

Differentiated Digital Scaffolding to Support Engagement and Learning Independence Among Students with Autism Spectrum Disorder

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Abstract

This study investigated Differentiated Digital Scaffolding (DDS) as an individualized support framework for improving engagement, participation, learning independence, and English vocabulary performance among students with autism spectrum disorder (ASD). The study used a mixed-method single-subject A–B–A design involving five primary school students with ASD, consisting of three verbal and two minimally verbal students enrolled at an inclusive elementary school in Central Java, Indonesia. Quantitative data were collected through the engagement and behavior observation checklist, DDS observation sheet, vocabulary probe test, response latency records, and prompt-level records. Qualitative data were obtained from classroom observations and teacher interviews. The results showed that on-task behavior among verbal students increased from 50–70% during baseline to 85–95% during the intervention. On-task behavior among minimally verbal students increased from 40–60% to 70–80%. Off-task behavior decreased from 3–8 to 1–2 episodes among verbal students and from 6–11 to 1–3 episodes among minimally verbal students. All participants also demonstrated vocabulary gains of 3–8 correct responses. Verbal students mainly responded through spoken labeling, while minimally verbal students responded through pointing, matching, and visual selection. The findings indicate that DDS supported more stable engagement, reduced prompt dependence, and increased participation through individualized verbal, visual, gestural, technical, and behavioral scaffolding.

INTRODUCTION

Students with autism spectrum disorder (ASD) often experience barriers to meaningful participation in inclusive classroom learning, including dependence on adult prompting, disengagement during instruction, delayed task initiation, off-task behavior, and emotional or behavioral withdrawal. Difficulties in sustaining engagement and transitioning between activities frequently lead teachers to provide repeated prompts and individualized assistance, which may unintentionally limit students' independence and active participation (Milley & Machalicek, 2012). Therefore, inclusive classrooms require individualized support systems that respond to students' communication profiles, attention regulation, emotional readiness, and learning independence (Meindl et al., 2020; Petersson-Bloom & Holmqvist, 2022).

These participation barriers become particularly visible in English learning activities because students are required to sustain attention, process visual and auditory input, and communicate understanding through verbal or non-verbal responses. Verbal students may still require support to maintain attention and initiate responses, while minimally verbal students may participate through gestures, pointing, visual selection, or augmentative and alternative communication. This diversity of communication profiles suggests that inclusive learning should recognize multiple forms of response as meaningful classroom participation (Kasari et

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al., 2013; Vogindroukas et al., 2022). In this study, vocabulary learning serves as an instructional context for observing how individualized support can strengthen engagement, participation, and learning independence.

Previous studies have explored visual supports, mobile applications, and computer-based interventions to improve communication and learning access for students with ASD (Fatmawaty et al., 2021; Hayes et al., 2010; Hussain et al., 2021; Khowaja et al., 2019). However, digital tools alone do not automatically create inclusive participation. Without individualized scaffolding, students with ASD may remain disengaged, dependent on adult assistance, or unable to interact independently with learning tasks (Alzrayer et al., 2014; Sandgreen et al., 2021; Wang et al., 2024). In the context of this study, the participating school was an inclusive elementary school in Central Java, Indonesia, which implemented the national Merdeka Curriculum together with an internally developed inclusive curriculum and an English Special Club (ESClub) designed to introduce English to students with ASD.

Differentiated Instruction, Vygotsky's Zone of Proximal Development, and scaffolding theory provide the conceptual foundation for Differentiated Digital Scaffolding (DDS), which is understood in this study as an individualized and adaptive support framework combining differentiated instruction, scaffolding, and digital mediation (Tomlinson & Imbeau, 2023; Vygotsky, 1978; Wood et al., 1976). DDS includes technical, pedagogical, and contextual scaffolds that help students remain engaged, reduce dependence on adult prompting, and participate more independently in learning activities. Vocabulary development is therefore positioned as an academic outcome emerging from improved engagement, participation, and individualized support rather than as the central problem of the study (Lord et al., 2018).

Although previous studies have examined digital tools for supporting language and communication development among students with ASD, limited research has investigated how individualized scaffolding can reduce prompt dependence, sustain engagement, and support independent participation among students with different communication profiles (Alzrayer et al., 2014; Khowaja et al., 2019; Milley & Machalicek, 2012). Therefore, this study aims to investigate how Differentiated Digital Scaffolding supports engagement, learning independence, and English vocabulary development, and how scaffolds are adjusted across verbal and minimally verbal students with ASD at an inclusive elementary school in Central Java, Indonesia.

METHODS

Design

This study adopted a mixed-method design using a single-subject A–B–A framework to investigate how Differentiated Digital Scaffolding (DDS) functions as an individualized and adaptive support intervention for students with ASD during English learning activities. The study focused on changes in engagement, participation, prompting dependence, learning independence, and vocabulary development, while documenting scaffold adjustments among verbal and minimally verbal students. The single-subject design enabled an in-depth examination of each participant's behavioral responses, engagement patterns, prompting needs, and participation across different intervention phases while integrating both quantitative and qualitative data to understand the individualized scaffolding process.

The study followed an A–B–A reversal design consisting of baseline, intervention, and maintenance phases, as presented in Table 1. This design was considered appropriate because it allowed the researchers to observe individualized changes in engagement, prompting dependence, participation patterns, and learning independence across intervention phases, which are particularly important in studies involving students with ASD (Ledford & Gast, 2024).

Table 1. Phases of the Study Design and Description of Interventions

Code	Phase	Description
A1	Baseline	The systematic DDS intervention was not implemented. Accuracy, latency, prompt level, engagement, and behavioral responses were recorded under standardized assessment conditions.
B	Intervention	Eight DDS sessions were conducted: four My Words sessions (B1) followed by four Solite Kids sessions (B2). Technical, pedagogical, and contextual scaffolding was recorded across sessions.
A2	Maintenance	The systematic DDS intervention was withdrawn. The 25-item vocabulary assessment was repeated, with accuracy, latency, and any prompt required recorded separately.

Participants

The participants were five students (N=5) diagnosed with autism spectrum disorder (ASD), aged between 7 and 8 years, and enrolled at an inclusive elementary school in Central Java, Indonesia. Participants were selected through purposive sampling to ensure representation of diverse communication profiles and support needs among students with ASD. The inclusion criteria were as follows: a) A formal diagnosis of ASD with or without comorbid conditions such as ADHD, b) Enrollment at the participating inclusive elementary school, c) Parental consent to participate in the study, and d) The ability to participate in classroom interaction through verbal communication, gestures, visual selection, or augmentative and alternative communication (AAC).

The participants included students with verbal and minimally verbal communication profiles, allowing the study to examine how DDS responded to different engagement patterns, prompting needs, participation behaviors, and modes of communication during English learning activities. Rather than positioning verbal and minimally verbal students as comparative categories, the study viewed communication diversity as an important consideration for individualized scaffolding and adaptive support (Tomlinson & Imbeau, 2023).

Instruments

The implementation of DDS was evaluated through instruments that examined students' engagement, participation, prompting dependence, learning independence, and vocabulary development, as well as recorded scaffold adjustments during English learning activities.

Vocabulary Probe Test

A vocabulary probe assessment was administered to observe students' receptive and expressive responses during English learning activities. The assessment was not intended solely to measure vocabulary achievement, but also to examine how students participated, responded to prompts, maintained attention, and demonstrated learning independence while interacting with digital learning tasks. Receptive responses included identifying vocabulary through pointing, visual selection, or object recognition, while expressive responses involved verbal labeling or spoken repetition depending on students' communication profiles (Lord et al., 2018; Nation, 2013).

Engagement and Behavior Observation Checklist

An engagement and participation observation checklist was used to document students on-task behavior, sustained attention, response initiation, prompting dependence, participation patterns, and behavioral regulation during the intervention sessions. The instrument was used

to examine how DDS supported meaningful participation, reduced disengagement, and increased students' independent involvement in learning activities (Vygotsky, 1978).

DDS Observation Sheet

A DDS observation sheet was used to document the individualized scaffolding processes implemented during the intervention. The instrument focused on the type, intensity, timing, and adjustment of support provided according to students' communication profiles, engagement levels, behavioral responses, and prompting needs. The observation categories included technical scaffolds, such as interface simplification and navigation support; pedagogical scaffolds, such as modeling and graduated prompting; and contextual scaffolds, such as interest-based vocabulary selection and behavioral support. This instrument assisted in examining how DDS functioned as an adaptive support framework that promoted sustained engagement, reduced dependence on adult prompting, and supported more independent participation (Tomlinson, 2017).

Response Latency and Prompt-Level Records

Response latency was recorded as the time between the delivery of a vocabulary instruction and the participant's first observable response, with a maximum response window of 10 seconds. Prompt levels were recorded on a four-point scale: 0 indicated an independent response, 1 indicated a light verbal or gestural prompt, 2 indicated direct visual, gestural, or modeling support, and 3 indicated intensive modeling or guided assistance. Accuracy, latency, and prompt level were analyzed as separate indicators so that a correct prompted response was not interpreted as independent performance.

Teacher Interview Protocol

Semi-structured interviews were conducted with three teacher informants, identified by the initials T1, T2, and T3 to protect their confidentiality. T1 provided classroom information concerning P1, T2 provided information concerning P2 and P4, and T3 provided information concerning P3 and P5. The interviews examined scaffold adjustments, prompting patterns, task pacing, technical support, behavioral responses, participation, and changes in learning independence across the intervention sessions.

Procedure

This study followed an A–B–A structure comprising baseline (A1), intervention (B), and maintenance (A2). Phase B consisted of eight sessions divided into two application conditions: four My Words sessions (B1) followed by four Solite Kids sessions (B2). Across the phases, accuracy, response latency, prompt level, engagement, behavioral regulation, and observed scaffold adjustments were recorded.

Baseline (A1) Phase

During A1, the systematic DDS intervention was not implemented. Participants completed the 25-item vocabulary assessment and engagement observation under standardized assessment conditions. When additional assistance was required, the prompt level was recorded separately from response accuracy and latency. The resulting A1 values served as the phase-level reference for participant-level comparisons.

Intervention (B) Phase

During Phase B, DDS was implemented across eight sessions. The first four sessions used My Words (B1), and the next four sessions used Solite Kids (B2). The teacher provided

technical, pedagogical, and contextual scaffolding according to the participant's recorded communication, attention, navigation, and task-response needs.

Technical scaffolds included interface simplification, navigation guidance, and distraction reduction. Pedagogical scaffolds included modeling, graduated prompting, repetition, and guided response support, while contextual scaffolds included interest-based vocabulary selection and behavioral regulation strategies. Support was faded after stable attention, repeated successful responses, and independent completion of a task step were observed. Support was maintained or temporarily increased when participants showed prolonged response latency, declining attention, frustration, refusal, or difficulty completing the task.

Data were collected daily to examine changes in students' engagement, sustained participation, prompting dependence, behavioral regulation, learning independence, and vocabulary development and to document scaffold adjustments throughout the intervention process.

Maintenance (A2) Phase

During A2, the systematic DDS intervention was withdrawn. Participants completed the same 25-item vocabulary assessment under standardized conditions, while response accuracy, latency, and any prompt required were recorded separately. A2 therefore examined short-term maintenance of vocabulary performance and response efficiency after the intervention sessions.

Data Analysis

Quantitative data were examined using participant-level visual analysis and descriptive phase comparisons. Level was summarized using the A1 value, the mean of the eight Phase B sessions, and the A2 value. Trend was examined from the direction of the eight Phase B session records. Phase B stability was classified as stable when at least 80% of session points fell within $\pm 25\%$ of the phase median; lower percentages were classified as variable. Immediacy was reported descriptively as the change from A1 to the first Phase B session. Overlap was reported descriptively as the percentage of Phase B points that were better than the single A1 value: higher for accuracy and lower for latency and prompt level. Because A1 and A2 each contained one phase-level assessment, the immediacy and overlap summaries were treated as descriptive rather than formal causal estimates.

Data obtained from the engagement and behavior observation checklist, vocabulary probe test, and DDS observation sheet were analyzed descriptively to identify patterns of engagement, response initiation, prompting reduction, independent participation, and behavioral responses. For phase-level latency summaries, cumulative response latency across the 25 vocabulary items was divided by 25 to calculate mean latency per item.

Qualitative data from teacher interviews and classroom observations were analyzed using thematic analysis (Braun & Clarke, 2006). The analysis involved data familiarization, initial coding, theme development, theme review, and interpretation. The qualitative findings were used to explain how DDS functioned as an individualized and adaptive support intervention by documenting scaffolding adjustments, teacher mediation, prompting patterns, student responsiveness, and participation experiences across different communication profiles. To enhance trustworthiness, triangulation was conducted across observation data, vocabulary assessments, DDS observation records, and teacher interview findings.

Ethical Considerations

The research protocol received ethical clearance from the Research Ethics Committee of Universitas Negeri Semarang through an expedited review under Ethical Clearance Statement No. B/7470/UN37.3.1/KEP.00/2026. The protocol was declared ethically compliant with the

seven WHO 2011 standards, with reference to the 2016 Council for International Organizations of Medical Sciences guidelines, including social value, scientific value, equitable distribution of burdens and benefits, risk assessment, protection from inducement or exploitation, confidentiality and privacy, and informed consent.

Formal permission to conduct the study was obtained from the principal of the participating inclusive elementary school. Written informed consent was obtained from the parents or legal guardians of all student participants after they received information about the purpose, procedures, potential benefits, and possible risks of the study. Participation was voluntary, and parents or legal guardians could withdraw their children from the study without academic or administrative consequences.

The identities of student participants and teacher informants were protected through coded identifiers. Student participants were identified as P1–P5, while teacher informants were identified as T1, T2, and T3. Identifying information was removed from interview excerpts, classroom observation records, tables, figures, and research reports. All research data were stored securely and were accessible only to the research team. The intervention was non-invasive and was adjusted to the developmental, communication, behavioral, and emotional needs of each participant.

RESULTS

The results are organized into four subsections according to the outcome, instrument, and evidence type. Participant-level values are retained in Tables 2–6 and Figures 1–3; the narrative reports the main patterns, important differences, and selected cases.

Engagement and Behavioral Regulation

Quantitative evidence on engagement and behavioral regulation was obtained from the Engagement and Behavior Observation Checklist. On-task behavior increased from 50–70% at A1 to 85–95% during Phase B among verbal participants and from 40–60% to 70–80% among minimally verbal participants. Off-task episodes decreased from 3–8 to 1–2 among verbal participants and from 6–11 to 1–3 among minimally verbal participants. Participant-level baseline engagement and behavioral characteristics are summarized in Table 2.

Table 2. Baseline Engagement and Behavioral Characteristics Across Participants

Participant	Communication Profile	Baseline Engagement	Baseline Off-Task Episodes	Baseline Maladaptive Behavior Episodes	Readiness
P1	Verbal	Low	8	3	45%
P2	Verbal	Moderate	4	1	60%
P3	Verbal	Moderate	3	1	70%
P4	Minimally Verbal	Low	11	5	40%
P5	Minimally Verbal	Low	6	2	75%

Prompt Dependence and Learning Independence

Quantitative evidence on prompt dependence and learning independence was obtained from prompt-level records and the DDS Observation Sheet. Prompt levels declined across the eight intervention sessions, but the trajectories differed: P2 and P3 reached the lowest prompt levels, P1 showed a gradual reduction, and P4 and P5 continued to require visual, gestural, modeling, or navigational assistance. Participant-level support records are summarized in Table 3.

Table 3. DDS Support Levels and Individualized Scaffolding Across Participants

Participant	Initial DDS Support Level	Main Support Needs	Scaffolding Focus	Independence Outcome
P1	Level 2 – Supported	Attention redirection, low readiness, off-task behavior	Visual cues, verbal prompts, environmental structuring, reduced distraction	Improved task focus and response initiation
P2	Level 4 – Fading	Emotional regulation, task persistence	Minimal prompts, fading, contextual reinforcement	High independent interaction with application
P3	Level 3 – Light Support	Language support, attention maintenance	Light verbal prompting, visual support, pacing, guided response	Increased participation with fewer prompts
P4	Level 1 – Intensive Support	Intensive prompting, sound distraction, task avoidance	Visual and gestural prompts, physical guidance, behavioral support	Longer engagement with continued intensive support
P5	Level 1 – Intensive Support	High scaffolding needs, distractibility, frustration with new materials	Visual-kinesthetic support, repeated modeling, guided navigation	Increased participation and device interaction with continued support

Individualized Scaffold Adjustments and Qualitative Evidence

Qualitative evidence on scaffold adjustments and participation was obtained from the DDS Observation Sheet, classroom observation records, and the semi-structured interview report. Recorded adjustments included navigation assistance, distraction reduction, short instructions, visual or gestural prompts, modeling, guided practice, fading, and interest-based reinforcement. The observed patterns are summarized in Table 4.

Table 4. Individualized DDS Adjustments Across Participant Profiles and Observed Needs

Communication Profile	Main Participation Challenge	DDS Scaffold Adjustment	Observed Participation Outcome
Verbal students	Attention regulation, response initiation, task persistence	Short verbal instructions, verbal reinforcement, attention redirection, reduced distractions, and scaffold fading	Longer engagement and more independent spoken responses
Minimally verbal students	Limited spoken response, dependence on prompts, difficulty initiating interaction	Visual cues, gestural prompts, physical guidance, guided navigation, and repeated modeling	Increased non-verbal participation and independent device interaction
Students with ADHD characteristics	Distractibility, fluctuating attention, short task tolerance	Short task sequences, repeated redirection, technical scaffolding, and reduced sensory distraction	More stable task focus and participation
Students with emotional or behavioral dysregulation	Frustration, refusal, withdrawal, task avoidance	Calming prompts, predictable routines, pacing adjustments, behavioral support, and temporary scaffold increases	Fewer refusals and more stable participation

T2 reported that P2 “could complete the activities independently and no longer required my demonstration.” This excerpt corresponded with the low prompt levels recorded for P2 during the later My Words and Solite Kids sessions.

Regarding P4, T2 stated that the participant “was able to remain in the activity longer when the environment was calm, and the instructions were short.” Classroom observation

records also documented less frequent redirection, correct picture selection, and repeated attempts after errors under these conditions.

Regarding P5, T3 explained that the participant “still needed support to maintain the flow of learning,” so scaffold fading could not be implemented too rapidly. Observation records showed that P5 requested assistance through gestures and occasionally shifted to drawing when attention declined, while continuing to participate through pointing, selecting, drawing, and writing.

Vocabulary Accuracy, Response Latency, and Participant-Level Visual Analysis

Quantitative and participant-level visual evidence on vocabulary accuracy, response latency, and prompt levels was obtained from the 25-item Vocabulary Mastery Assessment administered at A1 and A2, Vocabulary Progress Monitoring conducted across the eight Phase B sessions, and prompt-level records. Across participants, vocabulary accuracy generally increased, whereas response latency and prompt levels decreased during the intervention. P2 and P3 demonstrated the highest Phase B accuracy and the shortest response latency, while P4 and P5 continued to show longer response times. Verbal participants mainly responded through spoken labeling, whereas minimally verbal participants demonstrated vocabulary knowledge through pointing, matching, and visual selection. Phase-level summaries are presented in Table 5, and participant-level trajectories are displayed in Figures 1–3.

Table 5. Participant-Level Vocabulary Accuracy, Response Latency, and Prompt Levels Across A1, B1/B2, and A2

Participant	Outcome	Phase A1	Phase B		Phase A2
			B1	B2	
P1	Accuracy (%)	44.00	71.43	63.69	100.00
	Mean latency per item (s)	5.40	3.61	3.74	2.96
	Mean prompt level	2.84	1.17	0.97	0.92
P2	Accuracy (%)	80.00	95.83	95.83	100.00
	Mean latency per item (s)	3.04	2.05	2.09	2.20
	Mean prompt level	2.00	0.29	0.33	0.40
P3	Accuracy (%)	72.00	95.83	91.67	100.00
	Mean latency per item (s)	2.96	2.20	2.29	2.00
	Mean prompt level	2.36	0.48	0.41	1.00
P4	Accuracy (%)	64.00	75.00	75.60	80.00
	Mean latency per item (s)	6.12	4.37	4.18	4.60
	Mean prompt level	2.88	0.89	1.05	1.00
P5	Accuracy (%)	60.00	71.43	79.76	100.00
	Mean latency per item (s)	6.32	4.85	4.75	4.44
	Mean prompt level	2.88	1.09	1.17	2.00

Note. Accuracy is reported as a percentage. A1 and A2 values were obtained from the 25-item vocabulary assessment. B1 values are means across four My Words sessions, while B2 values are means across four Solite Kids sessions. Lower latency and prompt levels indicate improvement.

Table 6 reports level, Phase B trend and stability, descriptive immediacy, and descriptive overlap. Accuracy showed an upward Phase B trend for all participants. Accuracy was stable for P2, P3, P4, and P5 but variable for P1. Latency showed a stable downward trend for all participants. Prompt levels declined for all participants; the Phase B prompt series was stable for P1 and P5 and variable for P2, P3, and P4.

The first Phase B session improved on the A1 value for all three outcomes in P1, P2, P3, and P4. P5 showed immediate reductions in latency and prompt level, while his first-session accuracy was 10 percentage points below A1 before increasing in subsequent sessions. All

Phase B latency and prompt points were better than the A1 value for every participant; accuracy non-overlap was 100% for P1, P2, P3, and P4 and 87.5% for P5.

Because A1 and A2 each contained a single phase-level assessment, within-phase trend and stability could not be evaluated for those phases. The immediacy and overlap values are therefore descriptive summaries relative to one A1 point and should not be interpreted as complete demonstrations of experimental control.

Table 6. Participant-Level Visual Analysis Summary

Participant	Level : A1 → B mean → A2 (A/L/P)	Phase B trend and stability (A/L/P)	Immediate change: A1 → B1	Favorable B points vs A1 (A/L/P)
P1	44.00 → 67.56 → 100.00%	Up; variable	+6.00 pp	100.00%
	5.40 → 3.67 → 2.96 s	Down; stable	-1.57 s	100.00%
	2.84 → 1.07 → 0.92	Down; stable	-1.51	100.00%
P2	80.00 → 95.83 → 100.00%	Up; stable	+3.33 pp	100.00%
	3.04 → 2.07 → 2.20 s	Down; stable	-0.71 s	100.00%
	2.00 → 0.31 → 0.40	Down; variable	-1.33	100.00%
P3	72.00 → 93.75 → 100.00%	Up; stable	+11.33 pp	100.00%
	2.96 → 2.25 → 2.00 s	Down; stable	-0.63 s	100.00%
	2.36 → 0.45 → 1.00	Down; variable	-1.86	100.00%
P4	64.00 → 75.30 → 80.00%	Up; stable	+2.67 pp	100.00%
	6.12 → 4.28 → 4.60 s	Down; stable	-1.45 s	100.00%
	2.88 → 0.97 → 1.00	Down; variable	-1.88	100.00%
P5	60.00 → 75.59 → 100.00%	Up; stable	-10.00 pp	87.50%
	6.32 → 4.80 → 4.44 s	Down; stable	-0.99 s	100.00%
	2.88 → 1.13 → 2.00	Down; stable	-1.71	100.00%

Note. A = accuracy; L = mean response latency; P = mean prompt level; B mean = mean of the eight intervention sessions; pp = percentage points. Phase B stability was classified as stable when at least 80% of points were within $\pm 25\%$ of the phase median. Immediate change compares A1 with the first My Words session. Favorable B points are above A1 for accuracy and below A1 for latency and prompt level. Because A1 contained one point, immediacy and overlap are descriptive.

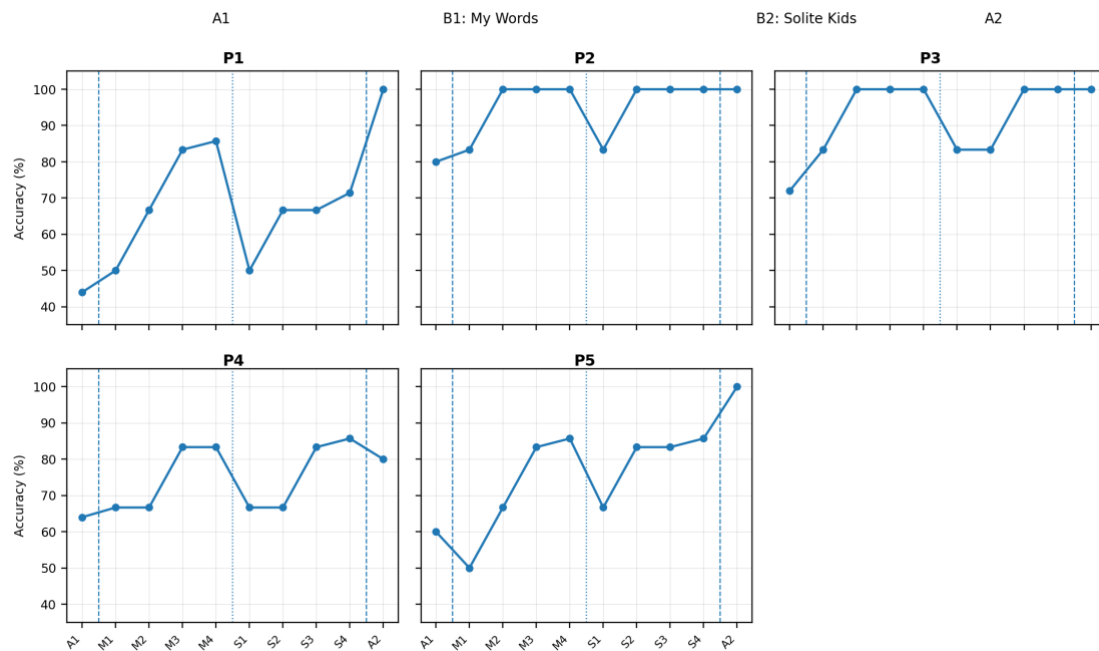


Figure 1. Participant-level vocabulary accuracy across A1, four My Words sessions (B1), four Solite Kids sessions (B2), and A2.

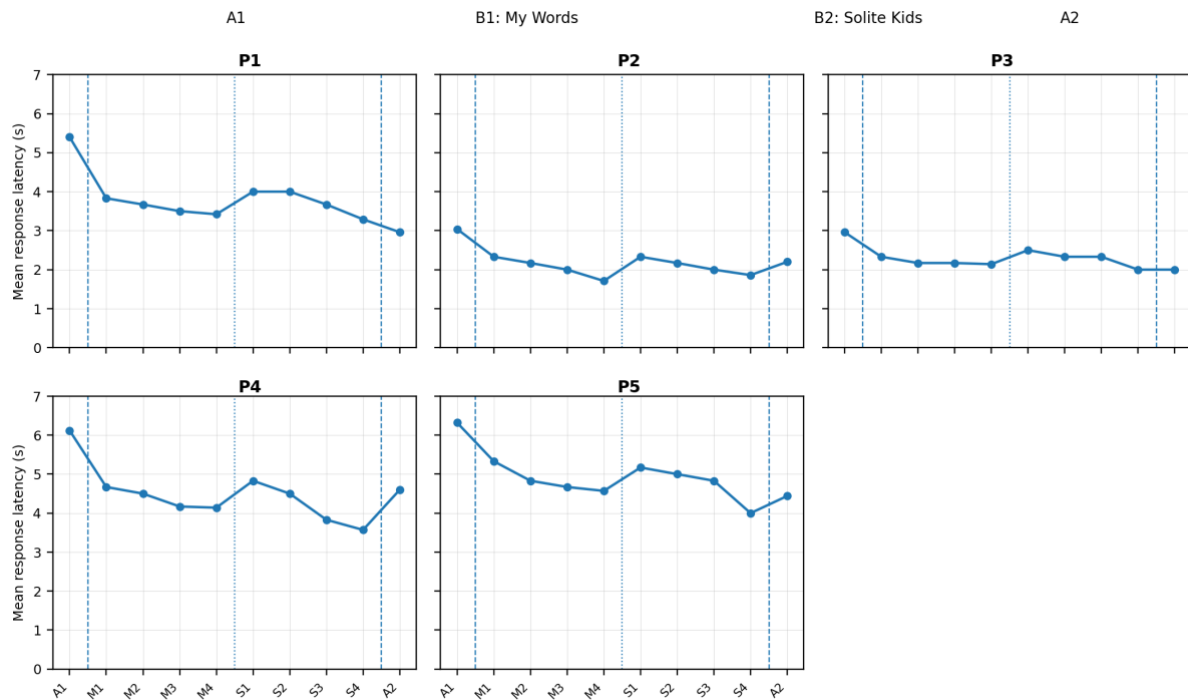


Figure 2. Participant-level mean response latency across A1, four My Words sessions (B1), four Solite Kids sessions (B2), and A2.

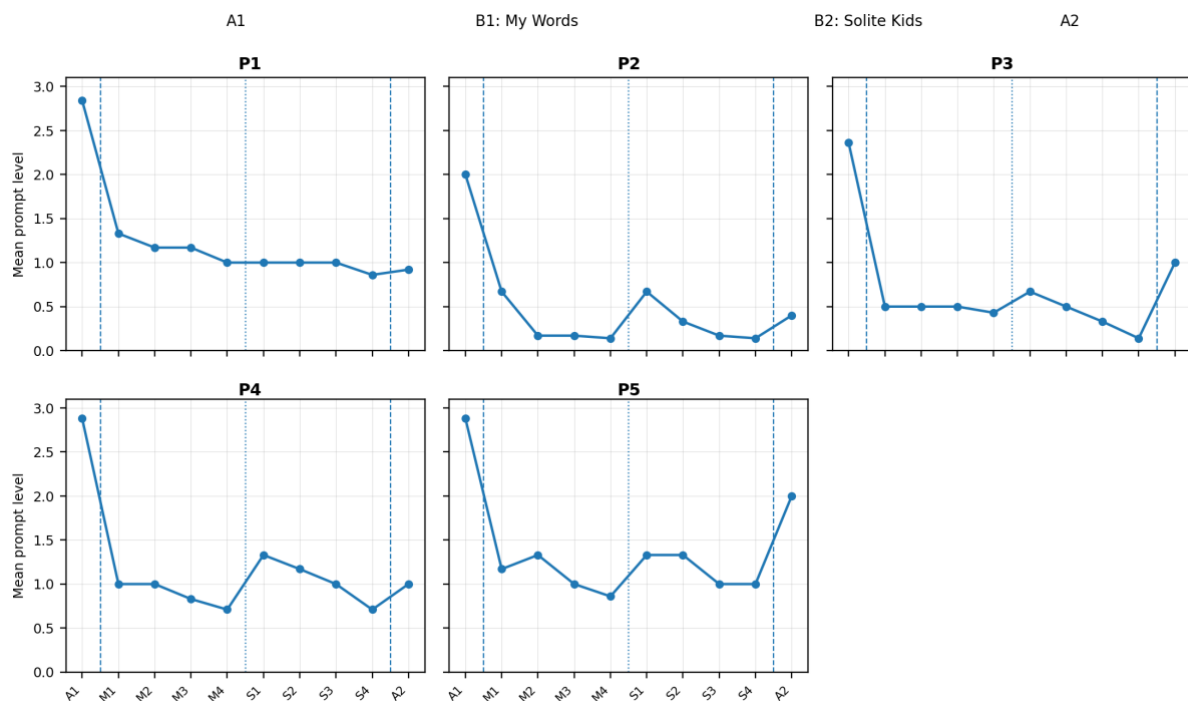


Figure 3. Participant-level mean prompt level across A1, four My Words sessions (B1), four Solite Kids sessions (B2), and A2.

DISCUSSION

This study examined Differentiated Digital Scaffolding as an individualized support framework for strengthening engagement, behavioral regulation, learning independence, and vocabulary development, while documenting individualized scaffold adjustments among students with ASD. The findings showed that the contribution of DDS did not arise from the

digital applications alone. The observed changes were closely related to the teacher's ability to adjust technical, pedagogical, contextual, and behavioral support according to each participant's communication profile and immediate learning needs.

The results also showed that DDS did not produce an identical pattern across all participants. Verbal students generally progressed toward reduced prompting and more independent spoken responses. Minimally verbal students also demonstrated improved participation and vocabulary performance, but continued to require more visual, gestural, navigational, and physical support. These differences indicate that DDS operated through individualized pathways rather than through a standard intervention sequence.

Engagement and Behavioral Regulation Through Individualized Scaffolding

The increase in on-task behavior and the reduction in off-task episodes indicate that DDS supported more stable engagement during digital English learning. Students became more able to attend to the application, initiate task-related actions, follow instructions, and continue activities for longer periods. These findings are consistent with previous research showing that students with ASD benefit from structured learning environments, visual supports, prompting, reinforcement, and carefully adjusted instructional demands (Hume et al., 2021; Meindl et al., 2020).

The engagement changes cannot be attributed only to the visual or interactive features of My Words and Solite Kids. The classroom records showed that the teacher regularly modified task length, instructional pacing, sensory stimulation, and prompt intensity. These adjustments were important because some participants became distracted by sounds, unfamiliar images, loading delays, or extended task sequences. Digital materials therefore functioned as learning resources, while DDS determined how students accessed and sustained interaction with those resources.

This interpretation is consistent with Alzrayer et al. (2014), Sandgreen et al. (2021), Wang et al. (2024) who found that digital interventions can support communication, learning, and behavioral outcomes among students with ASD. The present study adds a more specific explanation by showing that digital effectiveness depended on the organization of teacher support. The application did not independently reduce off-task behavior. The reduction occurred when digital interaction was combined with environmental structuring, brief instructions, attention redirection, predictable routines, and individualized reinforcement.

The decline in refusal, withdrawal, frustration, and task avoidance also suggests that engagement was connected to behavioral and emotional regulation. Participants were more likely to remain involved when the teacher recognized early signs of discomfort and adjusted the task before the behavior intensified. This finding supports evidence-based autism practices that emphasize antecedent adjustment, visual support, reinforcement, modeling, and structured teaching as methods for reducing barriers to participation (Hume et al., 2021; Odom et al., 2021; Wong et al., 2015).

Engagement in this study should therefore be understood as more than looking at a screen. It included sustained attention, willingness to continue, response initiation, behavioral stability, and participation through verbal or non-verbal modes. This broader understanding is important because students with ASD may demonstrate meaningful engagement in different ways. A spoken response, a point toward an image, a matching action, or an independent screen selection may each represent active participation when interpreted according to the student's communication profile.

Prompt Reduction, Learning Independence, and Maintenance

A central finding of this study was the gradual reduction in dependence on adult prompting. Participants who initially waited for repeated instructions became more capable of

initiating responses, navigating the applications, and completing task steps with less assistance. This pattern reflects the principle of scaffold fading, in which support is reduced after the learner demonstrates greater competence and stability (Vygotsky et al., 1978; Wood et al., 1976).

The findings also support (Tomlinson & Imbeau, 2023) view that instructional assistance should respond to differences in readiness, learning profile, and task demands. DDS did not require the teacher to reduce prompts at the same rate for every participant. P2 received fading support because she demonstrated stable engagement and independent interaction. P3 received light support, while P1 required more gradual prompt reduction because of attention difficulties. P4 and P5 continued to require intensive support because their participation depended more strongly on visual, gestural, physical, and navigational assistance.

This variation is important because scaffold fading should not be interpreted as the rapid removal of all support. Removing assistance before a student is ready can produce errors, frustration, withdrawal, or task avoidance. In this study, the teacher reduced scaffolding only after observing stable attention, repeated successful responses, shorter response latency, and lower prompt dependence. Support was maintained or temporarily increased when participants showed difficulty. DDS therefore operated as a dynamic decision-making process rather than a predetermined sequence.

The findings are consistent with Cengher et al. (2015), who showed that systematic prompt-fading procedures can support skill acquisition among children with ASD. The present study extends this principle to mobile-assisted vocabulary learning by showing that prompt fading involved more than verbal assistance. It also included reducing modeling, physical guidance, navigation support, visual cues, and environmental control according to the participant's progress.

The maintenance findings further strengthen the interpretation that participants developed greater task familiarity and learning independence. Vocabulary accuracy was maintained or increased during Phase A2, while mean response latency and prompt levels declined across participants. These patterns suggest that the changes observed during the intervention did not immediately disappear after the intensity of DDS was reduced.

The combined maintenance pattern should be interpreted as short-term retention with reduced assistance rather than complete independence. Lower latency and prompt levels indicated greater response efficiency and reduced dependence, while the remaining support needs of P4 and P5 showed that maintenance could coexist with continued individualized mediation.

The maintenance results should also be interpreted cautiously. The study involved five participants, and the maintenance phase occurred directly after the intervention. Therefore, the findings demonstrate short-term maintenance rather than long-term retention. Additional follow-up observations would be needed to determine whether vocabulary performance and independent responding remain stable over longer periods and in different classroom activities.

Scaffold Adjustments Across Communication Profiles

The findings showed that communication profile influenced the form of scaffolding required during DDS implementation. Verbal students mainly benefited from short oral instructions, verbal reinforcement, attention redirection, pacing adjustments, and fading. Minimally verbal students relied more strongly on visual cues, gestures, repeated modeling, guided navigation, pointing, matching, and physical assistance.

These differences should not be interpreted as evidence that verbal students were uniformly independent or that minimally verbal students were unable to learn. Verbal participants still showed attention, emotional regulation, and task persistence difficulties.

Minimally verbal participants demonstrated learning through receptive and non-verbal modes, including pointing, matching, selecting images, and interacting with the application interface.

This finding supports [Kasari et al. \(2013\)](#), who argued that minimally verbal students with ASD should not be evaluated through spoken language alone. Their communicative competence may appear through gestures, visual selection, aided communication, or other response forms. [Vogindroukas et al. \(2022\)](#) similarly emphasized the heterogeneity of language and speech characteristics among individuals with ASD.

DDS responded to this heterogeneity by adjusting both the expected response and the support used to obtain it. Verbal students could demonstrate vocabulary knowledge through naming and pronunciation. Minimally verbal students could demonstrate understanding through receptive identification. This approach allowed the same vocabulary content to be accessed through different participation pathways.

Taken together, these findings suggest that individualized support should not be treated as a fixed category attached to a communication label. Communication profile informed access and response options, but attention, sensory regulation, emotional state, and task familiarity also shaped the support required. From an inclusive education perspective, meaningful participation included both spoken and non-spoken responses and was evaluated in relation to each participant's available communication mode.

The findings also align with research on augmentative and alternative communication and tablet-based interventions. [Ganz et al. \(2012\)](#), [Ganz \(2015\)](#), and [Alzrayer et al. \(2014\)](#) showed that students with ASD can benefit from technology-supported communication when the devices are paired with appropriate prompting and instructional mediation. The current study confirms that access to a digital interface is not sufficient. Students also require support that matches their sensory tolerance, motor ability, attention regulation, and communication mode.

Individualized scaffold adjustments were also documented for participants with ADHD characteristics and for those who displayed emotional or behavioral dysregulation. Shorter task sequences and reduced distractions supported participants with fluctuating attention. Slower pacing, calming prompts, and predictable routines supported participants who showed frustration or refusal. These patterns indicate that DDS addressed communication needs together with behavioral, emotional, and sensory conditions.

Vocabulary Performance and Response Latency

Vocabulary development occurred across all five participants, with gains ranging from three to eight correct responses. Verbal students mainly demonstrated expressive improvement through spoken labeling, while minimally verbal students demonstrated receptive improvement through pointing, matching, and visual selection. These patterns indicate that vocabulary development can be demonstrated through different output forms according to the learner's communication profile.

The vocabulary results support previous findings that digital and multimedia environments can facilitate vocabulary learning among students with ASD when they provide visual representation, repetition, auditory input, and interactive practice ([Chen et al., 2019](#); [Hussain et al., 2021](#); [Wang et al., 2024](#)). However, the present findings suggest that these features became more useful when the teacher adjusted the task and support according to each participant's response.

P2 and P5 showed the largest vocabulary gains, although they had different communication profiles and received different DDS levels. P2 demonstrated strong independent verbal interaction and received fading support. P5 was minimally verbal and continued to receive intensive support. This difference shows that score gain alone does not fully represent learning independence. Vocabulary accuracy must be interpreted together with response mode, latency, prompt level, and the intensity of teacher assistance.

P1 showed a smaller vocabulary gain but demonstrated improved task focus and response initiation. P4 maintained a lower level of independent response but showed gains through receptive identification. These participant-level differences support the use of single-subject analysis because group-level summaries could conceal meaningful variations in how learning occurred.

Response latency provided additional information about task responsiveness. Verbal students generally responded more quickly, while minimally verbal students required more processing time and assistance. The latency differences may reflect variations in language production, attention, motor planning, comprehension, and prompt dependence. For this reason, longer latency should not automatically be interpreted as lack of understanding.

The reduction in latency during intervention and maintenance indicates that participants became more familiar with the task routines and initiated responses more efficiently. However, faster responses should not be treated as the sole indicator of success. For minimally verbal students, an accurate response produced after visual or gestural support remained a meaningful learning outcome. The combination of accuracy, latency, prompt level, and response mode provided a more complete account of vocabulary performance than vocabulary scores alone.

The maintenance results showed that participants retained or increased their vocabulary accuracy after support was reduced. This finding suggests that vocabulary learning was not limited to immediate prompted responses during Phase B. Nevertheless, the short maintenance period limits claims about long-term vocabulary retention. Future research should examine whether the learned vocabulary generalizes to new applications, classroom activities, real objects, and communication outside the intervention sessions.

Teacher Mediation and Implications for Inclusive Learning

Teacher mediation was central to the implementation of DDS. The teacher did not only deliver instructions. The teacher observed participant responses, selected the appropriate prompt, adjusted sensory conditions, controlled task pacing, and decided whether support should be increased, maintained, or faded. This continuous decision-making process distinguished DDS from the simple use of an educational application.

The teacher interviews and classroom observations showed that participants responded more consistently when support was timely and individualized. Brief verbal prompts and fading supported verbal students who were ready for greater independence. Visual cues, gestures, modeling, and navigation assistance allowed minimally verbal students to access the same learning content through alternative response modes.

These findings support [Vygotsky et al. \(1978\)](#) concept of the Zone of Proximal Development. Participants completed tasks that they could not consistently perform without assistance when the teacher provided support within their current developmental range. [Wood et al. \(1976\)](#) further explain that effective scaffolding involves controlling difficult task elements while allowing the learner to perform the components within their competence.

DDS also reflects differentiated instruction because the content, process, response mode, and learning environment were adjusted according to student readiness and learning profile ([Tomlinson & Imbeau, 2023](#)). The differentiation did not mean assigning entirely different learning goals to each participant. All students engaged with basic English vocabulary, but they received different forms of access and demonstrated learning through different responses.

The findings have practical implications for inclusive English classrooms. Teachers should not select digital applications only on the basis of attractive images, sounds, or game features. They should also consider navigation complexity, sensory demands, response format, task length, and the possibility of modifying prompts. A suitable application for one student may create distraction or frustration for another.

Teachers should also record more than test scores. Engagement, off-task behavior, response latency, prompt level, and response mode provide information needed to adjust support. These indicators help teachers determine whether a student is learning independently, responding only after intensive assistance, or experiencing barriers caused by the application or classroom environment.

DDS should therefore be viewed as a structured process of instructional adaptation. Digital applications provide vocabulary input and practice opportunities. Teacher mediation makes those opportunities accessible. The main contribution of DDS lies in connecting digital learning with individualized decisions about communication, attention, behavioral regulation, and independence.

Implications, Limitations, and Directions for Future Research

The findings indicate that DDS can support engagement, vocabulary learning, and learning independence when digital applications are combined with individualized teacher scaffolding. Teachers should adjust prompts, response modes, task pacing, sensory conditions, and application navigation according to each student's communication profile and support needs. Assessment should also consider vocabulary accuracy, response latency, prompt level, engagement, and verbal or non-verbal response modes.

The findings should be interpreted cautiously because the study involved only five participants from one inclusive school. The participants had different communication, behavioral, and sensory profiles, and the maintenance phase only examined short-term outcomes. The study also used two specific applications, while teacher mediation played a central role in the intervention.

The phase structure limited the scope of the single-subject visual analysis. A1 and A2 each included one phase-level vocabulary probe, whereas Phase B included eight session-level records. Consequently, changes in level could be described across A1, Phase B, and A2, while trend and stability could be examined during Phase B. Descriptive immediacy and favorable-point percentages were calculated relative to the single A1 value; however, these summaries should not be interpreted as formal phase-to-phase estimates or as evidence of complete experimental control. Future studies should collect at least three repeated observations in each phase to support a more rigorous visual analysis.

Future research should involve more participants, schools, teachers, and digital applications. Longer maintenance and follow-up periods are needed to examine retention and generalization. Further studies should also include treatment fidelity and inter-rater reliability to strengthen the consistency of the intervention and data collection.

CONCLUSION

This study shows that Differentiated Digital Scaffolding supported engagement, behavioral regulation, learning independence, and English vocabulary performance, together with individualized scaffold adjustment patterns among five students with ASD in an inclusive elementary school. The effects of DDS were not produced by the digital applications alone. They depended on individualized teacher mediation, including prompt adjustment, scaffold fading, task pacing, navigation assistance, sensory regulation, and support matched to each participant's communication profile.

During the intervention, verbal and minimally verbal students demonstrated increased on-task behavior and fewer off-task episodes. Participants also showed vocabulary gains of three to eight correct responses. Verbal students mainly demonstrated vocabulary knowledge through spoken labeling, while minimally verbal students responded through pointing, matching, gestures, and visual selection. Response latency and prompt records further showed that the participants followed different pathways toward more independent participation.

The maintenance findings indicated that vocabulary performance was maintained or increased after scaffolding was reduced. Participants also responded more quickly and required fewer prompts, although the level of independence varied. Minimally verbal students continued to require more visual, gestural, navigational, or guided support than verbal students.

These findings indicate that DDS can provide flexible access to digital English learning for students with different communication and support needs. However, the findings should be interpreted within the context of five participants from one inclusive school and a short maintenance period. Further studies should involve more participants, longer follow-up periods, and different educational settings to examine the retention and generalization of the observed outcomes.

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AUTHOR CONTRIBUTION STATEMENT

IVS responsible for conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing (original draft), visualization, and project administration. RH responsible for conceptualization, methodology, validation, formal analysis, data curation, writing (review and editing), visualization, and supervision HP responsible conceptualization, methodology, validation, formal analysis, data curation, writing (review and editing), and supervision.

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