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Leveraging Artificial Intelligence to Support Language Processing in Children With Dyslexia and Dysgraphia: A Design-Based Study

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Abstract—**This study examines the use of artificial intelligence (AI) in designing inclusive classrooms to support elementary school students with special educational needs (SEN), particularly those with dyslexia and dysgraphia, in Semarang, Indonesia. Using a design-based research (DBR) approach, the study was conducted in 15 elementary schools, involving 15 classroom teachers and their students identified as having literacy-related learning difficulties. Various AI-based tools, such as text-to-speech applications, digital writing assistants, and adaptive learning platforms, were integrated into the classroom learning process to enhance accessibility and personalize learning experiences. Data were collected through classroom observations, teacher interviews, student assessments, and system analytics generated during two iterative design and implementation cycles. Results indicate that AI integration contributed to improvements in students' reading fluency, spelling accuracy, and written expression. Teachers reported increased capacity for implementing differentiated learning, a better real-time understanding of student learning progress, and greater confidence in managing inclusive learning. This study offers a practical and replicable model for integrating AI into inclusive classroom design, demonstrating its potential to bridge the learning gap for students with specific literacy challenges and empower teachers in inclusive education practices.**

Index Terms—**inclusive classroom, artificial intelligence, dyslexia and dysgraphia, special educational needs, design-based research**

I. Introduction

Inclusive education aims to provide equal learning opportunities for all students, including those with special educational needs (SEN), such as dyslexia and dysgraphia. However, the implementation of inclusive education faces various challenges, particularly in supporting students with these specific learning disabilities (Nurullayevna et al., 2025).

Dyslexia and dysgraphia are often not identified early in primary school. This is due to a lack of understanding and training among teachers in recognizing the early signs of these disorders (Clemens & Vaughn, 2023). As a result, students do not receive timely intervention, which can negatively impact their academic development. Many teachers feel they lack the skills and knowledge to support students with dyslexia and dysgraphia. The lack of specialized training and adequate resources hinders their ability to implement effective learning strategies for students with special needs (Martan et al., 2023).

Students with dyslexia and dysgraphia often face stigma and discrimination in the school environment. They may be perceived as less intelligent or lazy, even though they have the same potential as other students (Zaini et al., 2024). This stigma can affect students' self-confidence and motivation to learn. Although technology can be an effective tool in supporting the learning of students with dyslexia and dysgraphia, many elementary schools have not yet utilized this technology optimally (Iliska & Gudoniene, 2025). Lack of access to assistive technology and inadequate training in its use hinder the implementation of innovative learning strategies (Daley & Rappolt-Schlichtmann, 2018).

Education for students with Special Education Needs (SEN), such as those with dyslexia and dysgraphia, requires a personalized, flexible, and adaptive approach to individual needs (S. Ahmed et al., 2025). In this context, the use of educational technology, particularly Artificial Intelligence (AI), plays a strategic role in increasing the effectiveness of learning and the accessibility of inclusive education (Rahim et al., 2025). In Semarang, Indonesia, challenges to inclusive education include a lack of supportive policies, limited resources, and a lack of public awareness of the importance of inclusive education. This exacerbates the gap in access to quality education for students with dyslexia and dysgraphia.

AI enables learning systems to adjust materials, pace, and learning styles based on analysis of student performance data. AI algorithms can detect students' areas of weakness, recommend specific interventions, and tailor learning content to their level of understanding (Gligorea et al., 2023). Tools like text-to-speech (TTS), speech-to-text, and AI grammar checkers like Grammarly, Read &Write, and other machine learning-based apps help students with dyslexia read aloud and spell correctly, and help students with dysgraphia write with visual support and autocorrect (Bhola, 2022).

AI is used in diagnostic platforms to detect early signs of learning disabilities such as dyslexia. These systems can analyze error patterns in reading or writing and recommend interventions to teachers or specialists (Alkhurayyif & Sait, 2024; Pragasthi & Vaishnavi, 2025). AI supports teachers in developing materials tailored to individual student needs and provides real-time feedback on student progress. Teachers can view analytical reports on each student's achievement and adjust learning strategies directly (Onesi-Ozigagun et al., 2024; Alkhater et al., 2025). Students with special needs who use AI technology report increased confidence in learning because they feel more supported and less dependent on direct assistance from teachers or classmates (Sharma et al., 2023).

Semarang, the capital of Central Java Province, is an urban area with complex geographic and social characteristics. Geographically, Semarang City is divided into a densely populated lowland area in the north and a highland area in the south that is developing as a new educational and residential area. This research was conducted in 15 elementary schools spread across various sub-districts, spanning the city center to the outskirts, to represent the diversity of educational conditions in this urban area. Semarang is known socially for its cultural and economic diversity, and its relatively high literacy rate. However, it still faces challenges in implementing inclusive education. Most of the schools studied are public schools with enrollments ranging from 200 to 400 students, including several students with special education needs (SEN) such as dyslexia and dysgraphia. The majority of these schools do not yet have full-time dedicated teachers, making the use of technology, particularly Artificial Intelligence (AI), a strategic solution to support more inclusive and adaptive learning. Furthermore, the diverse socioeconomic backgrounds of students demand a flexible and personalized learning approach to ensure optimal development for all students, including those with reading and writing disabilities.

This research aims to design and implement an innovative Artificial Intelligence (AI)-based learning design in inclusive classrooms to improve the basic literacy skills of students with special needs, including dyslexia and dysgraphia, in elementary schools in Semarang City. Specifically, this study evaluates the effectiveness of AI technology integration in improving students' reading fluency, spelling accuracy, and writing skills, and examines teachers' perceptions of the use of AI as a tool in differentiated learning. The primary contribution of this research is to provide a tested AI-based learning model in the context of inclusive education in elementary schools, strengthen teachers' capacity in managing learning for students with special needs, and provide empirical evidence regarding the positive impact of technology on improving access to and quality of inclusive education. Furthermore, the results of this study are expected to inform the development of adaptive technology-based education policies to support equitable distribution of educational services for all children, including those with specific learning disabilities such as dyslexia and dysgraphia.

Dyslexia is a specific learning disability that affects an individual's ability to read, write, and spell despite having normal intellectual ability. Children with dyslexia tend to have difficulty recognizing words, understanding the relationship between letters and sounds, and processing information related to reading fluently (Snowling et al., 2020). Common characteristics of dyslexia include confusion in letter order, spelling errors, and delayed reading ability compared to peers (Kunwar & Sapkota, 2022). Dysgraphia, on the other hand, is a disorder that affects a person's writing ability, including spelling, layout, and sentence structure. Students with dysgraphia often have difficulty handwriting, organizing ideas, and composing coherent, understandable writing (Chung et al., 2020). Both disorders can negatively impact the learning process and require a more intensive, support-based learning approach to address these challenges (Rokade et al., 2024).

Inclusive classroom design refers to a learning approach that enables students with diverse backgrounds, abilities, and special needs to learn together in a supportive and inclusive environment. The core principles of inclusive classroom design are valuing and embracing individual differences, as well as providing appropriate support to ensure each student can access learning materials tailored to their needs and abilities (Ranbir, 2024). Some key principles of inclusive classroom design include: first, accessibility, which involves providing materials and resources that are accessible to all students, including those with special educational needs (Priyadharsini & Sahaya Mary, 2024). Second, instructional differentiation, which involves developing strategies and materials tailored to students' levels of understanding and learning pace. Third, collaboration between teachers and specialists, which emphasizes collaboration between classroom teachers and special educators to create inclusive and effective learning experiences (Gheyssens et al., 2023).

Artificial Intelligence (AI) plays an increasingly important role in education, including in the context of inclusive education for students with special needs. AI enables personalized learning through in-depth data analysis, leading to learning tailored to individual student needs (Khatun et al., 2024; Pagliara et al., 2024). For example, AI can be used to monitor student progress in real time, provide faster and more accurate feedback, and adapt learning materials to suit students' ability levels. Furthermore, AI can facilitate the use of assistive devices such as speech recognition and automated text recognition applications, which are particularly beneficial for students with dyslexia and dysgraphia (Zhu, 2024). Thus, AI not only improves the quality of learning for students with special needs but also assists teachers in more effective and efficient classroom management (Mounkoro et al., 2025).

II. METHOD

Design-Based Research (DBR) is a research approach used to design and develop interventions or innovations in educational practice that can yield a deeper understanding of the context and learning process (Scott et al., 2020). DBR focuses on solving real-world problems by engaging in iterative cycles of design, implementation, evaluation, and revision to produce products that can be applied practically and theoretically (Tweeten & Hung, 2023).

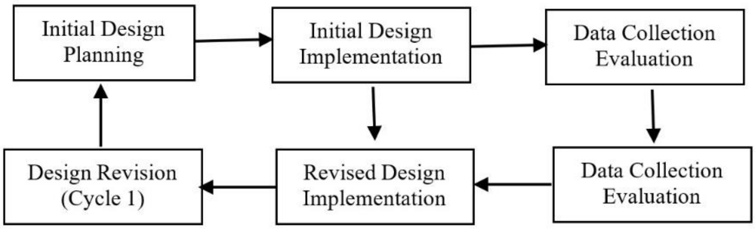

Figure 1. DBR Phase

This research was conducted in 15 public and private elementary schools across Semarang City, Central Java. School selection was conducted purposively, taking into account the institution's readiness to integrate learning technology and the availability of data on students identified as experiencing specific learning disabilities, namely dyslexia and dysgraphia. This setting aligns with the contextual approach in educational studies, which emphasizes the importance of engaging in authentic learning environments in testing the effectiveness of learning interventions (Yusyac et al., 2021; Creswell, 2018).

Participants in this study consisted of 15 classroom teachers serving in lower and middle grades (grades 1–4), as well as several students diagnosed with dyslexia and/or dysgraphia by the school through internal psychological assessments and professional referrals. The teachers had a minimum of a bachelor's degree (S1) and more than five years of teaching experience, with active involvement in the development and implementation of classroom learning innovations (Podolsky et al., 2019). These teachers served as facilitators in the use of AI-based technology and key informants in qualitative data collection through interviews and observations.

The primary subjects of this study were regular grade students with significant reading and writing difficulties but not enrolled in a special education program. These students' characteristics meet the diagnostic criteria for dyslexia and dysgraphia, including difficulty recognizing words, difficulty decoding letter sounds, and limitations in sentence construction and neat handwriting. Their involvement in this study aimed to evaluate the effectiveness of using AI-based learning aids to support basic literacy skills in an inclusive manner. By involving regular elementary school contexts, active teachers, and students with special learning needs, this study is expected to produce applicable and relevant findings for technology integration efforts in inclusive education.

This research used various AI-based tools and conventional instruments to support a holistic and in-depth data collection process. The use of AI technology aims to improve accuracy, efficiency, and adaptability in the process of collecting and monitoring student and teacher data (Agherai et al., 2025). Text-to-Speech (TTS), this technology is used to convert text to speech, assisting students with reading disabilities, and facilitating the accessibility of learning materials for students with special needs. TTS is also used to measure student responses in the context of using AI tools that support listening and comprehension literacy. 1) Handwriting Recognition, this tool detects and converts student handwriting into digital text, allowing researchers to analyze student writing skills more objectively and systematically. This technology is essential for documenting the learning process and handwriting outcomes as part of student literacy assessments. 2) Adaptive Dashboards, these dashboards are designed to provide real-time monitoring of student and teacher interactions with digital learning systems. These dashboards record system usage logs, including usage time, activity types, and student engagement with AI-based learning materials.

The research instruments used consisted of: 1) Observation Sheet: Used to record the behavior, responses, and interactions of students and teachers during the AI-based learning process. Observations were conducted systematically with predetermined criteria to measure aspects of engagement, participation, and adaptation to technology; 2) Teacher Interviews: Semi-structured interviews were conducted with teachers to explore their views, perceptions, and experiences in implementing AI technology in learning. Questions focused on the effectiveness of using digital tools and the challenges faced; 3) Student Literacy Test: Used to measure students' literacy levels before and after the implementation of AI-based interventions. The test covered text comprehension, critical thinking skills, and written expression skills; 4) System Usage Log: Digital records generated from students' interactions with the learning platform. This log includes the frequency of access, duration of use, types of activities accessed, and the results of automated assessments available in the system.

The data collection process in this study was carried out by combining qualitative and quantitative approaches in a complementary manner to obtain a complete picture of the impact of the use of AI technology in literacy learning in elementary schools. Qualitative Data Collection Techniques were obtained through in-depth interviews with teachers and classroom observations. Interviews aimed to explore teachers' meanings of the use of AI technology in daily learning practices, while observations aimed to document student and teacher responses to the interventions provided. The interview and observation processes were conducted with a naturalistic approach and recorded systematically through field notes and audio recordings. Quantitative Data Collection Techniques were collected through student literacy tests and system usage logs. The literacy test was used to measure changes in student achievement from pre-test to post-test, while the system log recorded students' digital activities as indicators of engagement and interaction in the learning process. This data was collected from all participants involved and coded for statistical analysis purposes.

Qualitative data from interviews and observations were analyzed using thematic analysis. The analysis stages included data transcription, open coding, identification of main themes, and interpretation of thematic meanings based on teachers' experiences in using AI technology. This approach allows researchers to gain a deeper understanding of teachers' perceptions and practices in the classroom (S. K. Ahmed et al., 2025).

Data from student literacy tests and usage logs were analyzed using descriptive statistics, including calculating the mean, median, standard deviation, and score distribution. This analysis was used to identify general trends in student achievement and patterns of engagement in system use. The findings from this analysis served as a basis for comparing the effectiveness before and after the intervention (Kim et al., 2023). Through this combined approach, the research results are expected to provide a comprehensive understanding of the contribution of AI technology to improving student literacy and supporting pedagogical innovation at the elementary school level.

III. Results

Observation data results are presented in Figure 2.

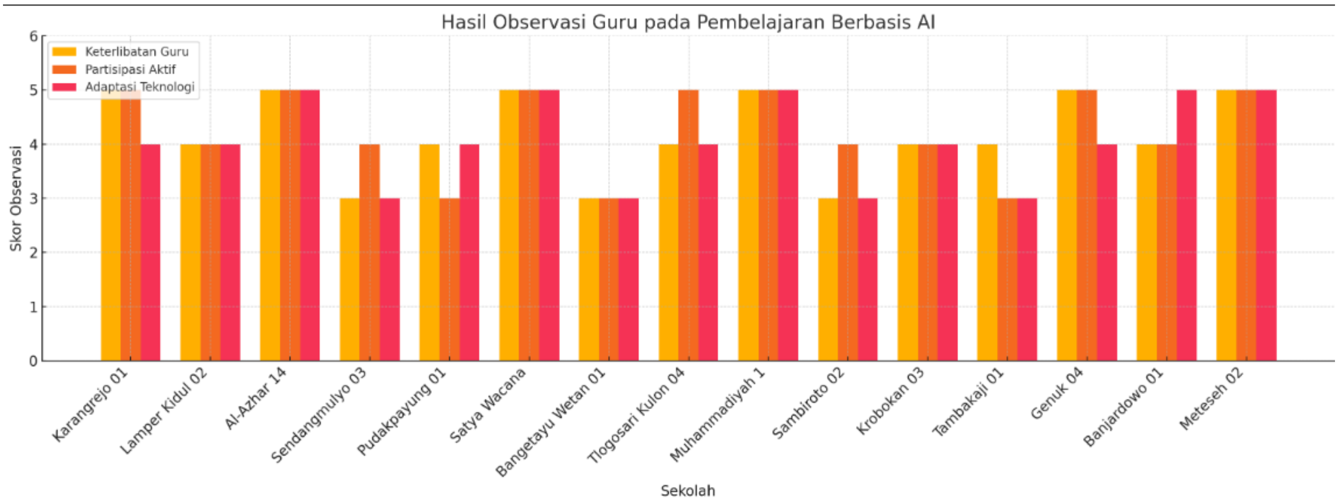

Figure 2. Initial Observation Data

Observations of 15 teachers at 15 elementary schools in Semarang revealed that teachers generally demonstrated high levels of engagement and participation in AI-based learning. Ten teachers (67%) were categorized as "high" to "very high" across all three observational aspects. The details are as follows: (1) Teacher Engagement: Most teachers appeared to actively follow the learning flow, engaging in discussions, and demonstrating enthusiasm for the potential of AI technology, such as the use of text-to-speech and adaptive dashboards. Teachers from SD Islam Al-Azhar 14, SD Kristen Satya Wacana, and SD Muhammadiyah 1 demonstrated very high engagement (score 5), even modifying learning scenarios independently. (2) Active Participation: Teacher participation in demonstration activities, practicing the use of AI tools, and providing technical guidance was quite encouraging. It appears that teachers with prior experience with technology tend to adapt more quickly and be more active, as was the case at SDN Tlogosari Kulon 04 and SDN Meteseh 02. (3) Adaptation to Technology: Although some teachers required initial adaptation time, overall they were able to understand the system's operating principles and utilize AI features according to student needs. Five teachers scored 5 in the adaptation aspect, particularly those who were previously familiar with digital media.

Several challenges were identified among teachers with an adaptation score of 3, primarily related to technical constraints such as internet connection, familiarity with the system interface, and the need for further training. However, the teachers' enthusiasm and openness to trying new things greatly contributed to the success of this technology integration.

TABLE 1
SUMMARY OF TEACHER INTERVIEW FINDINGS ON THE IMPLEMENTATION OF AI TECHNOLOGY IN LEARNING

Key themes	Categories	Teacher Representative Statement
Perceptions of AI	Positive views of AI	AI has been very helpful for my dyslexic students, especially in reading and writing.
	Perceptions of doubt or anxiety	Initially, I was hesitant to use AI because I wasn't familiar with the technology.
Effectiveness of Digital Tools	Improved learning accessibility	The text-to-speech application makes it easier for students to understand text.
	Personalization of learning	The AI platform helps me automatically adapt materials to students' abilities.
Implementation Challenges	Infrastructure limitations	Our school only has one device that can be used by all students.
	Teacher readiness to use technology	I need further training to fully utilize AI
	Limited technical support	If I encounter technical difficulties, I don't know who to contact for help.
Impact on Teaching	Improved learning strategies	With AI, I can see students' progress in real time.
	Improved instructional differentiation	AI makes me more confident in managing a diverse class.

Interviews with 15 teachers revealed that most had positive perceptions of the use of AI in learning, particularly in supporting students with special needs such as dyslexia and dysgraphia. Teachers reported that tools such as text-to-speech and adaptive dashboards were helpful in increasing the accessibility and personalization of teaching materials. However, several teachers also raised challenges such as limited devices, lack of training, and limited technical support.

Nevertheless, teachers generally felt that the integration of AI enriched their learning strategies, enabling a more targeted and responsive approach to student needs. Teacher readiness and a supportive environment remain key to ensuring the successful implementation of this technology across the board.

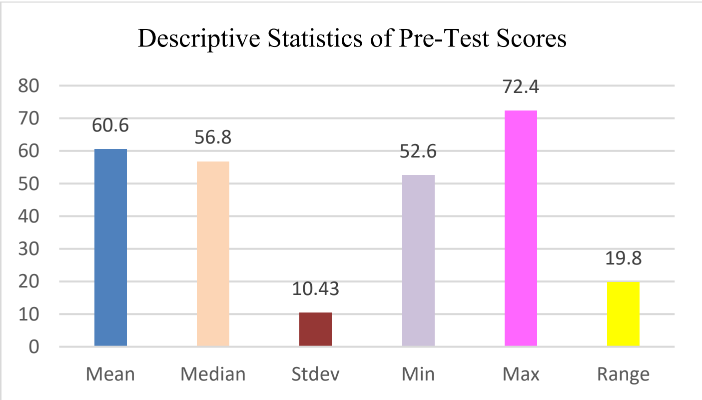

Figure 3. Pretest Results Data

The descriptive analysis of the pre-test scores showed that the average score for the three groups of students (dyslexic, dysgraphia, and regular students) was 60.6. The median, the middle score after sorting the data, was 56.8, indicating that half of the groups scored below that number, and the other half scored above it. A median score lower than the mean indicates a relatively high-scoring group (in this case, the regular students), which slightly skews the average.

The standard deviation of the pre-test scores was approximately 10.43, reflecting the degree of spread between the scores from the mean. This figure is quite large for data on a 0–100 scale, indicating a significant difference between the groups. This is evident in the large gap between the highest score (72.4 for regular students) and the lowest score (52.6 for dyslexic students), a difference of 19.8 points.

This data distribution indicates that before the learning intervention, there were significant differences in initial abilities between the student groups. This is important to consider when interpreting the effectiveness of learning interventions, as different starting levels can influence the magnitude of improvement achieved.

The results of the post-test data processing show that the average score achieved by students in all three groups was 74.9, with a median of 74.2. The minimum score was 68.4 and the maximum score was 82.1, resulting in a score range of 13.7. This indicates that the distribution of student scores after the learning process was relatively even at a fairly high score range.

The standard deviation of 6.88 indicates that the variation in scores between students was moderate. This means that although some students achieved higher scores, the differences in achievement between students were not extreme. This value indicates fairly good consistency in achievement, with the majority of students falling around the average score.

The distribution of post-test scores suggests that the learning process successfully improved student competency across all groups. Differences in scores between students remained, but were relatively controlled. The increase in scores compared to the pre-test data reinforces the conclusion that the learning strategy used was effective, particularly in promoting equitable understanding of the material across all groups of students.

TABLE 2
COMPARISON OF PRETEST-POSTTEST RESULTS

Student Group	Average Pre-Test Score	Average Post-Test Score	Change (%)	Description of Changes
Dyslexic students (n=15)	52.6	68.4	29.9%	Significant improvements in reading comprehension and speed with audiovisual aids
Dysgraphia Students (n=15)	56.8	74.2	30.6%	Strong improvements in narrative expression and rewriting through digital practice
Regular Students (n=15)	72.4	82.1	13.4%	Steady improvements, supported by consistent interaction and rapid comprehension

Literacy test results conducted before and after the digital learning intervention showed significant improvements in the achievement of students with dyslexia and dysgraphia. In the pre-test, the average literacy score for dyslexic students was 52.6 and for dysgraphia students, 56.8. These scores indicate significant challenges in text comprehension, reading speed, and the appropriateness of responses to the reading content, particularly for dyslexic students. Limitations in processing information in conventional texts are a contributing factor to low initial scores, particularly for students with reading disabilities.

After four weeks of implementing the digital learning platform, post-test results showed a significant improvement. Dyslexic students recorded an average score increase of 68.4 (an increase of approximately 29.9%), while dysgraphia students' scores rose to 74.2 (an increase of 30.6%). This technology-based intervention provides adaptive features such as automatic text readers, interactive visual exercises, and audio-visual quizzes, which have been shown to help students understand the material more thoroughly. These changes demonstrate that a multimodal approach to learning has a real impact on improving literacy competency in students with special needs.

Further analysis revealed that dyslexic students experienced significant improvements in text comprehension and reading speed. This improvement was largely due to the use of audio and visual media, which facilitated their comprehension of text content. Meanwhile, dysgraphia students showed a greater jump in scores in rewriting and narrative expression skills. The guided typing feature and drag-and-drop sentence construction exercises significantly helped reduce fine motor skills, which have been a major challenge for dysgraphia students in composing written narratives.

Overall, the successful improvement in post-test scores in dyslexic and dysgraphia students demonstrates that an inclusively designed digital learning system can be an effective solution for literacy learning. Compared to the regular student group, which only experienced an increase of around 13.4%, the special needs student group experienced a twofold increase. This demonstrates the importance of personalized media and individual-based digital learning strategies, particularly in the context of inclusive education, which aims to accommodate students' diverse learning styles.

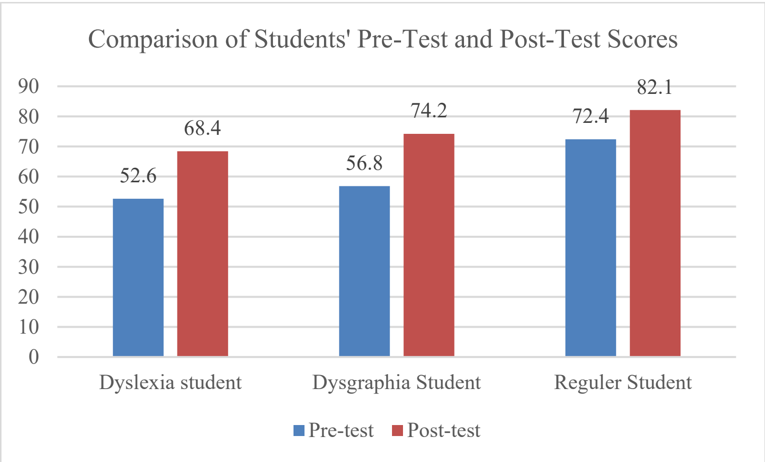

Figure 4. Data on Student Literacy Improvement Results

TABLE 3
RESULTS OF DESIGN IMPLEMENTATION EVALUATION IN THE DBR CYCLE

Evaluation Aspects	Cycle 1	Cycle 2	Change (%)
Student Understanding of Material	65%	80%	15%
Student Activeness in Class	70%	85%	15%
Quality of Student Assignments (Spelling)	60%	75%	15%
Student Writing Skills	55%	70%	15%
Teacher Response to Technology	60%	85%	25%
Teacher Use of Technology	50%	80%	30%

The evaluation of the implementation of the Design-Based Research (DBR) approach was conducted in two cycles to test the effectiveness of integrating AI in inclusive learning, specifically in supporting children with dyslexia and dysgraphia in elementary schools. The evaluation results showed significant improvements across all observed aspects, both for students and teachers.

From the student perspective, there was an increase in material comprehension from 65% in the first cycle to 80% in the second cycle. This indicates that AI-based learning media can help students better understand learning content, particularly through interactive features, voice, and text visualization. Student engagement in class also increased from 70% to 85%, indicating that the use of technology encourages active participation and more equitable student engagement in the learning process, including students with specific learning disabilities. This improvement was also supported by changes in the quality of student assignments in the spelling aspect, which increased from 60% to 75%, and student writing skills, which increased from 55% to 70%. This data confirms that AI-enabled digital approaches can provide immediate and contextual feedback, significantly assisting in self-correction and literacy reinforcement.

Meanwhile, from the teacher perspective, there was a greater and more significant improvement. Teacher response to technology increased from 60% to 85%, reflecting a growing acceptance and appreciation of AI-based tools in inclusive learning activities. Furthermore, teacher use of technology increased from 50% to 80%, indicating that teachers not only understand but also actively utilize technology in various stages of learning, from planning to assessment. This increase demonstrates that training support and teacher involvement in the design process are key to the successful implementation of technological innovation in education.

These data indicate that the DBR approach, implemented in two cycles, successfully increased the effectiveness of technology-based inclusive learning. The integration of artificial intelligence not only positively impacted the learning outcomes of students with special needs but also encouraged changes in teachers' attitudes and learning practices toward a more adaptive and technology-based approach. Thus, these findings reinforce the importance of collaborative design between researchers, educators, and technologists in developing contextual solutions in inclusive classrooms.

Significant Improvements: Based on the data above, the implementation of the second cycle with the revised AI-based design demonstrated significant improvements in almost all evaluation aspects. The largest improvement occurred in teacher use of technology, which saw a 30% increase, indicating that teacher training and support significantly impacted the use of technology in teaching. Student engagement, increased student activity and understanding of the material, also demonstrated the positive impact of the updated design. Students were not only more active but also experienced improvements in the quality of assignments, including spelling and writing. Regarding the role of technology in improving learning, these data demonstrate that AI technology plays a significant role in improving students' basic literacy skills, particularly in supporting students with dyslexia and dysgraphia. From the data presented above, the average percentage increase in all evaluation aspects between the first and second cycles can be calculated: the average increase from the evaluation results of the first cycle to the second cycle is 18.75%.

TABLE 4
SYSTEM USAGE LOG

Group	Access Frequency (x/week)	Average Duration (minutes/session)	Dominant Activity	Automated Assessment Score (Average)
Teacher (15)	5	60	Create quizzes, analyze results, upload materials	92% module completion
Dyslexic Students (15)	3	30	Interactive video/audio, reading practice	68% reading comprehension score
Dysgraphia Students (15)	4	45	Drag-drop, writing practice, visual quizzes	72% writing structure score

Based on data from digital learning system usage logs analyzed from 15 schools, it was noted that the intensity and quality of user interaction with the system varied depending on their role (teacher or student) and the type of special needs (dyslexia or dysgraphia). 1) Frequency of Access: teachers had the highest frequency of access, averaging five times per week, primarily for content management and assessment. Dyslexic students accessed the system an average of three times per week, while dysgraphia students accessed the system four times. 2) Duration of Use: teachers spent an average of 60 minutes per session, while dyslexic students tended to spend shorter sessions (30 minutes per session) than dysgraphia students (45 minutes per session), due to differences in digital reading and writing abilities. 3) Type of Activity: teachers most frequently accessed the quiz creation feature, results reports, and interactive materials. Dyslexic students tended to prefer learning videos and audio-visual reading exercises. Dysgraphia students were more active in interactive activities such as drag-and-drop and typing exercises. 4) Automated Assessment Results: The automated assessment showed that 73% of teachers successfully tailored their assessments to their students' needs. Of the students, 60% of dyslexic students showed an improvement in their scores after the third session, while 67% of dysgraphia students experienced significant improvement in writing structure after the fourth session.

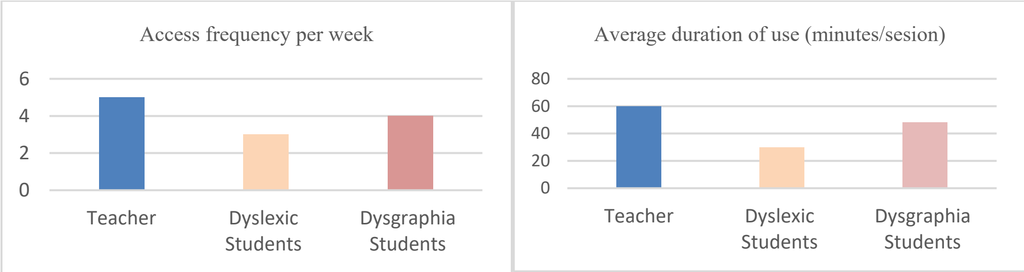

Figure 5. Access Frequency (left) and Time Duration (right)

Figure 5 shows clear differentiation in access frequency and duration between teachers, dyslexic students, and dysgraphia students. Teachers exhibit the highest frequency (5x/week) and longest duration (≈60 minutes/session), which reflects their dual role as content managers and facilitators. This high level of engagement suggests that teachers not only used the system for direct classroom support but also for preparation, monitoring, and assessment.

Dysgraphia students show slightly higher access (4x/week) and longer sessions (≈45 minutes) than dyslexic students (3x/week, ≈30 minutes). This aligns with the nature of their literacy challenges: dysgraphia requires more sustained practice with writing tasks, often supported by drag-and-drop and structured writing activities, which are time-intensive. Dyslexic students, meanwhile, benefit from shorter but frequent audiovisual activities to strengthen word recognition and reading fluency.

The different engagement patterns suggest that AI tools were appropriately adaptive to the cognitive and motoric demands of each special needs group. Dyslexic students' shorter engagement may indicate cognitive fatigue when exposed to text-heavy tasks, underlining the importance of multimodal (audio-visual) learning formats. Dysgraphia students' longer sessions reflect the necessity of extended practice in motoric and structural writing exercises.

The higher teacher engagement also highlights a capacity-building effect: teachers are not only consumers of AI but also active agents shaping its use. This demonstrates that AI integration, when supported by training and reflective design cycles, shifts teachers' role from passive implementers to technology mediators who contextualize digital tools for inclusive learning.

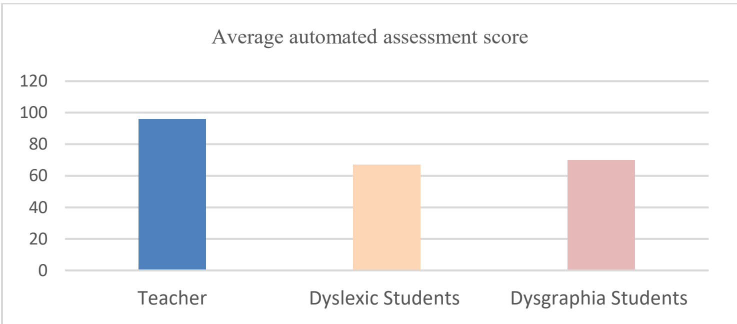

Figure 6. Average Score

The average automated assessment scores reinforce the system log findings where teachers achieved a high level of module completion (92%), indicating strong mastery and adaptation to AI-supported instructional practices. Dyslexic students scored an average of 68% in reading comprehension, which, although lower than their peers, represents significant progress compared to their pre-test baseline (52.6). This confirms that AI-mediated multimodal support improves decoding and comprehension skills. Dysgraphia students scored 72% in writing structure, which is slightly higher than the dyslexic group. Their improvement is consistent with the structured, repetitive digital writing exercises provided.

The post-intervention performance gap between SEN students (68–72%) and teachers (92%) highlights a persistent achievement disparity. However, the magnitude of improvement, especially the ~30% gains observed in dyslexic and dysgraphia students demonstrates that AI-based tools are effective compensatory mechanisms. This indicates that AI can serve as an equalizer in inclusive classrooms, even if complete parity with regular students or teachers has not yet been achieved.

The data suggests that dysgraphia students may benefit slightly more from structured AI interventions than dyslexic students, likely because writing scaffolds and visual supports directly reduce the motoric and organizational barriers they face. For dyslexic students, while significant gains were observed, sustained long-term interventions with adaptive pacing and gamified reinforcement may be needed to consolidate reading fluency.

Teacher Perspectives and Capacity Building

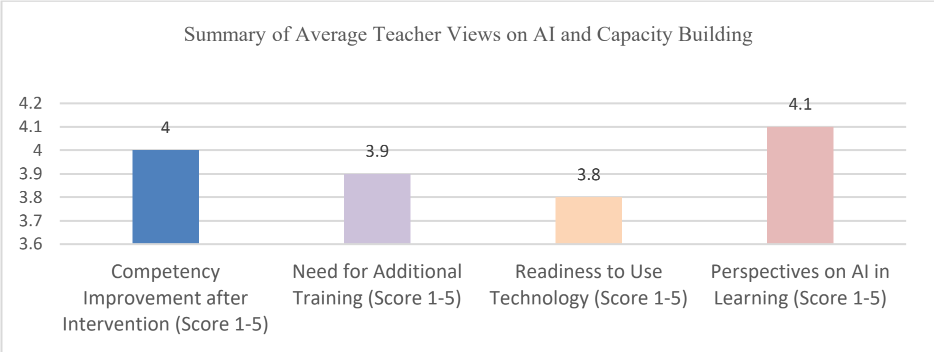

Figure 7. Teacher Perception Data

The evaluation of 15 elementary school teachers showed that they generally held a positive view of the use of AI in inclusive learning, with an average score of 4.2 out of 5. This reflects a positive acceptance of technological innovation as part of a learning strategy for students with special needs such as dyslexia and dysgraphia.

However, despite teachers' positive attitudes, their level of readiness to use technology independently was slightly lower, at 3.9, indicating that some teachers still face technical and adaptation challenges in integrating technology into their daily practices. This challenge was further reinforced by the high average score for the need for additional training, also at 3.9, indicating that most teachers felt they still needed further guidance or practical training on the use of AI in learning.

Nevertheless, encouraging results were seen in the increase in competency after the technology intervention, with an average score of 4.1. This indicates that the capacity-building program through technology-based DBR design has significantly improved teachers' ability to design and implement inclusive and adaptive learning.

These data indicate that acceptance of AI among teachers is quite high, but systematic support through ongoing training and mentoring is still needed to improve technological readiness and maximize the potential of artificial intelligence in inclusive learning at the elementary school level.

Design Iteration and Refinement

TABLE 5
COMPARISON OF INSTRUCTIONAL DESIGNS ACROSS CYCLES

Instructional Design Aspects	Cycle 1	Cycle 2
AI Technology Used	Text-to-Speech, Handwriting Checker, Speech Recognition	Simplified AI, one function per display
Teacher Role	Instructor, not yet a full facilitator	Active facilitator with individualized customization
Learning Strategies	Independent reading, copying simple sentences	Gradual digital worksheets with video guidance
Literacy Support Features	Basic interface without visual scaffolding	Dyslexia fonts, visual templates, interactive tutorials
Student Engagement	High interest, but confused by platform transitions	More focused, participatory, and more accurate task completion
Teacher Reflection Results	Needs simplification of pacing and interface layout	Teachers are better able to provide differentiated interventions

In the first cycle, the instructional design focused on the initial use of AI technologies, such as text-to-speech applications, digital handwriting checkers, and speech recognition. Teachers were given basic training on how to integrate these technologies into literacy learning activities. Initial interventions emphasized independent reading and copying simple sentences assisted by AI technology.

However, findings from classroom observations and teacher interviews indicated that some dyslexic students struggled to follow instructions due to the technology's overly complex interface. Teachers also reported that students with dysgraphia benefited from tablet-based writing activities but struggled to process rapid instructions. Therefore, adjustments were made to the pacing, scaffolding, and visualization of the instructions.

Student feedback also came from students, who expressed strong interest in interactive features and gamification but found it confusing to switch between digital platforms and manual writing activities. Therefore, at the end of the first cycle, the instructional design was revised to include supporting visual elements, step-by-step activity templates, and short demonstrative videos.

In the second cycle, the instructional design was adapted with a greater emphasis on: 1) Simplified use of AI, with the application's interface displaying only one function at a time. 2) Enhancing the teacher's role as a facilitator in bridging digital instruction with student responses. 3) Developing digital worksheets that are more structured and responsive to individual student needs, including the use of dyslexia-friendly fonts (e.g., Open Dyslexic). 4) Interactive, 1–2-minute AI video tutorial sessions to introduce each task.

Data from teacher reflections, student learning outcomes, and AI platform usage logs indicate increased student participation, interest, and accuracy in completing literacy tasks. Teachers also indicated that the design changes helped them provide differentiated interventions tailored to the needs of each student in inclusive classrooms.

IV. Discussion

The findings of this study indicate that the integration of AI into inclusive learning in elementary schools has significant potential to improve the literacy of students with learning disabilities such as dyslexia and dysgraphia. Teachers reported increased student engagement when using AI-based technologies, such as automatic text readers, reading speed adjusters, and automatic handwriting correctors. This provides a more individualized and adaptive learning experience, which has been difficult to provide in resource-constrained inclusive classrooms.

Results from two implementation cycles indicate that instructional design that considers teacher and student feedback can enhance the effectiveness of interventions. The first cycle showed that while AI engaged students, the complexity of using the technology made it difficult for some students. Adjustments in the second cycle, such as the use of supporting visual features, interactive tutorials, and reduced workload, successfully improved the functionality of AI in the context of inclusive classrooms. Thus, AI is not merely a technological tool, but also a medium for translating Universal Design for Learning (UDL) principles into practical practice.

Furthermore, these findings imply that teacher training in the pedagogical use of AI is crucial. Many teachers expressed a need for capacity building in designing and adapting AI technology to the needs of students with special needs. Therefore, teacher professional development must encompass an understanding of both technology and inclusive pedagogy. With proper integration, AI can be a catalyst for more equitable, equal, and equitable education for all students, including those with literacy challenges.

In the Indonesian context, the use of AI in inclusive learning is increasingly relevant, given geographic challenges, student diversity, and the limited number of special educators in remote areas. AI technology can be an alternative solution to bridge the gap in access to inclusive education, especially in elementary schools that lack dedicated assistant teachers. AI-based applications that operate offline or in a hybrid format are also well-suited to the uneven internet infrastructure in many parts of Indonesia.

Research findings indicate that with simple interfaces, localized features such as the use of Indonesian, and ease of content adaptation, AI technology can be functionally integrated into the classroom. Teachers in several public and private elementary schools are able to utilize AI-based applications after receiving brief training, although there is still a need for improved digital literacy. The use of a special dyslexia font, Indonesian-language text narrator, and voice recognition with local accents provide a more contextual learning experience for students with special needs.

However, the use of AI in inclusive education in Indonesia needs to be accompanied by supporting policies from local and central governments, including the provision of hardware and ongoing training for teachers. Furthermore, it is crucial to involve parents and the school community so that the use of technology is not merely instructional but also becomes part of a learning ecosystem that supports the social and emotional development of students with special needs. This indicates that the relevance of AI lies not only in its sophistication, but in its ability to adapt to local needs, values, and conditions.

A key strength of this study is its design-based approach with two implementation cycles, which allowed for contextual adjustments to the instructional design based on teacher reflections and student learning outcomes. The mixed methods study used combining quantitative data from teacher assessments and observations, with qualitative data from interviews and documentation provides a holistic picture of the effectiveness and challenges of using AI in inclusive learning. The success of the second cycle in increasing student engagement is an indicator of the success of a participatory approach that actively involves teachers in the innovation process.

However, this study also has several limitations. First, the number of respondents was limited to 15 teachers from several elementary schools, so generalizing the findings to all of Indonesia requires caution. Second, the study's duration, which only covered two learning cycles, makes the results more exploratory than longitudinal. Third, although several AI-based applications were used, the technology used was relatively simple and did not fully represent the full potential of AI, such as machine learning or automated adaptive learning.

Another limitation is the lack of quantitative, long-term effectiveness testing based on student literacy skills. Although there was an increase in teachers' perceptions of the effectiveness of AI and inclusive classroom management, the measurement of the direct impact on student learning outcomes was still descriptive and requires further study. Therefore, the results of this study are more appropriately viewed as a basis for developing more tested AI-based learning models in the context of inclusive education in Indonesia.

Several international studies have shown results consistent with this research. In Finland, for example, AI is being used to detect reading error patterns in dyslexic students, which are then used to develop data-driven interventions. Similarly, in South Korea, AI has been utilized in language teaching for children with special needs through a speech recognition application capable of providing personalized feedback. As in this study, teacher engagement and adaptive instructional design are key to the success of technology-based interventions.

However, striking differences are evident in the infrastructure and readiness of education systems in these countries compared to Indonesia. In developed countries, AI implementation is supported by advanced hardware, adequate teacher training, and structured educational policy support. In Indonesia, challenges such as limited devices, unequal teacher digital literacy, and disparities in education quality across regions are obstacles that need to be overcome before AI can play an optimal role as in these countries.

However, the unique Indonesian context also opens up opportunities for locally-based AI development. This study's findings demonstrate that adapting AI features to local language, culture, and student characteristics can yield positive results, even with modest technology. This demonstrates that the effectiveness of AI in inclusive learning is determined not only by technological sophistication, but also by design capabilities that are responsive to the social and educational contexts in which the technology is implemented.

V. Conclusion

This research makes a significant contribution to the context of inclusive education in Indonesia by developing and implementing an AI-based learning design tailored for students with dyslexia and dysgraphia. Through a two-cycle Design-Based Research (DBR) approach, it was found that the use of AI improved students' understanding of the material, learning engagement, and writing skills in an inclusive classroom context. Teachers also responded positively to the use of this technology, increasing their capacity to manage AI-based learning. Another contribution is the development of an adaptive instructional design model that can be replicated and further developed by other teachers and educational developers.

Recommendations for Schools, Policymakers, and Educational Technology Developers

Schools are advised to provide intensive and ongoing training to teachers in utilizing AI-based technologies, particularly those designed for specific needs such as dyslexia and dysgraphia. Policymakers need to expand inclusive policies that not only accommodate the needs of students with learning disabilities but also strengthen inclusive and adaptive educational technology infrastructure. Educational technology developers are encouraged to create AI solutions that are not only based on sophisticated algorithms but also consider pedagogical aspects, cultural context, and ease of integration in inclusive elementary classrooms in Indonesia.

Future research should expand the scope of participation to include students from diverse regional backgrounds and with varying levels of special needs to enhance the generalizability of the results. Furthermore, longitudinal studies evaluating the long-term impact of AI integration in inclusive learning are needed. Future directions could also focus on developing technology-based measurement tools to assess the literacy progress of students with special needs in real-time and adaptively. Furthermore, cross-disciplinary collaboration between educators, technologists, and educational psychologists is essential to create an effective and sustainable AI-based learning ecosystem.

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