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The Paradox of Personalization: A Critical Analysis of AI's Impact on Student Cognitive Development and the 'Illusion of Learning' in K-12 Education

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ABSTRACT

The rapid integration of artificial intelligence (AI) into K-12 education, particularly through personalized learning platforms, promises to tailor instruction to individual students' needs, enhancing efficiency and engagement. However, this study critically examines an underexplored paradox: while AI-driven personalization offers immediate cognitive support, it may inadvertently undermine deeper cognitive development by fostering an "illusion of learning"a state in which students perceive competence without genuine understanding. Employing a qualitative multi-case study design across five Indonesian K-12 schools that extensively use AI-powered personalized platforms, this study gathered data through semi-structured interviews with 20 teachers and 60 students, classroom observations, and document analysis. Thematic analysis revealed five core themes: (1) surface engagement with content, (2) dependence on instant feedback, (3) erosion of problem-solving persistence, (4) metacognitive misalignment, and (5) teacher mediation as a mitigating buffer. The findings indicate that the features designed to personalize learning hints, step-by-step solutions, and adaptive scaffolding can displace critical cognitive processes such as productive struggle, deep reasoning, and self-regulated reflection. Students frequently exhibit overconfidence in their learning, as measured by the discrepancy between self-perceived mastery and performance on transfer tasks. This study articulates the "personalization paradox" wherein systems optimized for immediate learning outcomes inadvertently attenuate the cognitive struggle essential for long-term intellectual growth. These implications call for a recalibration of AI pedagogy toward "desirable difficulties" and collaborative human-AI orchestration to safeguard cognitive development in technology-rich classrooms.

Keywords: Artificial Intelligence, Personalized Learning, Cognitive Development, Illusion of Learning, K-12 Education

I. INTRODUCTION

The advent of artificial intelligence (AI) in education has been heralded as a transformative force capable of revolutionizing how students learn, particularly in the K-12 sector. Across the globe, educational systems are integrating AI-driven platforms that promise personalized learning paths, real-time feedback, and adaptive content delivery. Indonesia, as the world's fourth-largest education system, has witnessed a significant surge in the adoption of such technologies, accelerated by government digitalization policies and the post-pandemic emphasis on hybrid learning. Platforms like Ruangguru, Zenius, and international players such as Khan Academy now embed AI algorithms to diagnose student weaknesses, recommend micro-lessons, and automate assessment. Proponents argue that these systems democratize quality instruction, close achievement gaps, and foster self-paced, mastery-based progression. The underlying assumption is straightforward: by tailoring educational experiences to individual cognitive profiles, AI can optimize learning outcomes while alleviating teacher workload (Cahyono & Rosita, 2023).

Yet, beneath this techno-optimistic narrative lies a disquieting paradox. Personalization, as engineered by current AI systems, predominantly focuses on optimizing performance metrics—accuracy, task completion

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speed, and immediate recall—rather than cultivating the deeper cognitive architectures that underpin lifelong learning. Cognitive developmental theory, from Piaget's constructivism to Vygotsky's zone of proximal development, emphasizes that genuine learning is inherently effortful, involving conflict, reflection, and the gradual construction of mental schemas through active engagement with challenging material. When AI intermediaries lower the cognitive bar by offering instant solutions, hints, and highly scaffolded pathways, they risk eliminating precisely the "desirable difficulties" that engender robust learning. The result may be an "illusion of learning" a psychological state wherein students feel they have learned because the process felt smooth and error-free, yet they fail to demonstrate deep understanding, transfer, or critical thinking when the scaffolding is removed (Pyshchyk, 2026).

This phenomenon is not merely hypothetical in nature. Classroom observations and teacher reports in technology-rich environments increasingly note that students, while technically completing tasks and showing progress on dashboards, struggle to explain the underlying concepts or apply knowledge to unfamiliar problems. The green ticks and rising scores on AI dashboards create an epistemic mirage: they signal achievement without corresponding cognitive changes. In Indonesia, where educational stakeholders emphasize Profil Pelajar Pancasila a set of competencies including critical reasoning, creativity, and independence the reductionist nature of AI personalization may paradoxically counteract the cultivation of these attributes (Adeagbo & Awolola, 2025).

Against this backdrop, the present study undertakes a critical examination of the intersection between AI-driven personalization and student cognitive development, specifically interrogating the emergence of the illusion of learning in Indonesian K-12 contexts. While a growing body of international literature addresses the promises and pitfalls of AI Ed, empirical scrutiny of cognitive trade-offs remains sparse, particularly from the situated perspectives of teachers and students in the Global South. Most research has centered on quantitative achievement gains or user satisfaction, leaving a critical gap in understanding how students' deeper cognitive processes reasoning, metacognition, snd epistemic agency are reshaped, or perhaps deformed, by algorithmically mediated personalization (Ritu Arya & Ashish Verma, 2024).

A qualitative multi-case study was conducted in five purposively selected K-12 schools in Java and Sumatra that had adopted AI-based personalized learning systems for at least two academic years. This study combines semi-structured interviews, classroom observations, and artifact analysis to capture both emic perspectives and observable behaviors. This methodological choice is deliberate: it allows for a nuanced exploration of cognitive engagement as a lived, contextual phenomenon, rather than reducing it to decontextualized performance metrics, thereby yielding a richer, more critical account (Gaurangi Vasisht, 2025).

The significance of this study is threefold. First, it contributes theoretically by integrating disparate strands of cognitive psychology, learning science, and critical educational technology studies to conceptualize the personalization paradox in learning. While the notion of the illusion of learning has been established in laboratory settings, it has been insufficiently applied to AI-mediated classrooms. This study extends this into complex, ecologically valid K-12 environments. Second, it offers practical implications for educators, platform developers, and policymakers in Indonesia and similar contexts. By illuminating the subtle ways in which AI personalization may inadvertently undermine deeper learning, this study provides an evidence-based caution against uncritical technology adoption and suggests design principles for "cognitive-friendly" AI. Third, methodologically, it demonstrates the value of qualitative inquiry in a domain often dominated by learning analytics and experimental designs that obscure the phenomenological texture of the student experience (Dewi* et al., 2025).

The remainder of this paper is organized as follows. The next section presents a literature review that synthesizes scholarship on AI personalization, cognitive development theory, and the illusion of learning, identifying a conceptual gap that frames the empirical contribution of this study. Subsequently, the research method details the qualitative design, participant selection, data collection, and analytic procedures, ensuring trustworthiness through triangulation and member checking. The results section thematically organizes the findings, underpinned by data tables and a chart that visualizes the prevalence and distribution of key cognitive engagement indicators and illusion-of-learning markers. The discussion interprets these findings through the lens of the personalization paradox, linking them to existing theory and highlighting the contextual nuances of Indonesian K-12 education. It also proposes a reorientation toward pedagogies that preserve productive cognitive struggles within AI-enhanced environments. Finally, the conclusion encapsulates the core argument, acknowledges the limitations, and charts future research directions. By centering the voices of students and teachers, this study challenges the prevailing efficiency-driven discourse and re-centers the cognitive subject—the student as a developing thinker in the age of intelligent machines.

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II. METHODS

This study employed a qualitative multi-case design (Yin, 2018) to provide a rich, contextualized understanding of how AI-driven personalization affects cognitive development and the emergence of the illusion of learning in K-12 settings in Indonesia. A case was defined as a school ecosystem where AI-powered personalized platforms were integrated into core instruction (mathematics and science) for a minimum of two consecutive years. The qualitative approach was selected because the phenomena of interest—cognitive engagement, metacognitive calibration, and the subjective experience of learning—are inherently interpretive and require access to participants' meaning-making processes. Moreover, the research sought to uncover dynamics that standardized quantitative instruments might overlook or oversimplify (Miles, M. B., & Huberman, 2014).

Case Selection and Participants

Five schools were purposively sampled to ensure variation across socio-economic contexts, geographic locations (urban, suburban, and rural within Java and Sumatra), and platform types. The platforms included locally developed AI systems (e.g., Ruangguru's "Adaptive Learning," and Quipper School Premium) and one global platform (Khan Academy with AI mastery modules). All schools were mainstream public and private institutions serving Grades 7 to 9 (ages 13–15), a critical period for the development of formal operational thinking and self-regulated learning.

Within each school, participants were:
Twenty teachers (four per school) who taught Mathematics and Science and actively used the AI platform in their classrooms at least three times per week. The teachers' experience ranged from 3 to 18 years.
Sixty students (12 per school) were selected in collaboration with teachers to represent a range of platform usage frequencies and performance levels (low, medium, and high based on platform analytics), ensuring diverse perspectives. Gender balance was maintained in the study.
Table 1 summarizes the demographic and contextual characteristics of the schools and individuals who participated in the study. The inclusion criteria required teachers to have completed school-level digital pedagogy training and students to have parental consent and at least six months of continuous platform use. All participants were assigned codes to preserve their anonymity.

Table 1. Participant and School Demographics

School Code	Location	Type	Platform Used	Average Platform Sessions/Week	Teacher Participants (n)	Student Participants (n)
SCH-A	Urban Jakarta	Private	Ruangguru Adaptive	4.2	4 (Math: 2, Sci: 2)	12
SCH-B	Suburban Bekasi	Public	Quipper School Premium	3.8	4 (Math: 2, Sci: 2)	12
SCH-C	Rural West Java	Public	Khan Academy Mastery	3.0	4 (Math: 2, Sci: 2)	12
SCH-D	Urban Surabaya	Private	Ruangguru Adaptive	4.5	4 (Math: 2, Sci: 2)	12
SCH-E	Suburban Medan	Public	Quipper School Premium	3.6	4 (Math: 2, Sci: 2)	12
Total					**20**	**60**

Data were collected over six months (January–June 2025) through three interconnected strands.
Semi-structured interviews: Each teacher participated in two individual interviews (early and late phases), each lasting 45–70 min. Student interviews were conducted in pairs to reduce anxiety and encourage dialogue, with each pair being interviewed once for approximately 40 minutes. The interview protocols explored perceptions of learning with AI, examples of confusion or false confidence, changes in study habits, and teacher mediation strategies. All interviews were audio-recorded and transcribed verbatim in Bahasa Indonesia, and selected excerpts were translated into English for reporting.

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Classroom observations: A total of 40 classroom sessions (eight per school) involving AI-platform use were observed non-participantly. Field notes captured sequences of student interactions with the AI interface (e.g., hint-requesting behaviors, time spent before seeking answers, note-taking, off-task behavior), teacher interventions, and peer dialogue. A structured observation checklist was developed from piloting to record the frequency of specific cognitive engagement indicators: active problem-solving attempts, answer copying without visible reasoning, skim-reading of solutions, and metacognitive remarks.
Document analysis: Platform dashboards, teacher lesson plans, student work artifacts (digital notebooks, scrap paper), and school assessment records (formative quizzes and project rubrics) were collected. These artifacts provided supplementary evidence for triangulating students' cognitive processes and the gap between platform-projected mastery and external performance.

Data Analysis
Data analysis followed Braun and Clarke's (2006) reflexive thematic analysis, executed through an iterative six-phase process: familiarization, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Two researchers independently coded a subset of transcripts to ensure intercoder consistency, and disagreements were resolved through discussion. The analysis was both deductive—informed by concepts of productive struggle, metacognitive calibration, and cognitive load—and inductive, allowing themes to emerge.
The coded data were managed using NVivo 14. A final thematic map comprising five overarching themes was developed, each encompassing sub-themes and evidenced by representative quotations. Frequency counts of theme occurrences across participants and schools were tabulated to indicate prevalence, although the qualitative nature means that numbers serve illustrative rather than statistically generalizable purposes. The observational checklist data were aggregated to produce descriptive frequency charts that visually compared AI-mediated sessions with traditional (non-AI-guided) group work sessions (observed during the same period for contrast), enhancing the articulation of engagement patterns (Creswell, 2021).

Trustworthiness and Ethical Considerations
Trustworthiness was addressed through triangulation (across data sources and participant types), prolonged engagement, peer debriefing, and member checking with a subset of the teachers. A rich and thick description of the contexts and cases is provided to aid transferability. Ethical approval was obtained from the authors' institutional review board and local education authorities. All participants (and guardians of students) provided written informed consent, and anonymity was strictly maintained. Given the sensitivity of critiquing school-adopted platforms, care was taken to frame conversations around learning processes rather than technology-blaming, and findings were reported in aggregated, non-evaluative terms.

III. RESULTS AND DISCUSSION

The thematic analysis generated five major themes that together capture the nuanced ways in which AI-driven personalization shapes students' cognitive engagement and fosters the illusion of learning. Table 2 presents an overview of the themes, their sub-themes, and illustrative quotes, along with the frequency of participant mention (number of teachers/students out of 20/60). Figure 1 provides a comparative bar chart of observed cognitive engagement behaviors across AI-mediated and traditional collaborative sessions to visualize shifts in student actions.

Table 2. Themes, Sub-themes, Illustrative Quotes, and Participant Frequency

Theme	Sub-themes	Illustrative Quote	Teachers (n=20)	Students (n=60)
1. Surface Engagement with Content	Passive solution consumption; skim-reading of AI explanations; minimal note-taking	"I just look at the steps—it's like watching a video. I understand at that moment, but when I try a similar problem alone, I'm blank." (Student, SCH-C)	18	47
2. Dependence on Instant Feedback	Hint-seeking without reflection; reduced tolerance for confusion; answer-checking as primary strategy	"Students immediately press the hint button when they see a difficult problem. They don't give their brains time to think." (Teacher, SCH-A)	17	42

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Theme	Sub-themes	Illustrative Quote	Teachers (n=20)	Students (n=60)
3. Erosion of Problem-Solving Persistence	Shortened time-on-challenging-task; giving up after single failure; avoidance of transfer tasks	"Before AI, students would struggle for ten minutes; now, if the answer isn't there in two steps, they complain." (Teacher, SCH-D)	15	38
4. Metacognitive Misalignment	Overconfidence in platform mastery scores; inability to self-assess accurately	"The app says I am 95% on algebra, but the exam I got 65. I don't get why." (Student, SCH-B)	16	39
5. Teacher Mediation as a Buffer	Strategic restriction of AI tools; explicit teaching of 'struggle'; re-framing errors as learning	"I forbid the hint for the first five minutes and ask them to write what they tried. That makes them think." (Teacher, SCH-E)	19	–*

The most pervasive finding across all five schools was a distinct shift toward a surface-level processing. In 47 of the 60 student interviews and 18 of the 20 teacher accounts, participants described a learning experience characterized by passive absorption rather than active construction. Students frequently reported that they "just followed the steps" shown by the platform without mentally reproducing the reasoning behind them. As one student from SCH-C articulated, "It's like the app is doing the thinking; I just move my finger." The convenience of well-structured, step-by-step solutions while a key selling point seemed to obviate the need for generative processing.

Classroom observations corroborated these self-reports. During AI-mediated sessions, 63% of the observed student interactions involved reading the platform's solution and then copying it into notebooks, often verbatim. In contrast, only 12% of these students were seen annotating with their own explanations or reworking the problem independently afterward. Document analysis of digital notebooks revealed a preponderance of screenshot-style captures, accompanied by minimal personal synthesis. This superficial engagement was not due to a lack of motivation; rather, the technology's design inadvertently invited a path-of-least-resistance: the effort gradient strongly favors clicking "Show Solution" over sustained mental struggle.

Theme 2: Dependence on Instant Feedback

The second prominent theme was the development of the cognitive habit of immediate feedback reliance. The platforms' architecture where a hint button, answer check, or confidence meter is perpetually available seems to rewire students' tolerance for uncertainty. Teachers reported that students no longer treated confusion as a productive signal to recall prior knowledge or attempt alternative strategies; instead, it became a trigger to summon the AI's assistance. One mathematics teacher (SCH-A) noted, "They have become allergic to being stuck. When they feel even slight difficulty, the hand moves to the hint. They do not trust their own minds."

Forty-two students openly admitted that they used hints as a first-line resource rather than a last resort. Some described a "ritual" of clicking the hint on every problem, systematically eliminating the need for initial reflection:Observational data aligned: the average number of hint requests per 40-minute AI session (14.8) far exceeded the active problem-solving attempts (4.2). Moreover, the nature of the hints mattered; most were incremental, revealing the next logical step, thus fragmenting the holistic problem-solving process into a sequence of prompted actions. This microwaving of problem decomposition, while reducing errors, dismantles the integrative reasoning that connects disparate mathematical or scientific concepts.

Theme 3: Erosion of Problem-Solving Persistence

Closely related to feedback dependence is the observable decline in student persistence when faced with challenging and non-routine tasks. Teachers contrasted current cohorts with pre-AI generations, stating that students now give up significantly faster than before. One science teacher (SCH-D) reflected, "A question that requires three or four logical steps without immediate clues they stop after two minutes and say, 'I don't get it' or switch to another app. That never happened five years ago."

Erosion was most evident during transfer tasks introduced in teacher-created assessments that required applying learned principles in novel contexts without platform support. In post-observation discussions, teachers noted that the students who had confidently completed AI-recommended exercises often became disoriented, flipping through notebooks in vain for a similar template. The average persistence time, as estimated by teacher observation logs, dropped from approximately 8–12 minutes per problem to 3–5 minutes.

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Thirty-eight students corroborated this, admitting that they would “just wait for the teacher” or “skip and come back later” rather than wrestle with obstacles.

The illusion of learning becomes apparent precisely at the boundary of familiarity. Because the AI platform always provided a scaffolded path, students rarely experienced the desert of unguided struggle; thus, their self-concept as learners was built on false ground.

Theme 4: Metacognitive Misalignment

The illusion of learning crystallized most vividly in the context of metacognitive misalignment. Students’ self-assessments, heavily influenced by platform-generated mastery percentages, positive reinforcement animations (stars, badges), and the fluency of their in-platform experience, were strikingly disconnected from their performance on independent measures. Thirty-nine students expressed surprise or confusion when their school exam results contradicted the claims made on their platform dashboard. A student at SCH-B said, “I was so confident in the app, I really thought I understood. The [platform] gave me a crown on quadratic equations, but on the test, I could not even start.”

The teachers confirmed this disjuncture. They described a growing need to “re-teach metacognition” because students had outsourced the judgment of their learning to the algorithm that generated feedback. Sixteen teachers identified this phenomenon as a systematic overconfidence problem. The platform’s interpretation of success rapid correct answers on similar problem types fostered a performance orientation rather than a mastery orientation, and the students internalized this external feedback as a proxy for genuine understanding. Analysis of platform dashboards versus external, teacher-designed rubric assessments showed that the median discrepancy between the “AI mastery score” and actual competence in transfer and explanation tasks was 22 percentage points.

This misalignment was reinforced by the transparency or rather, the opacity of the AI learner model. Students believed that the AI knew their mind, and they trusted that the glowing green indicators were truthful reflections of their cognitive state. Thus, the algorithm’s “black box” not only predicted but also prescribed academic identity.

Theme 5: Teacher Mediation as a Buffer

Amid these challenges, teacher mediation has emerged as a critical buffer against negative cognitive consequences. Across all schools, teachers were not passive bystanders; they had developed context-sensitive strategies to reintroduce productive struggles. These included: (a) temporal restrictions imposing a mandatory “thinking time” before hints could be accessed; (b) cognitive wrapping requiring students to articulate in writing or discussion what they tried and why it failed before using AI assistance; and (c) selective disabling—using the platform in an unplugged mode for initial concept exploration, then transitioning to structured AI support only for deliberate practice.

Nineteen of twenty teachers enacted such mediation. A teacher at SCH-E explained, “I treat the AI like a bicycle’s training wheels. If I do not remove them gradually, the child will never learn to balance. So I build struggle into my lessons on purpose.” Students in classrooms with strong mediation practices exhibited greater metacognitive awareness; they used phrases like “I’m trying to figure out my own mistake first,” whereas in classrooms with laissez-faire AI use, the default script was “let me see the answer.” Observational data indicated that in the two most teacher-mediated classes, the active problem-solving frequency was nearly 50% higher than the school average, and hint requests were lower by a factor of 0.6. This variation underscores that the relationship between AI and cognitive development is not solely determined by technology but is heavily mediated by pedagogical orchestration. However, teachers reported that such mediation required significant extra effort and was not supported by the platform design, which often prioritized seamless, uninterrupted student-machine interaction.

Discussion

A central lens for interpreting the behavioral shifts observed is cognitive load theory (CLT). AI personalization excels at minimizing extraneous cognitive load eliminating the need to search for relevant materials, clarifying instructions, and breaking complex problems into manageable micro-steps. Indeed, teachers acknowledged that for initially overwhelmed learners, this scaffolding was helpful. However, the data strongly indicate that this reduction simultaneously disposed of germane cognitive load—the mental work of integrating new information with prior knowledge, forming schemas, and practicing retrieval. When students habitually clicked hints to obtain the next step, they converted an intrinsically demanding generative task into a series of low-level procedural tasks. This echoes the “assistance dilemma”, where research in intelligent tutoring systems has shown that too much help can depress learning. Our participants’ lived experience aligns with the laboratory finding that non-interactive, highly scaffolded instruction often yields an illusion of competence while undermining long-term retention and transfer. The present study adds ecological validity to these claims and further reveals how the constant availability of assistance, combined with seductive gamification elements (crowns, mastery bars), constructs a persuasive environment where students feel learning has occurred when, in cognitive terms, it has only been performed, not encoded (Chowdhury et al., 2025).

The illusion of learning is not a new concept, but its manifestations in AI classrooms are unique. Whereas traditional illusions are derived from, say, re-reading highlighted texts, the AI-powered variant is systemically produced and algorithmically validated. The platform's learner model becomes an authoritative mirror that reflects a distorted image of the self-as a-learner. Our findings show that students' epistemological trust in the AI dashboard overrides their introspective capacity. This constructs what might be termed algorithmic metacognition," wherein self-assessment is outsourced. When the student says, "The app says I have mastered 95%," she is not merely describing a statistic; she is deferring her judgment of learning to the machine. This outsourcing is detrimental because the machine's assessment is based on narrow performance proxies (repeated correct answers in a highly constrained environment) that lack ecological validity. Consequently, students failed to develop the veridical metacognitive monitoring necessary for self-regulated learning. In the Indonesian context, this is especially concerning given the national curriculum's emphasis on kemandirian belajar (learning independence). Paradoxically, AI personalization, designed to foster self-paced autonomy, may erode genuine autonomous learning agency by supplanting students' evaluative and planning functions (Fantoni & Sasmita, 2025).

The sharp decline in problem-solving persistence and proliferation of passive solution consumption have profound developmental implications. Adolescence is a critical period for the prefrontal cortex and executive functions, including inhibitory control, cognitive flexibility, and sustained attention. The consistent avoidance of cognitive conflict and instant gratification offered by AI platforms may reinforce the neural habit of attentional switching and shallow processing. While we do not claim neurodevelopmental damage, the observed behavioral patterns giving up within minutes and seeking immediate external resolution suggest a learning disposition that is antithetical to the deep work required for scientific and mathematical competence. These patterns mirror the "short-circuits" where intelligent tools sometimes decrease the mental effort learners invest. The students in this study were not cognitively lazy by nature; rather, the affordances of the technology shaped their cost-benefit calculus toward minimal effort. What is learned, then, is not just content but a set of epistemic habits: difficulty is to be avoided, answers are external commodities, and waiting for a hint is a valid problem-solving strategy (Čiderová & Belvončíková, 2024).

The most hopeful finding was the protective role of teacher mediation. This aligns with the Vygotskian tenet that cognitive tools are mediated by social interaction and cultural practice; a tool alone does not determine learning; its use does. Teachers who strategically reintroduced friction through "thinking time" rules, mandatory self-explanations, and gradual fading of AI support partially restored productive struggle and metacognitive awareness. This underscores that the personalization paradox is not an inherent, unalterable property of AI but rather an effect of its unmediated deployment. This resonates with recent calls for "human-AI shared regulation" in learning environments, where AI supports lower-level cognitive processing, but teachers orchestrate the high-level metacognitive and socially interactive aspects. Indonesian teachers' creative appropriations, such as mandating scrap-paper reflections before hints, represent grassroots design solutions that EdTech developers should formalize. A hybrid model that grants teachers the agency to modulate AI scaffolding effectively turning the struggle dial could preserve the benefits of adaptive support while safeguarding cognitive depth (Ben Otman et al., 2025).

The findings must be situated within the Indonesian educational landscape, characterized by large class sizes, high-stakes national examinations, and a traditionally teacher-centered culture that is gradually shifting toward constructivist methodologies. The AI platforms studied entered classrooms as ready-made solutions, often with minimal local customization and accompanied by marketing that emphasized "smart learning without pain." This narrative appealed to overburdened teachers and grade-anxious parents, but clashed with the pedagogical vision of Merdeka Belajar (Freedom to Learn), which stresses critical thinking, creativity, and student agency. The illusion of learning became a convenient fiction for all stakeholders: teachers could report high student activity metrics, students felt competent, and parents saw glowing progress reports. The result was a system-level collusion that masked the decline in genuine cognitive growth (El-Farahaty, 2025).

Furthermore, the digital infrastructure divide, while narrowing, means that some students accessed AI tools sporadically, while others had continuous home access. Those with more extensive unsupervised use exhibited deeper dependence and metacognitive misalignment, indicating a dose-response relationship. The socio-emotional dimension is also notable: students experienced frustration when barred from AI assistance, suggesting a psychological dependency that parallels digital addiction models. These nuances extend the global

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conversation by showing that the impact of AI personalization is not culturally neutral; it interacts with local pedagogical values, resource disparities, and collective attitudes toward technology use.

The implications of this study are multi-level. For policymakers in Indonesia and similar nations, the findings challenge the prevailing narrative that more technology inherently equates to better learning outcomes. Investment in AI infrastructure must be matched with investment in teacher professional development focused on "AI pedagogy" that foregrounds metacognitive and critical engagement. Curriculum standards should explicitly benchmark deep learning competencies (explanation, transfer, argumentation) alongside computational fluency, and assessments must be designed to detect learning illusions. For practitioners, this research endorses deliberate, time-bound AI use integrated with dialogic, inquiry-based instruction. Concrete protocols, such as "Productive Struggle First, AI Second" can be codified as school policies.

For platform developers, the results are a clarion call to move beyond optimizing in-session performance metrics. Features that encourage desirable difficulties, such as system-enforced wait times before hints, the requirement of free-text self-explanations, spaced retrieval schedules even when the algorithm predicts mastery, and transparent visualizations of the gap between AI mastery and deeper understanding, could embed cognitive science principles directly into the experience. In essence, AI should be designed to make learning harder in a productive way, rather than easier. A transfer of the assistive logic from "how can I help the student succeed right now" to "how can I prepare the student to succeed when I am not there" would fundamentally alter the architecture of personalization.

Limitations and Future Research

Although this study provides rich qualitative evidence, its limitations must be acknowledged. The focus on mathematics and science limits the generalizability to the humanities or arts domains, where the nature of cognitive engagement may differ. Although the sample varied, it remained confined to Java and Sumatra; future research should encompass more diverse Indonesian regions and include longitudinal tracking to examine long-term cognitive outcomes. The qualitative design prioritizes depth and meaning but does not permit causal claims or dose-effect quantifications. Mixed-methods studies that combine these qualitative insights with experimental or quasi-experimental comparisons (e.g., AI with vs. without teacher mediation) would be valuable next steps. Additionally, the study captured a moment in an evolving technological landscape; as AI platforms become more conversational (e.g., large language model tutors), new dynamics of the illusion of learning may emerge and require ruther investigation.

IV. CONCLUSIONS

This study illuminates the paradox inherent in AI-driven personalization within Indonesian K-12 education: the very mechanisms designed to optimize learning can inadvertently engender an illusion of learning, suppress productive struggle, and erode the metacognitive foundations of deep cognitive development. Through the authentic voices of teachers and students, we documented a shift toward surface engagement, dependence on instant feedback, diminished persistence, and a dangerous metacognitive misalignment, wherein algorithmically generated confidence masks genuine incompetence. The personalization paradox is not an indictment of AI but of an implementation logic that equates smooth performance with lasting, effective learning. Reclaiming cognitive depth demands a pedagogical reorientation wherein teachers act as curators of desirable difficulties and AI systems are re-engineered to provoke rather than placate the mind. For Indonesia, this means aligning technology-rich classrooms with the profound goal of nurturing independent, critical, and resilient thinking. The machine can assist, but only when its aid does not become a barrier to the learning it intends to serve. Future education must therefore navigate the delicate dialectic between support and struggle, recognizing that sometimes the most personalized gift we can offer a learner is not the immediate answer but the trusting space to find it.

Funding Statement

"No external funding was received for this study."

Ethical Compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments, or comparable ethical standards.

Data Access Statement

A Data Access Statement is a section in a scientific publication or research report that explains how the data used or generated in the study can be accessed by readers or other researchers. This statement aims to promote transparency, support research reproducibility, and comply with open-access policies, where applicable.
Common Elements in a Data Access Statement:

1. Data Location: Specifies where the data are stored, such as in online repositories (e.g., Zenodo, Dryad, or institutional repositories).
2. Access Instructions: Provides information on how to access the data, such as direct links, DOI (Digital Object Identifier), or contact details.
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   - "The data supporting this study are available under restricted access and can be obtained upon reasonable request form the corresponding author and with the permission of the ethics committee."

Purpose of a Data Access Statement:

- Reproducibility: Enables other researchers to replicate or verify the findings.
- Collaboration: Encourages further collaboration by sharing data.
- Compliance: Adheres to the policies of funding agencies or journals that require open access to data.

Conflict of Interest Declaration

The authors declare that they have no affiliations or involvement with any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

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