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Fragmented AI Adoption in Indonesian Special Education: An Adaptive Multi-Layer Iterative Model for Differentiated Instruction in Intellectual Disability Contexts

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Abstract: This study aims to investigate patterns of AI utilization for students with intellectual disabilities and develop the Adaptive Multi-Layer Iterative Model (AMLIM) as a conceptual framework for integrating AI into differentiated instruction practices for students with intellectual disabilities in Indonesia. Using a qualitative-dominant mixed-methods design, this study combines systematic literature synthesis and survey data from 80 special education teachers from public and private special schools across multiple provinces in Indonesia, predominantly West Java and South Sumatra. Data were analyzed using descriptive statistics and thematic synthesis. Results show that 81.5% of teachers perceived AI as beneficial for instructional material development, but only 30.9% had received formal AI-related training, while 85.2% relied primarily on social media for AI-related knowledge. Although 64.2% adapted AI-generated materials to students' individual needs, implementation remains fragmented and concentrated in instructional preparation rather than systematic assessment and documentation. To address these limitations, this study proposes the Adaptive Multi-Layer Iterative Model (AMLIM), a feedback-based framework integrating pedagogical processes, adaptive personalization, assessment documentation, and governance structures. The model promotes a more systematic, documented, and accountable approach to AI-supported differentiated instruction in special education.

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Introduction

The development of Artificial Intelligence (AI) in education has shown a significant transformation in recent years (Hwang et al., 2020; Zhai et al., 2021). AI is no longer merely used as an administrative tool, but has evolved into an adaptive system capable of supporting personalized learning, student performance analysis, and data-driven feedback (Ouyang et al., 2022; Viberg et al., 2020). Various studies show that AI has the potential to increase learning responsiveness by dynamically adjusting materials and strategies to the individual needs of learners (Chen, Chen, & Lin, 2020; Holmes et al., 2019; Tsai et al., 2020). However, the development of these technological capabilities has not been fully accompanied by a systemic and structured pedagogical integration framework (Ifenthaler & Yau, 2019).

In the Indonesian context, the adoption of AI in education remains partial and predominantly technical in orientation. Recent evidence from early childhood education settings indicates that AI has begun to support inclusive practices; however, its implementation remains limited in terms of systemic integration (Nurnaningsih & Salehudin, 2025). AI is generally used to generate teaching materials, develop assessment items, and simplify instructional texts, yet it has not been fully embedded within the broader cycle of

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instructional planning, student assessment, and developmental documentation. Findings from a survey involving 80 special education teachers further reveal that AI use is primarily concentrated on content production, with limited application in pedagogical decision-making, individualized progress monitoring, and school-level learning management systems. This pattern indicates structural fragmentation in AI adoption, driven by limited teacher competence in pedagogically meaningful AI integration, uneven digital infrastructure across special education settings, and the absence of institutional frameworks that systematically align AI implementation with differentiated instructional planning and assessment. This condition reflects broader concerns in the global discourse on AI governance in education, where technological adoption often outpaces pedagogical and regulatory readiness (Akgun & Greenhow, 2022).

This issue becomes even more complex in education for students with intellectual disabilities. This group requires a structured, repetitive, and highly individualized learning approach, with consistent and documented progress monitoring. In a pedagogical framework, the differentiated instruction approach provides a relevant foundation because it emphasizes the adaptation of content, process, product, and learning environment based on students' readiness, interests, and learning profiles (Tomlinson, 2017). However, in practice, the implementation of differentiation still relies heavily on teacher capacity and manual management, making it difficult to maintain continuous, data-driven adaptation (Tsai et al., 2020).

International literature recognizes the potential of AI in supporting personalized learning through recommendation systems, learning analytics, and real-time material adaptation (Zawacki-Richter et al., 2019; Holmes et al., 2019; Hwang et al., 2020). Such adaptive support aligns with the concept of the Zone of Proximal Development (ZPD), which emphasizes guided assistance that enables learners to progress beyond their independent capabilities (Vygotsky, 1978). However, most research focuses on general education and higher education (Ouyang et al., 2022; Zhai et al., 2021), while studies that explicitly link AI with differentiation practices in special education are still limited. Furthermore, the emerging discourse highlights technological aspects rather than formulating layered and sustainable pedagogical integration models (Ifenthaler & Yau, 2019; Akgun & Greenhow, 2022). Therefore, the main problem addressed in this study is the absence of a systematic and integrative framework that connects AI capabilities with differentiated instructional practices in special education contexts.

Based on these conditions, there are three main gaps in existing research. First, there is no integrative framework that explicitly links AI with differentiated instruction in the context of intellectual disability. Second, research on AI adoption in Indonesia emphasizes technological readiness and digital literacy, without developing an adaptive pedagogical architecture. Third, there is no layered and iterative model that can ensure the integration of AI takes place systematically and in line with the dynamics of student development, as recommended in the ethical and sustainable AI framework (Holmes et al., 2019).

Based on this gap, this study aims to investigate patterns of AI utilization for students with intellectual disabilities and develop the Adaptive Multi-Layer Iterative Model (AMLIM) as a conceptual framework for integrating AI into differentiated instruction practices for students with intellectual disabilities in Indonesia. This model is designed as a layered system that encompasses pedagogical dimensions, AI-based adaptive technology, and reflective-iterative mechanisms to ensure alignment between technology use and student learning development, in line with recommendations for human-centered and transparent AI development (Tsai et al., 2020; UNESCO, 2021). Thus, this study contributes theoretically

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through the formulation of an integrative model that bridges AI and differentiated pedagogy, and practically by offering a systemic, adaptive, and sustainable implementation framework in special education.

Research Method

This study employed a qualitative-dominant mixed-methods design for conceptual model development, integrating conceptual literature synthesis with quantitative survey data to construct the proposed Adaptive Multi-Layer Iterative Model (AMLIM). This design was selected to enable the integration of theoretical insights and empirical field requirements in formulating an Artificial Intelligence (AI) based framework for special education, as recommended in technology-based educational model development research (Ouyang et al., 2022; Hwang et al., 2020). The conceptual development approach emphasizes the integration of literature analysis and empirical evidence as the foundation for systematic and theoretically grounded model construction, ensuring conceptual rigor and practical relevance (Creswell & Creswell, 2017). The research was conducted sequentially through problem identification, conceptual literature mapping, field needs assessment, thematic analysis, and iterative formulation of the Adaptive Multi-Layer Iterative Model (AMLIM). This process aligns with design-based research principles and educational technology model development frameworks emphasizing iterative refinement grounded in theoretical synthesis and contextual evidence (Anderson & Shattuck, 2012; Wang & Hannafin, 2005; McKenney & Reeves, 2021).

The empirical component involved 80 special education teachers from public and private special schools (SLB) across multiple provinces in Indonesia, predominantly West Java and South Sumatra, selected through purposive sampling to capture variation in institutional context and instructional practice. Participants were selected based on having at least two years of teaching experience, involvement in the development of individualized learning plans, and familiarity with digital or AI-supported instructional tools, in accordance with principles of contextual participant selection in educational research (Palinkas et al., 2015). Data were collected online through digital questionnaires, a commonly adopted approach in technology-based educational research (Ifenthaler & Yau, 2019). The survey instrument consisted of closed and open-ended questions designed to examine patterns of AI utilization, levels of integration across the instructional cycle, involvement in student progress documentation, institutional governance support, and perceptions regarding the need for an integrative AI-based framework. To ensure construct appropriateness and indicator clarity, content validity was assessed through expert judgment by two academics specializing in educational technology and special education, following established validation procedures for educational research instruments (Boateng et al., 2018).

Survey data were analyzed descriptively to identify trends in AI utilization patterns in the field. This descriptive approach was used to map actual practices and implementation gaps prior to conceptual model construction (Viberg et al., 2018). Findings indicate that AI is primarily utilized for instructional material preparation and adaptive content support, yet remains insufficiently integrated into student development evaluation cycles, learning progress documentation systems, and institutional governance structures. These patterns reinforce evidence of structural fragmentation in AI adoption within special education, as similarly identified in broader global studies of educational AI implementation (Akgun & Greenhow, 2022).

Meanwhile, qualitative data derived from open-ended responses and literature synthesis were analyzed using thematic analysis through open coding, categorization, theme

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identification, and conceptual integration, following systematic and iterative procedures (Braun & Clarke, 2021). The analysis was conducted reflectively to ensure alignment between theoretical dimensions and empirical needs. Based on this synthesis, the Adaptive Multi-Layer Iterative Model (AMLIM) was formulated as an integrative framework connecting AI and differentiated instruction in intellectual disability contexts through an adaptive and iterative multi-layer structure. The model development process was conducted reflectively and conceptually to ensure internal coherence, practical relevance, and theoretical contribution to more systemic and sustainable AI integration in special education, consistent with principles of human-centered and evidence-based AI development (Holmes et al., 2019; UNESCO, 2021).

Results and Discussion

This study focuses on the learning context of students with intellectual disabilities at the elementary and secondary levels. Survey findings from 80 special education teachers indicate that these students demonstrate diverse and highly individualized learning needs, including limitations in information processing, slower learning pace, a strong need for structured instruction, and reliance on visual supports and repetitive reinforcement. These characteristics require differentiated instructional approaches that are responsive, adaptive, and systematically monitored over time. Most teachers reported developing lesson plans based on Individualized Education Programs (IEPs), reflecting awareness of the need for personalized instructional planning. However, the implementation of differentiated instruction remains uneven across classrooms and continues to depend heavily on individual teacher initiative. This fragmentation is also reflected in AI adoption patterns: while 81.5% of teachers reported using AI to support instructional material development and evaluation preparation, only 30.9% had received formal AI-related training. Furthermore, 85.2% reported relying primarily on social media as their main source of AI-related knowledge, indicating that AI integration is largely shaped by informal individual exploration rather than systematic institutional support. These findings suggest that AI is predominantly used for isolated instructional tasks rather than as part of an integrated system for assessment, progress monitoring, and adaptive instructional decision-making.

Patterns of AI Utilization in the Field

This study was conducted through two main approaches: a systematic literature review and a field survey. The literature review identified key concepts related to the integration of Artificial Intelligence (AI) in education, differentiated instructional principles, and the importance of educational technology governance. Global evidence emphasizes that effective AI implementation depends not only on technological availability but also on pedagogical alignment and institutional governance structures (Ifenthaler & Yau, 2019; UNESCO, 2021).

Meanwhile, the field survey was conducted to map current patterns of AI adoption among special education teachers. Descriptive analysis reveals that teachers generally demonstrate positive perceptions toward AI and recognize its potential to support differentiated instruction, particularly in instructional material development and adaptive content preparation. However, the findings also indicate significant gaps in formal training, institutional support, and pedagogically grounded implementation. This pattern is consistent with both national and global findings showing that AI adoption often remains focused on instructional assistance rather than being embedded within integrated pedagogical systems (Syahputra et al., 2025; Akgun & Greenhow, 2022; Ouyang et al., 2022).

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Table 1. Empirical Patterns of AI Utilization in Special Education Practice

Dimension	Indicator	Percentage
Perceived instructional usefulness	Teachers perceiving AI as beneficial for instructional material development	81.5%
Engagement with AI development	Teachers actively following AI developments	66.7%
Formal professional preparation	Teachers having participated in AI-related training	30.9%
Primary knowledge acquisition source	Teachers relying on social media for AI-related knowledge	85.2%
Adaptive instructional modification	Teachers adapting AI-generated materials to student needs	64.2%
Observed student impact	Teachers reporting increased student engagement	42.0%
Implementation barrier	Teachers identifying limited instructional time as a major challenge	67.9%

Table 1 demonstrates that AI utilization in special education is characterized by high perceived instructional usefulness but limited formal pedagogical preparation. While 81.5% of teachers recognized AI as beneficial for instructional material development and 66.7% actively followed developments in AI, only 30.9% had received formal training. The predominance of social media as the primary source of AI-related knowledge (85.2%) suggests that adoption is largely driven by informal individual exploration rather than systematic institutional capacity-building. Although 64.2% of teachers reported adapting AI-generated materials to meet the individualized needs of students with intellectual disabilities, implementation remains constrained by limited instructional time (67.9%) and insufficient pedagogical guidance. This pattern indicates that AI is primarily utilized to support immediate instructional tasks rather than functioning as part of integrated data-driven adaptive learning systems (Hwang et al., 2020; Tsai et al., 2020). These empirical gaps provide the basis for the development of the Adaptive Multi-Layer Iterative Model (AMLIM) proposed in this study.

Structural Fragmentation of AI in Special Education

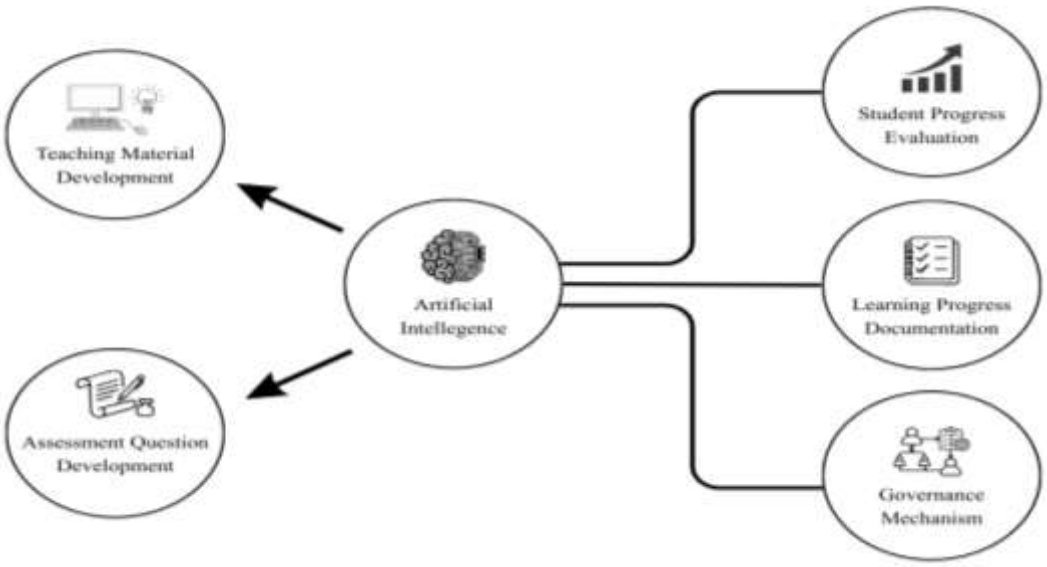

Figure 1. Structural Fragmentation of AI Integration in Special Education

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Figure 1 Structural Fragmentation of AI Integration in Special Education remains predominantly concentrated in instructional material development and assessment preparation, with limited evidence of systematic integration into longitudinal assessment, learning documentation, or institutional governance structures. This visualization demonstrates that AI continues to occupy a peripheral rather than embedded role within the broader learning ecosystem.

This condition is reinforced by empirical findings showing that while 81.5% of teachers perceived AI as beneficial for instructional material development, only 30.9% had received formal AI-related training, and most relied on informal knowledge sources such as social media. As a result, AI implementation remains highly dependent on individual teacher initiative rather than institutionalized pedagogical systems. Consequently, student learning data is not yet systematically leveraged to support continuous adaptive instructional decision-making. This fragmentation aligns with broader critiques of AI implementation that emphasize the risks of technological adoption without coherent systemic design and institutional policy frameworks (Ifenthaler & Yau, 2019; UNESCO, 2021).

Formulation of the Adaptive Multi-Layer Iterative Model (AMLIM)

Based on the synthesis of literature findings and empirical evidence, the Adaptive Multi-Layer Iterative Model (AMLIM) was developed as an integrative framework to address the structural fragmentation identified in current AI adoption practices. The model consists of five interconnected layers: student profiles, AI-based personalization, differentiated instruction, assessment and documentation, and a governance framework as an external regulatory layer ensuring sustainability and accountability. This layered architecture aligns with recommendations for educational AI systems that emphasize the integration of pedagogical responsiveness, adaptive technologies, and ethical governance (Holmes et al., 2019; UNESCO, 2021).

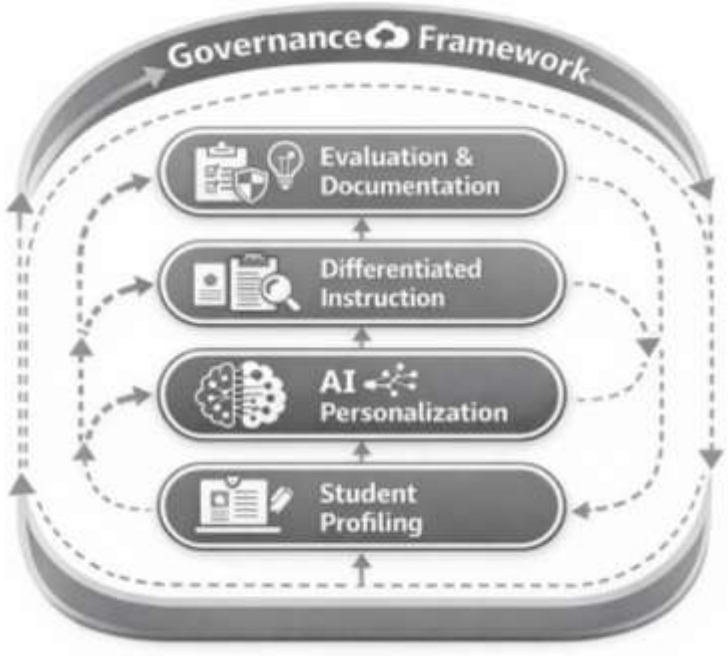

Figure 2. Structural Fragmentation of AI Integration in Special Education

Figure 2 illustrates a layered structure interconnected through iterative feedback mechanisms. Student profiles serve as the foundational layer by capturing individualized learning characteristics and developmental needs. This data is processed through the AI

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personalization layer to generate adaptive instructional recommendations. These recommendations are implemented within the differentiated instruction layer through adjustments to content, process, and expected learning outcomes, consistent with differentiation principles (Tomlinson, 2017).

Learning outcomes are subsequently documented within an integrated evaluation and reporting system, providing updated evidence for the next adaptive cycle. The governance layer ensures that the entire process operates within clear institutional policies, ethical standards, and accountability mechanisms, consistent with human-centered AI frameworks (UNESCO, 2021; Akgun & Greenhow, 2022).

Overall, the findings reveal a significant gap between teachers' positive perceptions of AI and its systematic pedagogical implementation in special education settings. Although AI has begun to support adaptive instructional preparation, its utilization remains concentrated in immediate instructional support functions rather than forming a fully integrated data-driven learning ecosystem. AMLIM is therefore proposed as a systemic solution to bridge this gap through iterative and layered integration. The model positions AI not merely as a technical tool, but as an embedded component within a structured, documented, and sustainable pedagogical cycle.

Discussion

The findings of this study indicate that AI utilization in special education remains concentrated in technical instructional support and has not yet been systematically integrated into pedagogical assessment, progress documentation, or adaptive decision-making processes. This fragmentation reveals a substantial gap between AI's potential to support differentiated instruction and its actual implementation in classroom practice. More importantly, this gap carries particular implications in the context of students with intellectual disabilities, where instructional effectiveness depends heavily on continuous individualized monitoring, iterative adjustment, and systematic documentation of developmental progress.

These findings align with previous studies demonstrating that AI adoption in K–12 education remains largely focused on operational functions such as content generation and task automation rather than pedagogical transformation (Kasneci et al., 2023). Holmes et al. (2023) similarly argue that the educational value of AI depends on meaningful alignment between technological affordances, pedagogical frameworks, and institutional readiness. The present study extends this argument by showing that in special education contexts, this misalignment has amplified consequences because instructional adaptation for students with intellectual disabilities requires much more than efficient content production.

Unlike general classroom contexts, teaching students with intellectual disabilities requires highly structured, repetitive, and individualized instructional cycles. Learning progress often occurs incrementally and may only be observable through longitudinal documentation of behavioral responses, task completion patterns, reinforcement effectiveness, and adaptive support needs. Assessment and documentation are therefore not merely administrative processes; they function as essential pedagogical mechanisms for identifying developmental trajectories, adjusting individualized educational programs (IEPs), and determining appropriate instructional modifications. Without systematic integration of AI into these processes, differentiated instruction remains dependent on teacher intuition and fragmented manual observation.

This explains why the absence of AI-supported assessment and documentation identified in this study represents a critical limitation. While teachers may successfully use AI to generate instructional materials, such isolated use does not address the central challenge of special education: continuously adapting instruction based on evolving learner profiles.

Survey findings showing limited formal training (30.9%) and strong reliance on informal knowledge sources further suggest that teachers are insufficiently supported in leveraging AI for data-informed pedagogical decision-making. As a result, AI remains positioned as an auxiliary production tool rather than as a mechanism for sustaining adaptive instructional cycles.

The absence of governance mechanisms identified in this study is also consistent with broader concerns regarding AI implementation in education. Dwivedi et al. (2023) and Tlili et al. (2023) emphasize that effective AI integration requires explicit frameworks for accountability, transparency, and educational data governance. Cotton, Cotton, and Shipway (2023) further note that technological adoption frequently outpaces ethical and regulatory readiness. In the context of intellectual disability education, this governance gap is especially significant because student data often involves sensitive developmental information requiring careful ethical oversight and secure longitudinal management.

From a theoretical perspective, this study contributes to extending differentiated instruction theory through the integration of AI-supported adaptive learning systems. Existing literature emphasizes that effective personalization depends on learning analytics, continuous feedback, and responsive instructional adaptation (Viberg et al., 2018; Chen et al., 2020). This study demonstrates that within intellectual disability contexts, such integration is particularly necessary because personalization must respond to subtle developmental variations that are often difficult to capture through conventional instructional monitoring. The proposed AMLIM model addresses this need by connecting student profiles, AI-based personalization, differentiated instruction, assessment documentation, and governance into a coherent iterative system.

From a practical standpoint, AMLIM offers educational institutions a structured pathway for transitioning from fragmented AI adoption toward systematic pedagogical integration. By embedding assessment and documentation within AI-supported adaptive cycles, the model enables schools to strengthen individualized instructional planning, improve longitudinal monitoring of student development, and align technological innovation with ethical governance requirements. Thus, this study contributes to advancing an AI integration paradigm that is not only technologically innovative but also pedagogically responsive to the unique instructional demands of students with intellectual disabilities.

Conclusion

This study concludes that the integration of Artificial Intelligence (AI) in special education remains partial and has not yet been systematically embedded within instructional processes. The findings reveal a critical disconnect between AI capabilities, differentiated instructional practices, and the absence of structured governance and evaluation systems, limiting the realization of data-driven adaptive learning. The core variables identified in this study, AI integration, differentiated learning practices, and institutional governance structures, demonstrate that in the context of special education for students with intellectual disabilities in Indonesia, AI has not yet functioned as part of a comprehensive pedagogical ecosystem.

To address this fragmentation, this study proposes the Adaptive Multi-Layer Iterative Model (AMLIM) as an integrative framework connecting pedagogical, analytical, and governance dimensions through iterative feedback cycles. The model offers a structured and accountable conceptual foundation for embedding AI within differentiated instruction for students with intellectual disabilities. As a conceptual contribution, AMLIM extends current discussions on educational AI by positioning assessment, documentation, and governance as

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central components of adaptive learning systems in special education contexts.

Recommendation

Based on these findings, it is recommended that educators and policymakers prioritize the systematic integration of Artificial Intelligence (AI) into differentiated learning environments, particularly by connecting AI utilization to student assessment processes, longitudinal documentation of learning progress, and institutional governance frameworks. Educational institutions should prioritize the development of AI-supported assessment and documentation infrastructures that enable continuous adaptive instructional decision-making. In parallel, policymakers should establish clear regulatory guidelines and governance mechanisms to ensure the ethical, transparent, and sustainable implementation of AI in special education contexts.

Future research should empirically examine the implementation of the Adaptive Multi-Layer Iterative Model (AMLIM) in authentic classroom settings and evaluate its effectiveness in strengthening differentiated instructional practices and improving learning outcomes for students with intellectual disabilities. Further studies are also needed to design and test scalable AI-supported system prototypes that integrate assessment, documentation, and adaptive instructional processes at the institutional level.

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