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AI-Based Adaptive Learning for Autistic Children: Effects on Task Engagement and Motivation in Cameroon's Inclusive Primary Schools

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Abstract:

Background: Behavioural engagement strongly predicts academic achievement, yet it is systematically depressed among autistic children, whose heterogeneous learning profiles are poorly served by uniform whole-class instruction. In sub-Saharan Africa, where less than 1% of global autism research is conducted, and teachers receive little preparation in differentiated methods, no experimental study has tested whether AI-based adaptive learning can raise the engagement of autistic learners.

Objectives: This study evaluated the effects of AI-based adaptive learning on the task engagement and behavioural motivation of children with ASD Level 1 in inclusive primary schools in Yaoundé, Cameroon, compared with traditional whole-class instruction over twelve weeks.

Methods: A quasi-experimental study embedded in a convergent parallel mixed-methods design engaged 48 children with ASD Level 1 (24 experimental, 24 control) across one public and one private inclusive school. Grounded in the Zone of Proximal Development, Cognitive Load Theory, and Self-Determination Theory, the intervention used two adaptive applications: Khan Academy Kids and Autism ACE, an offline-capable application co-developed for local infrastructure conditions. Data were collected through the Structured Behavioural Observation Grid, automated usage logs, and teacher and parent interviews analysed using reflexive thematic analysis.

Results: Children in the adaptive condition completed over three times more task items per session (3.37 vs. 1.04; $t = 6.38$, $p < .001$, $d = 1.21$), displayed more positive affect ($d = 0.60$) without increased distress, and disengaged less often. Engagement followed a U-shaped trajectory inconsistent with a novelty effect. Teachers reported reduced mathematics avoidance and strengthened capacity to differentiate instruction; the principal challenge was managing overexcitement and session transitions.

Discussion: AI-based adaptive learning is feasible in Central African inclusive classrooms and substantially raises the behavioural engagement of autistic children, providing the first controlled evidence for this population and context. The findings position engagement as the gateway through which adaptive instruction operates, and identify infrastructure reliability and teacher professional development in inclusive AI use as the conditions under which these gains can translate into broader learning outcomes.

Keywords: *Autism Spectrum Disorder, behavioural engagement, artificial intelligence in education, adaptive learning technologies, inclusive education, time-on-task, sub-Saharan Africa*

I. INTRODUCTION

Mathematical competencies are foundational skills that support schooling, daily living, and later economic participation, yet they are among the most difficult academic domains for children with Autism Spectrum Disorder (ASD), with approximately one quarter of these learners presenting a mathematics learning disability (Karal & Riccomini, 2024). A consistent body of intervention evidence shows that this difficulty is conditional rather than fixed: when instruction is structured, individualised, and adapted to the learner, children with ASD make large gains in mathematics (Apanasionok et al., 2021; Karal & Riccomini, 2024; Liu et al., 2024). Together, these studies establish that the problem is not the capacity of the autistic child but the fit between the child and the instruction. Where this literature remains silent is on the mechanism of that fit. Intervention effects are large, but moderator analyses fail to identify which features drive them (Liu et al., 2024), which suggests that the active ingredient lies not in any single instructional component but in a condition common to all adapted instruction. Task engagement is the most plausible candidate for that condition. Across the engagement literature, three findings align. First, behavioural engagement observable as time-on-task is the strongest engagement-related predictor of academic achievement (Lei et al., 2018). Second, autistic learners participate less in classroom academic tasks than their peers, and this reduced participation restricts their access to instruction before any question of ability arises (Sparapani et al., 2023). Third, interventions that raise on-task behavior in learners with disabilities produce corresponding gains in achievement (Education and Treatment of Children, 2024). Read together, these findings position engagement as the gateway through which all instruction must pass: adapted instruction works because, and to the extent that, it keeps the child engaged. One caution qualifies this alignment. When engagement is inferred from time-on-task alone, it may reflect sustained attention rather than genuine motivation (Frontiers in Digital Health, 2026). Rigorous designs therefore require two separate measures: observed time-on-task and an independent index of motivated behaviour a requirement the present study meets.

Almost all of this evidence comes from high-income countries. Reviews of the African research base converge on the same conclusion from different angles: less than 1% of the world's autism research has been conducted in Africa, with no school-based intervention studies identified; three quarters of the studies that do exist come from only two countries, South Africa and Nigeria; and while roughly 95% of children with developmental disabilities live in low- and middle-income countries, research and services in sub-Saharan Africa have not followed them (Abubakar et al., 2016; Franz et al., 2017; Genovesi et al., 2022). The convergence of these reviews, conducted independently and across different periods, makes the gap uncontested: autistic children in sub-Saharan Africa are numerous and increasing, and the evidence on how to teach them is nearly absent. Central Africa, including Cameroon, does not appear in this evidence base at all.

The reason engagement collapses for autistic children in the region's classrooms is structural, and studies from four countries describe the same chain. ASD is highly heterogeneous: autistic children display distinct and variable learning profiles, and academic ability is not predicted by symptom severity. Teaching them therefore requires differentiated instruction. Yet mainstream teachers across South Africa, Ghana, and Cameroon report the same condition: positive attitudes toward inclusion combined with fragmented autism knowledge acquired informally, initial training that never covered autistic learners, and no in-service preparation in differentiated methods (Discover Education, 2024; Nthibeli et al., 2022; Sepadi, 2025; Tah, 2025). The alignment of these four studies, across different school systems and languages of instruction, indicates a regional pattern rather than a national exception. Cameroon represents the more severe end of it: participation of children with disabilities in schooling is low, and a dedicated national inclusive education policy was articulated only in October 2024, with implementation still in its earliest phase (Tah, 2025; MINEDUB, 2024).Where teachers cannot differentiate, whole-class instruction treats heterogeneous learners as identical and for the autistic child, engagement is depressed before instruction begins.

Regional evidence on educational technology suggests a way through this structural problem, and its logic converges directly on engagement. In Malawi, a randomised controlled trial found that a self-paced, child-centred maths application produced significantly greater learning gains than teacher-led practice (Pitchford, 2015); in Rwanda, a program of studies with autistic children showed that digital content can be adapted to inclusive classrooms and that participatory-designed applications are usable and motivating for these learners (Ntalindwa et al., 2021, 2022). What unites these two lines of work is the mechanism they imply: the technology succeeds by doing what the untrained teacher cannot, adjusting pace and difficulty to the individual child, and thereby holding the child on task. What separates them is design: the Malawian trials are experimental but not autism-specific, while the Rwandan studies are autism-specific but not experimental. No study in the region has yet combined experimental control, an autistic sample, and an inclusive classroom setting. The wider evidence confirms this absence: Campbell systematic reviews of disability interventions in low- and middle-income countries located no eligible study from Central Africa, drawing instead on India, Iran, China, South Africa, and Egypt (Hunt et al., 2025; Saran et al., 2023). In Cameroon, the need side of this equation is documented by national learning data only 35% of Grade 2 and 30% of Grade 6 learners reach minimum proficiency in mathematics (Frontiers in Education, 2026), and by field research showing that barriers for children with disabilities span infrastructure, materials, and cost (Sightsavers, 2018).

Artificial intelligence (AI)-based adaptive learning is the current form of the mechanism identified above, and the recent evidence on it aligns on engagement as its primary effect. Across a quasi-experimental platform study, a systematic review of 21 empirical studies, and user-experience research on adaptive platforms including Khan Academy, the same pattern repeats: AI-based systems that adjust difficulty, pacing, and feedback in real time produce higher engagement and motivation than uniform instruction, with learning gains following (Education and Information Technologies, 2025; Frontiers in Computer Science, 2025; Issues in Information Systems, 2025). This alignment matters for autism precisely because the core instructional problem in ASD is heterogeneity: a system that individualises continuously is, in principle, the direct answer to a population whose members each learn differently. Yet the populations behind this evidence are general student samples in high- and middle-income settings. Whether AI-based adaptive learning raises the observed engagement of autistic children in an African inclusive classroom is an empirical question that no study has answered.

The present study answers it. Over twelve weeks, children with ASD Level 1 in two inclusive primary schools in Yaoundé, Cameroon, received mathematics instruction either through AI-based adaptive learning applications (Khan Academy Kids and Autism ACE) or through traditional whole-class instruction. Engagement was measured through structured behavioural observation using momentary time sampling, together with a behavioural motivation composite derived from the observational grid. The objective of this article is to test whether AI-based adaptive instruction produces significantly higher time-on-task engagement and behavioural motivation than traditional classroom instruction among autistic children in this context.

I. Theoretical Framework

This study is grounded in three complementary theories that together explain why adaptive instruction should raise the engagement of autistic learners. Vygotsky's (1978) Zone of Proximal Development (ZPD) holds that learning occurs when tasks sit just beyond the child's independent capacity but within reach of guided support; tasks below this zone produce boredom and tasks above it produce withdrawal. Sweller's Cognitive Load Theory extends this logic to the architecture of working memory: instruction that exceeds the learner's processing capacity generates overload, and overload is expressed behaviorally as disengagement from the task [26], [27]. For autistic children, whose learning profiles are heterogeneous and whose attentional and processing resources vary widely from child to child [13], these two theories converge on the same prediction: a single, uniform level of whole-class instruction will place most autistic learners outside their zone or beyond their load capacity most of the time, and their engagement will fall accordingly. AI-based adaptive learning applications operationalise both theories simultaneously: by adjusting task difficulty and pacing to each child's responses in real time, the system continuously repositions the task within the child's ZPD while regulating the cognitive load imposed at each step [29], [27].

Deci and Ryan's Self-Determination Theory (SDT) explains the motivational consequence of this fit [8], [22]. SDT holds that engagement is sustained when three psychological needs are met: competence, autonomy, and relatedness [22]. Adaptive systems address the first two directly calibrated task difficulty produces repeated experiences of success that build perceived competence, and self-paced interaction gives the child control over the rhythm of learning that whole-class instruction cannot offer [8]. Behavioral motivation, in this framework, is not a fixed trait of the autistic child but an observable output of an environment that meets or fails these needs [22]. Taken together, the three theories form a single causal chain that structures Hypothesis 2 of this study: adaptive instruction places tasks within the child's zone and load capacity [26], [29], this fit satisfies competence and autonomy needs [22], and the result is measurable as higher time-on-task engagement and higher behavioural motivation relative to traditional instruction. The observational measures used in this study momentary time sampling of on-task behaviour and a behavioural motivation composite are direct empirical translations of the constructs this chain predicts.

A. Objectives of the Study

The objective of this paper is to evaluate the effects of AI-based adaptive learning on the task engagement and behavioural motivation of children with ASD Level 1 in inclusive primary schools in Yaoundé, Cameroon, compared with traditional whole-class instruction over twelve weeks.

Specific Objectives:

- To compare time-on-task engagement, measured through structured behavioural observation using momentary time sampling, between children receiving AI-based adaptive instruction and children receiving traditional classroom instruction.

- To compare behavioral motivation, measured through a composite derived from the observational grid, between the experimental and control groups across the twelve-week intervention period.

III. METHODOLOGY

A. Study Setting

This study was conducted in two inclusive primary schools in Yaoundé, Cameroon, selected to represent the two institutional forms through which autistic children access mainstream schooling in the country. The first is a public institution, the CNRPH Etoug-Ebé, which operates within the national rehabilitation infrastructure and serves children from predominantly low-income households. The second, Les Étoiles de Demain (Bastos-Nlongkak), is a private inclusive school serving a more resourced urban population. The two settings differ in funding, class size, and material conditions, but share the structural constraints documented for Cameroonian inclusive education: limited teacher preparation in special needs pedagogy, scarce adapted materials, and the absence of a clearly articulated national inclusive education policy [28]. Site selection was conducted in collaboration with school authorities, ensuring institutional consent and logistical feasibility from the outset.

B. Research Design

The study employed a twelve-week quasi-experimental design embedded in a convergent parallel mixed-methods framework [6]. This article reports the quantitative strand relevant to Hypothesis 2: the comparison of task engagement and behavioural motivation between an experimental group receiving AI-based adaptive instruction and a control group receiving traditional whole-class instruction. Random assignment of individual children was not feasible in intact inclusive classrooms; group allocation therefore followed a non-equivalent groups logic, with baseline observation data used to verify initial comparability. The design prioritizes ecological validity: instruction, observation, and measurement all took place under ordinary classroom conditions.

C. Study Timeframe

The intervention ran for twelve consecutive weeks within the national academic calendar. Baseline behavioural observations were conducted immediately before the intervention began, observation continued at structured intervals throughout the twelve weeks, and endline measures were completed at the end of the intervention period.

D. Intervention

Children in the experimental group received mathematics instruction through two AI-based adaptive learning applications: Khan Academy Kids, a freely available adaptive early-learning platform, and Autism ACE, an offline-capable application co-developed during fieldwork specifically for the connectivity and infrastructure conditions of Cameroonian schools. Both applications adjust task difficulty, pacing, and feedback to the individual child's responses. Children in the control group received traditional whole-class mathematics instruction delivered by their classroom teachers following the standard curriculum. Instructional content coverage was equivalent across conditions; the mode of delivery was the manipulated variable.

E. Measures

Task engagement was measured through structured behavioral observation using momentary time sampling, recording whether each child was on-task at fixed sampling points during mathematics instruction. Behavioral motivation was measured through a composite score derived from the structured observational grid, capturing observable indicators of task initiation, persistence, and voluntary continuation. Observers were trained on the grid prior to baseline, and observation procedures were identical across the two conditions.

F. Sampling: School Selection

The two schools were purposively selected in collaboration with school authorities. Selection criteria required institutions to be inclusive primary schools in Yaoundé enrolling children with a confirmed diagnosis of ASD Level 1 in mainstream classrooms, and willing to host a twelve-week classroom-based intervention. One public school (CNRPH Etoug-Ebé) and one private school (Les Étoiles de Demain, Bastos-Nlongkak) were retained, allowing the sample to reflect the two main institutional routes through which autistic children access schooling in Cameroon. Experimental and control conditions were matched on grade level and instructional content to ensure reasonable comparability. As a quasi-experimental study conducted in intact classrooms, the sampling strategy prioritised ecological validity over statistical representativeness; findings should be interpreted within these inferential limits.

G. Child Participants

A total of 48 children with Autism Spectrum Disorder Level 1 participated: 24 in the experimental group and 24 in the control group. Inclusion criteria required a documented diagnosis of ASD Level 1 (DSM-5-TR) confirmed through school and clinical records, enrollment in a mainstream inclusive classroom at one of the two schools, and parental consent. The experimental group comprised 18 boys and 6 girls (mean age 9.08 years, SD = 0.78, range 8–11); the control group comprised 16 boys and 8 girls (mean age 9.12 years, SD = 0.61, range 9–12). The predominance of boys in both groups is consistent with the well-documented male-to-female ratio in ASD diagnosis and is acknowledged as a contextual characteristic rather than a sampling choice. Parental or guardian written informed consent was obtained for every child, supplemented by age-appropriate verbal assent. Table 1 presents the full participant breakdown by group, gender, and age.

H. Teacher and Parent Participants

The qualitative strand included the adults closest to the children's classroom experience. Eight classroom teachers participated: five from the experimental classrooms and three from the control classrooms. Fifteen parents and caregivers of participating children also took part: ten from the experimental group and five from the control group. Teachers and parents were purposively selected on the basis of direct, sustained contact with the participating children during the intervention period teachers as the adults delivering or supervising daily mathematics instruction, and parents as observers of the children's dispositions toward schooling and mathematics outside the classroom. All participation was voluntary, and written informed consent was obtained from each adult participant prior to data collection. Teachers and parents shared their perspectives on the children's task engagement, persistence, and motivation through semi-structured interviews, providing process-level insight into how engagement was expressed and how it evolved across the twelve weeks.

TABLE I

STUDY PARTICIPANTS BY GROUP

Participants	Intervention	Control
Children with ASD Level 1	24 (18 boys / 6 girls)	24 (16 boys / 8 girls)
Teachers	5	3
Parents and caregivers	10	5

I. Data Collection Tools

- Two instruments served this study. The primary quantitative instrument was the Structured Behavioural Observation Grid (SBOG), which measured both constructs of interest: time-on-task engagement, recorded through momentary time sampling in which trained observers noted whether each child was on-task at fixed sampling points during mathematics instruction, and behavioural motivation, computed as a composite from the grid's observable indicators of task initiation, persistence, and voluntary continuation.

- Direct behavioral observation was chosen over self-report because children with ASD Level 1 at this age cannot reliably complete introspective questionnaires, and because observed behavior captures engagement as it actually occurs in the classroom rather than as it is remembered or reported; the Scale for Early Mathematics Motivation (SEMM), initially administered, was excluded from analysis as a measurement artifact, leaving the SBOG composite as the study's motivation measure. Observation procedures were identical across the experimental and control conditions.

- The qualitative instrument was a semi-structured interview guide administered to teachers and to parents and caregivers, chosen to capture process-level perceptions of how the children's engagement and motivation were expressed and how they evolved across the twelve weeks of information that sampling-point observation cannot provide. Teacher weekly reflection diaries and application usage logs provided supplementary contextual data.

J. Quantitative Data Analysis

Descriptive statistics were computed for time-on-task engagement rates and behavioral motivation composite scores in each group, with baseline comparability verified through independent-samples t-tests. Between-group differences at the end of the twelve-week intervention were then tested using independent-samples t-tests ($\alpha = .05$), accompanied by Cohen's d effect sizes with confidence intervals, following the estimation-focused conventions of Cumming [7] and Lakens [15]. Observation data were aggregated to the individual child before analysis, so that each child contributed a single score per outcome and measurement occasion.

K. Qualitative Data Analysis

Qualitative data from teacher and parent interviews were analysed using reflexive thematic analysis, following Braun and Clarke [3] six-phase framework: familiarisation, initial coding, theme construction, theme review, theme definition and naming, and write-up. Triangulation across the quantitative and qualitative strands was used to examine convergence between the observed engagement outcomes and participants' process-level accounts. Representative quotes illustrate key themes in the Results, with generic identifiers used in place of names to protect confidentiality.

L. Ethical Considerations

The study was conducted in adherence to established ethical principles for research involving children and adult participants. Research authorisation was obtained from the University of Yaoundé I and from the two participating schools before any data collection began. Written informed consent was obtained from all adult participants, who were informed of the study's objectives, the voluntary nature of participation, the right to withdraw without consequence, and confidentiality protections. For the children, a two-stage process was followed: signed parental or guardian consent for every child, supplemented by age-appropriate verbal assent confirmed individually before any observation took place; children who appeared uncomfortable were not observed. Given the vulnerability of the participating population, observation procedures were designed to be non-intrusive and embedded in ordinary classroom activity. All data were anonymised, with unique identification codes assigned to every participant, and stored securely with access restricted to the researcher. Participants were informed at consent that anonymised data would be used for academic publication.

IV. RESULTS

A. Items Completed: the Primary Engagement Signal

The clearest indicator of the whole study concerns the number of items actually completed by the child during an observation session. This indicator measures the child's concrete productivity in the learning situation: how many exercises, tasks, or items he manages to bring to completion in the allotted time. Table 4.7 and Figure 4.7 present the results

TABLE II
ITEMS COMPLETED PER SESSION (SBOG, /6) BY CONDITION

Indicator	Exp. (M)	Exp. (SD)	Ctrl (M)	Ctrl (SD)
Items completed per session	3.37	1.94	1.04	1.92

Note: independent-samples t-test: $t = 6.38$, $p < .001$, $d = 1.21$ (large effect). The indicator is expressed over six observation intervals per session.

The gap between conditions is pronounced. Children in the experimental group completed an average of 3.37 items per session, compared with 1.04 in the control group more than a threefold difference. An independent-samples t-test confirms this difference is statistically significant, $t = 6.38$, $p < .001$, with an effect size of $d = 1.21$, large by Cohen's (1988) criteria. In practical terms, a d of 1.21 indicates that the median child in the experimental group completed more items than approximately nine out of ten children in the control group.

This indicator carries a measurement advantage over questionnaire-based data: it reflects directly observable behavior, coded live by observers, with no reliance on the child's self-report. The result shows that, when working with the adaptive system, autistic children produced more work, persisted longer, and completed more exercises within the same session time.

The magnitude of the effect warrants attention, as it is uncommon in educational research. Meta-analyses of instructional interventions report median effects around 0.40 [11], and reviews of adaptive educational technologies place average effects near 0.60 to 0.70

[14] (Xu et al., 2019). The present effect exceeds these reference points. Two observations follow. First, an effect of this size is statistically robust even in a modest sample. Second, it invites precision about what the indicator captures: in-session productivity, which is the behavioral expression of engagement rather than a direct measure of competency growth.

A final methodological point supports confidence in this result. The items-completed measure is an objective, verifiable count, only weakly exposed to desirability bias or subjective interpretation. Its superiority in the experimental group cannot be attributed to observer leniency toward the device, since the tally is factual, and each session was coded independently. The result therefore withstands the main alternative explanations.

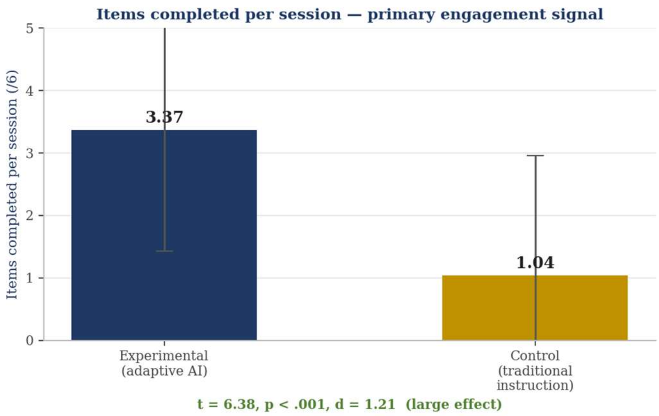

Fig. 1 Figure 4.7. *Mean number of items completed per session by condition. Error bars: standard deviation.*

B. Observed Affective Indicators

TABLE III

OBSERVED AFFECTIVE INDICATORS (SBOG, INTERVALS /6) BY CONDITION

Affective indicator	**Exp.**	**Ctrl**	**t**	**p**	**d**
Visible positive affect (VPA)	3.70	2.65	3.16	.002	0.60
Visible anxiety / distress (VAD)	2.11	1.93	0.58	.56	0.11
Neutral / stable affect (NSA)	3.28	2.51	—	—	—

Two main findings stand out. First, children in the experimental condition showed positive affect during more observation intervals on average (3.70) than those in the control group (2.65), t = 3.16, p = 0.00, d = 0.60. According to Cohen [5], this corresponds to a medium effect size. In other words, children using the device exhibited more visible enjoyment and enthusiasm than peers receiving traditional instruction. Second, and this is a key point, the frequency of visible distress or anxiety did not differ between conditions, t = 0.58, p = 0.56, d = 0.11, indicating a negligible effect. The device therefore did not introduce extra distress, which is a legitimate concern when presenting a new technology to autistic children who are sensitive to change, while it clearly increased displays of positive affect. The affective advantage is thus asymmetric and favorable: more pleasure without more distress.

C. On-Task Engagement and Temporal Trajectory

TABLE IV

ON-TASK ENGAGEMENT MODALITIES AND TIME-ON-TASK (SBOG) BY CONDITION

Engagement modality	**Experimental**	**Control**
Active engagement (ATE)	4.11	4.05
Partial engagement (PE)	3.31	3.46
Passive disengagement (OTP)	2.43	3.30
Active disengagement (OTA)	2.52	3.04
Time-on-task (% valid)	87.30%	82.40%

Active on-task engagement is similar across conditions (4.11 vs. 4.05 intervals). The differences concern disengagement: passive disengagement (2.43 vs. 3.30) and active disengagement (2.52 vs. 3.04) are both less frequent in the experimental condition. In other words, with comparable levels of active engagement, children using the device disengage from the task less often. The time-on-task metric, calculated

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on valid sessions only, is 87.30% in the experimental condition compared with 82.40% in the control condition. For this calculation, 68 records with implausible values above 100% were excluded; this data-entry issue, which reduces the precision of the time-on-task estimate, will be discussed in Chapter 5 under measurement limitations. The time course of active engagement in Figure 4.9 merits close attention because it allows a classic alternative explanation to be tested: the novelty effect. One could suspect that the higher engagement in the experimental condition reflects a short-lived increase driven by the initial appeal of a new technological device, which would fade as the novelty diminishes.

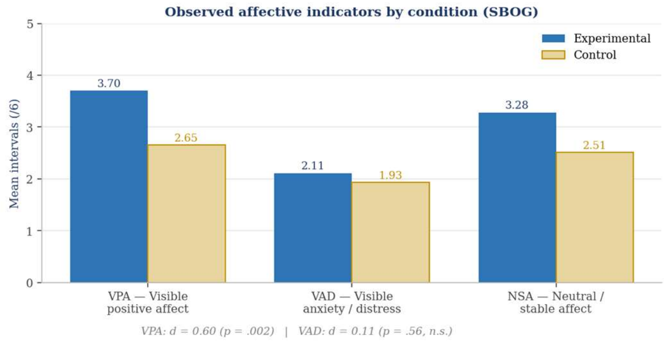

Fig. 2 Trajectory of active on-task engagement (ATE) over the weeks of intervention, by condition.

. In the experimental condition, active engagement was high at Week 2 (4.69 intervals), declined at the midpoint in Week 5 (3.35), then rose again by Week 8 (3.80). A novelty account predicts a steady, monotonic decline; the data show a U-shaped pattern instead. The mid-course dip followed by recovery is consistent with a familiarization process, in which children pass through an adjustment phase before regaining sustained engagement. Positive affect followed the same non-monotonic course: high at Week 2, lower at Week 5, recovered by Week 8. The simultaneous dip and recovery of two distinct indicators one behavioral, one affective at the same measurement points strengthens the familiarization interpretation over a short-lived surge. Two conclusions follow. First, since the engagement advantage cannot be reduced to the appeal of a new device, its source lies in the properties of the adaptive system itself: the structure of the tasks it presents and the fit it achieves with each child's learning profile. Second, the recovery of engagement by the end of the twelve weeks indicates that the behavioral benefit has some stability under habituation, a point relevant to the assessment of longer deployments.

D. Autonomous Interaction with the Device

TABLE V

AUTONOMOUS DEVICE-INTERACTION INDICATORS (SBOG, INTERVALS /6), EXPERIMENTAL GROUP

Interaction indicator	Mean (/6)	Interpretation
Initiated interaction (II)	3.43	High
Response latency ≤ 10 s (RL)	3.30	High
Help-seeking (HS)	2.30	Moderate

Children in the experimental group displayed a strong capacity for autonomous interaction with the device. On average, they initiated interactions in 3.43 of six intervals, and response latencies were short in 3.30 intervals, indicating prompt, self-driven engagement rather than passive waiting. Help-seeking was moderate (2.30 intervals), indicating use of adult or system support at a level compatible with functional autonomy.

The combination of the three indicators is informative. High initiation paired with high help-seeking would indicate superficial autonomy: a child who engages but cannot advance unaided. Few initiations with long latencies would indicate passivity or disengagement. The pattern observed here high initiation, short latency, moderate help-seeking is the configuration most consistent with genuine autonomy: the child engages promptly and independently while still requesting help when needed. This pattern also indicates that the tasks remained accessible without being trivial, consistent with the operating aim of an adaptive system.

One measurement constraint must be stated. This observation category applies, by design, to the experimental condition only: no device-interaction grid exists for the control condition, which had no digital tool. These indicators therefore support no between-group comparison and should be read as an internal characterisation of the experimental group's engagement, complementing the comparative indicators reported above.

E. Digital Usage Traces of the Device

TABLE VI

USAGE INDICATORS FROM THE DEVICE'S DIGITAL TRACES (EXPERIMENTAL GROUP)

Usage indicator	Value	Precision
Work sessions recorded	644	—

Pupils having used the device	24	—
Interactions recorded	993	—
Mean accuracy (%)	67.99%	SD = 39.48
Mean time per session (s)	190.47	med. = 183.50
Mean score per session	193.94	med. = 140.00
Hint usage	0.01	very low

These digital traces point to three main findings. The digital traces support three findings. First, usage was high: 644 work sessions were completed, with 993 interactions logged. These figures indicate sustained, genuine use rather than occasional engagement. Second, mean accuracy was 67.99%, placing performance in a middle band success frequent enough to sustain effort while challenge remained. This level corresponds to the difficulty window an adaptive system is designed to maintain. Third, hint usage was near zero (0.01), a pattern consistent with the autonomy documented in the SBOG interaction indicators: most work was carried out independently. The system also generates an automatic engagement estimate; although it relies on proprietary heuristics and should be interpreted with caution, most sessions were classified as showing moderate or high engagement, with low-engagement sessions in the minority.

Engagement in the experimental condition is therefore supported by three methodologically distinct sources: direct behavioural observation (SBOG), teachers' accounts, and automated usage logs. Because these sources involve different recording agents trained observers, classroom teachers, and the system itself their convergence strengthens the empirical basis of the finding.

Two cautions apply. The traces pertain only to the experimental condition, since the control group had no comparable tool, and therefore support no between-group comparison. In addition, some indicators show uneven distributions, including median attempt counts of zero and missing response-time values, so only the most robust trends are retained here. Within these limits, the usage logs confirm, through a fully automated channel, what observers and teachers independently reported: children in the adaptive environment engaged with it genuinely, over time, and largely independently.

F. Qualitative Findings

This section presents findings from key informant interviews (KIIs) conducted with teachers and head teachers

3.3.1 Adaptive AI as a Catalyst for Engagement and the Reduction of Mathematical Avoidance

The most consistent finding across teacher interviews in the experimental classrooms was a qualitative shift in how the children related to mathematics. Teachers described mathematics, before the intervention, as the subject their autistic learners feared and avoided most, and reported that this relationship changed visibly once the adaptive applications were introduced. One teacher summarized the change directly:

"The AI method completely changed the narrative learners who used to fear math now engage actively. Math lessons are one of their favourite lessons; all my slow learners are very much interested" (TR3, experimental group).

Another contrasted the two instructional formats in similar terms:

*"Before, math felt boring and uninteresting to most of them, but now it's interactive and relatable through the adaptive game" **(TR4, experimental group).***

Teachers attributed this shift to the playful format of the applications, noting that the children experienced the sessions as games rather than as evaluated schoolwork:

*"They think they are playing a mathematics game, but these games have a great impact on how they remember things now" **(TR4, experimental group).***

These accounts converge with the quantitative findings: the higher task productivity and more frequent positive affect observed on the SBOG appeared, in the teachers' descriptions, as children who approached mathematics willingly rather than under instruction.

3.3.2 Supporting the children's emotional regulation during sessions.

A second, unanticipated dimension of this theme concerned the applications' role in supporting the children's emotional regulation during sessions. Teachers of autistic learners described emotional breakdowns as a recurrent feature of ordinary mathematics instruction, and reported that the adaptive environment softened these episodes: "Most of these children have emotional breakdowns; during this period the app really helped to strengthen this part for me" (TR1, experimental group). This account is consistent with the SBOG affective data, which showed more visible positive affect in the experimental condition without any corresponding rise in visible distress, and it extends that finding by suggesting the mechanism teachers perceived: a non-evaluative, self-paced environment that reduced the interpersonal pressure of whole-class instruction.

The third strand of this theme was pedagogical:

teachers reported that the applications strengthened their own teaching, not only the children's engagement. Several described the data generated by the platforms as a diagnostic window onto individual learners:

"*Through the app I am able to understand my learners better, and I can develop a teaching plan" **(TR1, experimental group);***

*"*It tells me where learners need more support and how I can support them that was very helpful for me"* (*TR5, experimental group).* Others emphasised efficiency and *instructional design **

"It helped me design and share my teaching better"; "The app helped me manage my time well; I can develop as many lessons as possible"and one teacher identified a concrete curricular gain in a domain that had previously resisted instruction:

"I used to struggle with teaching them money; now they can see money on the app, and they can relate to a lot of the resources on it."TR 1 experimental group

3.3.**3Challenges: Overexcitement and the Boundary Between Engagement and Distraction**

Teachers' accounts were not uniformly positive, and the challenges they described were, notably, challenges of excess engagement rather than of disengagement. The excitement surrounding the intervention was reported as difficult to contain: several children became overexcited during sessions, and some resisted the transition out of the applications when sessions ended

"*Some did not want to stop playing the games" **(TR, experimental group)**.*

One teacher acknowledged the ambivalence this created for classroom management:

"Sometimes I felt it reduce their distraction l, I like the fact that some learners accelerated their learning" **(TR, experimental group).**

These accounts qualify the quantitative engagement findings in an important way: the high task productivity and positive affect recorded on the SBOG coexisted, at the process level, with a real cost in transitions and self-regulation that teachers absorbed. For autistic children, for whom transitions are already demanding, the boundary between productive engagement and absorption that resists interruption emerged as the intervention's principal classroom-management challenge a limitation that speaks not against the engagement effect but to the need for structured session endings and transition supports in future implementation.Taken together, these accounts indicate that the engagement effect operated through a dual channel: the adaptive system engaged the child directly, and it simultaneously equipped the teacher to differentiate instruction the precise capacity whose absence the introduction identified as a structural cause of depressed engagement in the region's inclusive classrooms.

V. DISCUSSION

This study tested whether AI-based adaptive learning produces higher behavioral engagement than traditional whole-class instruction among children with ASD Level 1 in inclusive primary schools in Yaoundé. The findings support the hypothesis across four convergent indicators. Children in the adaptive condition completed more than three times as many task items per session (3.37 vs. 1.04; d = 1.21), displayed positive affect during significantly more observation intervals (d = 0.60) with no corresponding rise in visible distress (d = 0.11, n.s.), disengaged from the task less often at comparable levels of active engagement, and interacted with the device autonomously initiating tasks, responding quickly, and seeking help only moderately. Teacher and parent accounts converged with these observations, describing children who had feared mathematics approaching it willingly, and the applications' own usage logs confirmed sustained, largely independent use across 644 recorded sessions.

The magnitude of the primary effect deserves careful interpretation rather than celebration. A d of 1.21 exceeds the median effects reported for instructional interventions generally [11] (around 0.40) and for adaptive educational technologies specifically [14] (0.60–0.70; Xu et al., 2019), and it also exceeds the engagement effects reported in adaptive-platform studies with general student populations (Education and Information Technologies, 2025; Issues in Information Systems, 2025). Two explanations, not mutually exclusive, account for this. The first is population specificity. The meta-analytic literature shows that autistic learners respond strongly to individualized, structured instruction [2], [13], [17], and moderator analyses in that literature fail to isolate any single instructional feature as the active ingredient [17]. The present findings suggest a reading of that puzzle: what adapted instruction shares across its forms is continuous fit between task and learner, and for a population defined by heterogeneity, the gain from restoring that fit is larger than for populations for whom uniform instruction already roughly serves. The second explanation is indicator specificity. Items completed measure in-session productivity observable, countable work rather than competency growth- and productivity is precisely where an engagement effect should register first. The indicator's objectivity is also its strength: a factual count, coded live, exposed neither to self-report distortion nor to observer indulgence.

The pattern of results maps closely onto the theoretical chain set out in Section 1.1. The digital traces place mean accuracy at approximately 68%, a difficulty band in which success is frequent enough to sustain effort while challenge remains, the operational signature of a task held within the child's zone of proximal development [29] and below cognitive overload [26]. The autonomy profile high spontaneous initiation, short response latency, moderate help-seeking, and near-zero hint usage is the behavioural expression of the competence and autonomy needs that Self-Determination Theory identifies as the conditions of sustained motivation [8], [22]. And the asymmetric affective result more visible pleasure without more visible distress is what SDT predicts of an environment that removes evaluative social pressure without removing structure. The temporal trajectory completes this account.

Active engagement followed a U-shaped course, high at Week 2 (4.69 intervals), lower at Week 5 (3.35), recovering by Week 8 (3.80), with positive affect dipping and recovering in synchrony. A novelty effect would predict monotonic decline; the observed rebound points instead to familiarization and consolidation, indicating that the engagement benefit has some stability under habituation. This addresses directly the caution raised in recent critical work that technology-engagement findings in autism may reflect transient attention capture rather than durable motivation (Frontiers in Digital Health, 2026): the present design measured engagement and motivated behavior separately, over time, and through three methodologically independent sources observers, teachers, and automated logs and all three converged.

The integration of the qualitative strand both corroborates and qualifies the quantitative picture. Teachers' accounts of children who "used to fear math" now treating it as a favourite lesson give experiential content to the affective statistics, and their descriptions of the applications as diagnostic tools, showing where each learner needs support, enabling differentiated planning identify a second causal channel the observation grid could not capture: the system equipped teachers to individualize, the very capacity whose absence regional studies identify as a structural barrier in inclusive classrooms [20], [28] (Sepadi, 2025). At the same time, the qualitative data surfaced the cost side that the quantitative indicators concealed. The principal implementation challenge teachers reported was excess engagement overexcitement and resistance to ending sessions a meaningful burden for autistic children, for whom transitions are already demanding. Engagement, these accounts suggest, is not an unalloyed good but a resource requiring management, and future implementation needs structured session endings and transition supports built into the protocol.

Situated in the regional literature, the contribution of this study is positional. Experimental evidence for tablet-based mathematics learning in African classrooms existed but not for autistic samples [21]; autism-specific educational technology research existed in the region but not in experimental form [18]; and systematic reviews of disability interventions in low- and middle-income countries contain no Central African intervention study at all [12], [23]. This study occupies that intersection: to our knowledge, it provides the first controlled behavioural-observation evidence on AI-based adaptive learning with autistic children in a Central African inclusive school context.

Several limitations bound these conclusions. The design was quasi-experimental, without randomisation, in two schools in one city; causal inference rests on group comparability rather than random assignment, and generalisation beyond comparable urban inclusive settings is not warranted. The time-on-task estimate was weakened by a data-entry anomaly: 68 observation records with values above 100% were excluded from that computation, reducing its precision although the primary indicator, items completed, is untouched by this problem since each session was coded independently. The device-interaction and usage-log data characterize the experimental condition only, by design, and support no between-group comparison. Motivation was measured behaviorally rather than by self-report after the study's self-report instrument was excluded as a measurement artifact a defensible choice in this population, whose communication profiles undermine introspective questionnaires, but one that leaves the internal experience of motivation inferred rather than directly assessed. Finally, twelve weeks documents the establishment of an engagement effect, not its long-term maintenance.

VI. CONCLUSION

This study asked whether AI-based adaptive learning raises the behavioral engagement of autistic children in a context where the evidence base is thinnest and the need greatest. The answer, across four convergent indicators and three independent measurement sources, is that it does: children with ASD Level 1 in Yaoundé's inclusive classrooms completed three times more work, showed more visible enjoyment without more distress, disengaged less, and took hold of the technology autonomously and their teachers, in parallel, gained a tool for the differentiation their training had never provided. The effect survived the novelty window, aligned with the theoretical chain from task-learner fit to motivated behavior, and was earned under ordinary classroom conditions with an offline-capable application built for the constraints of the setting. The finding does not close the question of learning outcomes over the long term, and it comes with a management cost that teachers named honestly. But it establishes the essential precondition: engagement, the gateway through which all instruction must pass can be opened for autistic children in Central African classrooms with tools that already exist. The task ahead is to test how far, how durably, and at what scale.

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