+	+	+		9	7	77%
2	3	+	+	+	+							4	4	100%
2	4	+	+	O	+	+	+	+	+			8	7	87%
3	1	+	+	+	+	+						5	5	100%
		Fall					Passed/Achieved							

Data Recording and Monitoring

Table 1 shows that some sessions consisted of more than five cycles due to the implementation of Smart

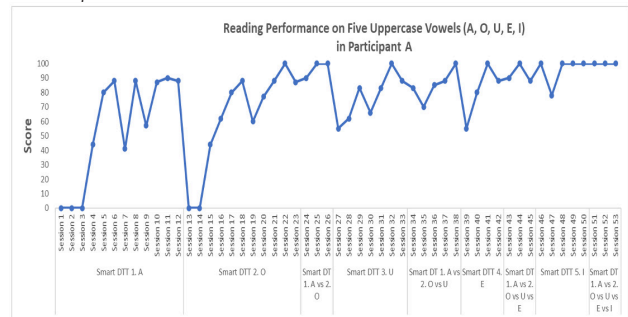
Establishing Operation (Smart EO), which lies outside the scope of this study. In each session, participants' percentage scores were plotted on progress graphs that served as visual tools for monitoring development and identifying potential regression. Recording was consistently carried out across both daily and maintenance programs. When stagnation or decline was observed, results were discussed during weekly meetings involving the consultant, program director, supervisor, and all therapists. The professional team then provided recommendations for corrective action to optimize learning outcomes. An example of the graphical recording format is presented in Table 2.

Table 2.
Graph of scoring calculation



The instrument was then implemented with five ASD participants by fifteen certified Smart ABA therapists. The results of implementing the systematic procedure for teaching reading in children with ASD using Smart ABA for Participant A are presented in Figure 4.

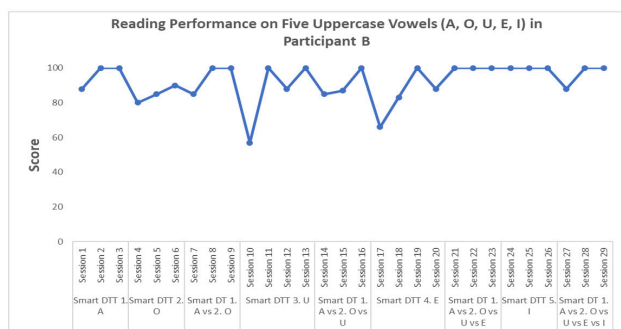
Figure 4:
Reading Performance on Uppercase Vowels in Participant A



The first two activities (A and O) were the most challenging for Participant A. Figure 4 shows that a longer time was required to reach the mastery criterion at this stage. The responses were still unstable and frequently declined. This indicates that the initial learning phase required greater effort and adjustment. However, after passing this stage, the learning process became more efficient. In subsequent letters, Participant A showed more consistent improvement. The time needed to reach mastery gradually decreased. By the end of the program, performance became stable and was well maintained across sessions.

The results of implementing the systematic procedure for teaching reading in children with ASD using Smart ABA for Participant B are presented in Figure 5.

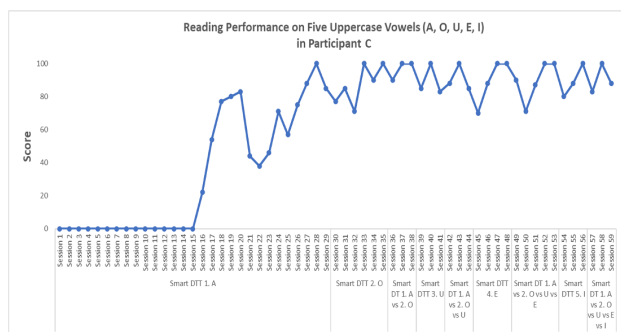
Figure 5:
Reading Performance on Uppercase Vowels in Participant B



Participant B showed generally high performance across sessions, with scores frequently reaching 90–100. Early sessions were relatively stable, although occasional declines appeared, particularly around Sessions 10 and 17. These drops indicate temporary difficulty when new targets were introduced. However, recovery was quick, and performance improved again in subsequent sessions. As training progressed, responses became more consistent. By the later sessions, Participant B maintained stable and high scores, suggesting effective learning and good retention of the vowel reading skills.

The results of implementing the systematic procedure for teaching reading in children with ASD using Smart ABA for Participant C are presented in Figure 6.

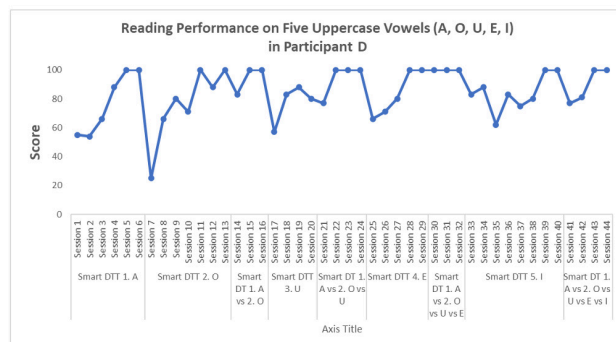
Figure 6:
Reading Performance on Uppercase Vowels in Participant C



Participant C showed very low performance in the early sessions, with scores remaining at zero until around Session 15. A sharp increase appeared after Session 15, indicating the initial emergence of the skill. However, performance was still unstable, with noticeable fluctuations in the middle phase. Several drops occurred when new targets were introduced. Despite this, improvement continued. In later sessions, scores frequently reached 90–100 and became more consistent. This pattern indicates gradual learning, improved adaptation, and stable retention over time.

The results of implementing the systematic procedure for teaching reading in children with ASD using Smart ABA for Participant D are presented in Figure 7.

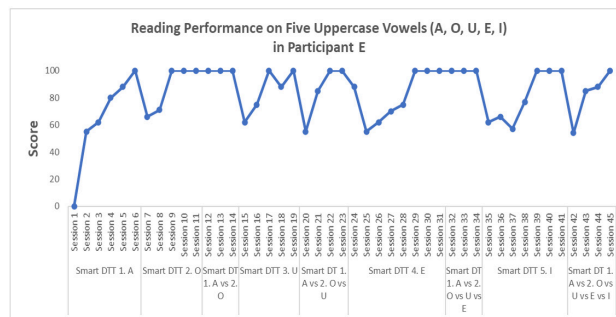
Figure 7:
Reading Performance on Uppercase Vowels in Participant D



Participant D demonstrated relatively high performance from the initial sessions. Scores rose to high levels within a short period. However, several sharp dips were observed, particularly around Sessions 7, 17, and 35, indicating temporary difficulties or adjustments. Although fluctuating, recovery was rapid after the dips. In subsequent sessions, performance returned to high levels and became more stable. By the end of the program, scores were consistently high, indicating strong learning, good adaptation, and stable retention of vowel reading skills.

The results of implementing the systematic procedure for teaching reading in children with ASD using Smart ABA for Participant E are presented in Figure 8.

Figure 8:
Reading Performance on Uppercase Vowels in Participant E



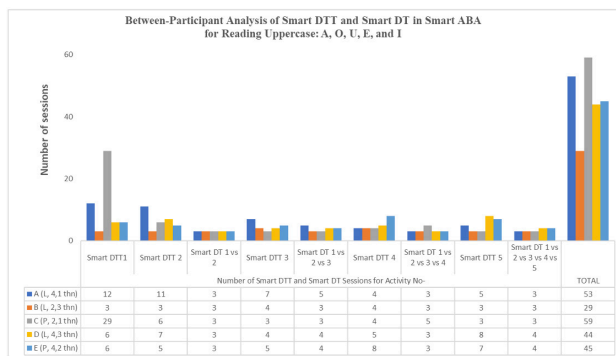
Participant E showed rapid performance improvement after the initial sessions. Scores rose rapidly, from very low to high levels. This indicates early mastery of the skill, although there were some fluctuations throughout the sessions, particularly when new targets appeared. Some dips occurred, but recovery was relatively rapid. In many sessions, scores reached 100, indicating strong performance. Toward the end, responses became more consistent. Overall, this pattern indicates effective learning, good adaptation,

and stable retention of vowel reading skills despite occasional variability.

To further clarify these individual differences, Figure 9 provides a between-participant comparison of session distribution across instructional phases, highlighting variations in learning efficiency and progression under the Smart ABA framework.

Figure 9.

Results of reading five uppercase vowel letters (A, O, U, E, I) from five participants



All five participants showed variations in the time required to achieve mastery of five uppercase vowel letters (A, O, U, E, I) using the Smart ABA framework. Participant A (4 years, 1 month) completed the program in 53 sessions, while Participant B (2 years, 3 months) achieved mastery fastest in 29 sessions. Participant C (2 years, 1 month) required 59 sessions, whereas Participants D (4 years, 3 months) and E (4 years, 2 months) completed their programs in 44 and 45 sessions, respectively. The overall average was 46 sessions, equivalent to approximately two weeks, demonstrating the efficiency of Smart ABA in accelerating reading acquisition with consistent performance across all participants.

The initial Smart DTT phase proved to be the most challenging, as it marked the children's first exposure to reading. Subsequent Smart DT 1 vs 2 phases demanded higher focus and behavioral control due to increasing discriminative complexity. Following these stages, the number of required sessions gradually declined, reflecting improvements in compliance, attention, and cognitive engagement. This trend indicates that Smart ABA not only enhances academic skills but also effectively stimulates adaptive behavior, focused attention, and discrimination abilities through its systematic and structured learning process.

Comparisons among participants revealed that chronological age was not the primary determinant of learning speed. Variations were more strongly associated with behavioral readiness, instructional compliance, and reinforcement consistency throughout the learning process. All participants reached reading mastery within an average of two

weeks (11–12 effective days), while home-based generalization showed 100% retention after three days. These findings confirm Smart ABA's effectiveness as a structured, measurable, and replicable instructional model that supports early literacy development in children with ASD, both in therapeutic and home-based learning contexts.

Discussion

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition marked by persistent deficits in communication, social interaction, and adaptive functioning, typically appearing before the age of three (Blaxill et al., 2022; Salari et al., 2022). The global prevalence of ASD has risen significantly over the past two decades, underscoring the urgency of early, targeted interventions to improve developmental outcomes (Jiang et al., 2024). One of the most challenging areas for children with ASD is verbal communication, which affects their capacity for social participation, learning, and independence (Dehqanova & Tagonova, 2022; Tawil et al., 2018). Reading requires the integration of visual, linguistic, and cognitive processes, domains often impaired in autism due to attentional and sensory deficits (Linderholm et al., 2018; Kim & Klassen, 2018). Enhancing reading ability has been shown to improve communication, autonomy, and academic achievement (Boyle et al., 2019; Light et al., 2019). Bandura's Social Learning Theory (Bandura, 1977) highlights the role of observation and modeling in developing literacy skills among children with ASD.

Applied Behavior Analysis (ABA) offers an evidence-based framework for modifying behavior through reinforcement, prompting, and stimulus control (Du et al., 2024). Its intensive form, Early Intensive Behavioral Intervention (EIBI), provides structured and repetitive instruction that strengthens language, cognition, and social adaptation (Bull Ellegaard et al., 2024; Sandbank et al., 2024). Smart ABA advances ABA by integrating systematic instructional sequencing, a two-on-one therapist model, and real-time quantification of progress (Arneliza et al., 2026), addressing methodological gaps through transparent and replicable teaching procedures aligned with Sustainable Development Goal 4, which promotes inclusive and quality education for all. An important distinction in instructional format lies between the commonly used one-on-one ABA approach and the two-on-one model implemented in Smart ABA.

In many ABA applications, instruction is delivered by a single therapist who is also responsible for recording responses (Reichow et al., 2012; Virués-Ortega, 2010; Wong et al., 2015). While this approach is effective, it may limit real-time data accuracy and reduce opportunities for immediate observational support. In contrast, the two-on-one model in Smart ABA allows

one therapist to focus on instruction while the therapist assistant (TA) records responses systematically and provides prompt support when needed. This division of roles enhances data accuracy, maintains child engagement, and reduces inter-rater bias. The presence of two trained therapists also enables continuous monitoring and immediate adjustment of instructional strategies, which may contribute to faster skill acquisition and more stable performance outcomes observed in this study. The use of a two-on-one instructional model in Smart ABA is grounded in the need for precise and continuous behavioral monitoring. In one-on-one settings, therapists are required to simultaneously deliver instruction and record responses, which may divide attention and reduce the accuracy of real-time data capture. In contrast, the two-on-one model allows a clear division of roles, where one therapist focuses on instruction while the therapist assistant (TA) ensures accurate trial-by-trial recording and immediate prompt delivery. This structure supports more precise data collection, faster instructional adjustments, and reduced response latency, which are critical in early skill acquisition, particularly in children with ASD who require consistent and immediate feedback.

This study suggests that Smart ABA may be more effective in supporting early reading development among children with ASD. While ABA has been widely applied to teach reading-related skills, previous studies have not consistently provided explicit descriptions of instructional sequencing, mastery timelines, or systematic measurement procedures. In contrast, Smart ABA integrates structured instructional sequencing, a two-on-one model (one child with two therapists), and real-time quantitative measurement to support objective progress evaluation. The findings indicate that this approach may facilitate faster skill acquisition and enhance performance stability across intervention phases. In this study, participants achieved the mastery criterion for five uppercase vowels (A, O, U, E, and I) in an average of 46 sessions, or approximately two weeks. The use of a clearly defined mastery criterion allows progression to subsequent learning stages to be determined objectively, ensuring that each skill is acquired consistently before advancing. This duration appears more efficient compared to reports from previous ABA-based studies that did not explicitly document mastery timelines. These results suggest that the structured and measurable nature of Smart ABA may contribute to more efficient and consistent learning outcomes.

The findings also revealed progressive improvements in compliance, attention, and cognitive ability, suggesting that the Smart ABA system may support adaptive behavior and early literacy through systematic, structured, and measurable procedures. Singh et al. (2017) reported an 80% improvement in

reading comprehension after 12 sessions, Solis et al. (2016) achieved 73–83% gains over two weeks, and Bekmurat and Autayeva (2023) observed significant lexical improvements after nine months of adapted ABA therapy. Arciuli and Bailey (2021) highlighted the importance of quantitative monitoring in reading programs. Beckerson et al. (2024) found comprehension improvements after 200 hours of Visualizing and Verbalizing training, Reisener et al. (2014) noted fluency gains after 30 sessions, and Boyle et al. (2019b) confirmed the effectiveness of shared reading for comprehension. However, most of these studies did not clearly describe standardized instructional procedures, systematic measurement approaches, or the time required to reach the mastery criterion. Smart ABA bridges this methodological gap by providing a structured, quantifiable, and replicable instructional framework including clearly defined mastery criteria applicable across educational and therapeutic contexts. This approach may contribute to more efficient and consistent learning outcomes.

Implications for Practice

This study explicitly documents the mastery of five uppercase vowels (A, O, U, E, I) within an average of 46 sessions, or approximately two weeks, suggesting both efficiency and methodological consistency within the Smart ABA framework. The findings enrich the ABA literature by introducing time-based measurement as a meaningful metric for assessing intervention effectiveness. This approach addresses a methodological gap in ABA research by emphasizing that time tracking enhances clinical validity, data transparency, and replicability. The structured Smart ABA model provides an evidence-based instructional framework that enables objective progress monitoring, supports individualized learning, and aligns with Sustainable Development Goal 4 which aims to ensure quality and inclusive education for all children through measurable and replicable therapeutic outcomes.

Implications for Future Research

Documenting the duration required for skill mastery serves not only as an indicator of efficiency but also as an early diagnostic tool for identifying stagnation or regression. Boyle et al. (2019) highlighted the importance of structured and systematic instructional approaches in improving early language and literacy outcomes in children with ASD, which is consistent with the emphasis on systematic measurement and transparent data recording in the Smart ABA system. Future studies should extend this framework to broader literacy domains, adaptive behaviors, and diverse age groups, as well as examine its scalability within inclusive educational systems aligned with the Sustainable Development Goals (SDGs).

Conclusion

This study demonstrates that Smart ABA significantly enhances early reading skills in children with ASD through a systematic learning structure, standardized teaching techniques, a two-on-one model (one child with two therapists), and transparent quantitative measurement. Compared to conventional ABA, Smart ABA requires a shorter duration, with an average of 46 sessions or approximately two weeks to achieve mastery of five uppercase vowel letters (A, O, U, E, I), indicating greater efficiency and consistency.

Beyond its empirical impact, Smart ABA provides an important methodological contribution by introducing time-based tracking as an indicator of intervention effectiveness. These findings make a significant contribution to the development of evidence-based interventions for children with ASD and support the achievement of Sustainable Development Goal (SDG) 4, which aims to ensure inclusive and quality education for all children.

This study's main limitation lies in its small sample size of five nonverbal children with ASD under five years old, which restricts the generalizability of the results. Future research should include a larger and more diverse participant sample to enhance external validity, and investigate the effectiveness of Smart ABA across a wider range of developmental stages and literacy domains in older children with ASD.

Use of Artificial Intelligence Tools

The authors used ChatGPT as a supporting tool for language refinement, grammar checking, and improving the readability of the manuscript. All research activities, interpretation, and final decisions regarding the manuscript were made by the authors, who bear full responsibility for its content.

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