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Integrating Diagnostics, Modularity, and Cultural Contexts: A DMC Framework for Adaptive Learning in Indonesian Secondary Schools

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ABSTRACT

Adaptive learning platforms (ALPs) in Indonesia's secondary education are growing, yet often emphasize technical performance while neglecting learner diagnostics and socio-cultural relevance. This study addresses the need for a more holistic framework that integrates diagnostic assessment, modular instruction, and cultural contextualization. Using a *case-informed literature review* approach, the study examined adaptive learning practices in eight diverse institutions—four junior high schools (SMP) and four Islamic junior high schools (MTs)—selected for their innovation and regional representation. Data sources included academic literature, institutional documentation, and digital platform analysis. Findings revealed two key trends: SMPs tend to excel in implementing AI-driven diagnostics and modular pathways, while MTs emphasize cultural and religious integration in content design. However, neither school type fully integrates diagnostics with contextualized learning. Based on these insights, the study proposes the DMC (Diagnostic–Modular–Culture) framework, comprising: (1) individualized diagnostics via pre-assessment tools, (2) differentiated modular learning tracks (remedial, standard, enrichment), and (3) integration of socio-cultural content into instructional design. The DMC model offers a scalable, inclusive framework for adaptive learning tailored to Indonesia's educational diversity. Its implementation supports personalized instruction while reinforcing learner identity and cultural engagement, aligning with the principles of *Kurikulum Merdeka*.

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1. INTRODUCTION

The rapid development of digital technologies has powerfully transformed educational landscapes worldwide, including at the Junior High School (SMP) and Madrasah Tsanawiyah (MTs) levels in Indonesia. Among the emerging innovations, the Adaptive Learning Platform (ALP) has acquired

significant attention. This digital learning system, with all its dynamics, adjusts instructional content, methods, and pacing based on the distinct characteristics of individual learners (Fadillah et al., 2024; Vicent & Segarra, 2010). In the Indonesian context, the adoption of adaptive platforms is gaining momentum, particularly in alignment with *Kurikulum Merdeka* (Independent Curriculum), which emphasizes differentiated instruction and the repositioning of teachers as facilitators of personalized and meaningful learning experiences (Mardiati et al., 2024; Sa'id et al., 2024).

Despite these promising developments, most adaptive learning initiatives in Indonesia remain predominantly rooted in performance and technology-driven approaches, such as automated diagnostic tools based on quiz scores or student interaction logs. These approaches, while technologically sophisticated, often overlook the socio-cultural milieus in which learners are rooted (Tan et al., 2025). In fact, Indonesian students are situated within diverse linguistic, religious, and cultural communities that profoundly influence their educational experiences (Cahyono, 2023). This underscores the critical need to drive in contextual and cultural dimensions into the design of digital learning platforms.

The current studies on adaptive learning that integrates technology and culture at the secondary school level tend to diverge into two predominant trajectories, namely the first focused on performance-based digital adaptation, and the second on incorporating local cultural values into learning design. However, these two elements have largely evolved in isolation. For instance, some previous studies report the use of artificial intelligence is employed to group students by academic achievement in real-time (Putri & Maharani, 2023). Meanwhile, others highlight efforts to integrate local narratives and religious values into digital learning environments (Nisa & Aimah, 2024). However, few frameworks attempt to synthesize these approaches in a coherent and scalable way. This disconnect signals a critical gap in the development of ALPs that can simultaneously accommodate diagnostic data and socio-cultural content.

Moreover, the modular structure of learning pathways remains underdeveloped. While some institutions have implemented content variations, such as remedial or enrichment modules, these often lack a solid foundation in learner diagnostics. In other cases, local cultural content is incorporated without mechanisms to monitor learning outcomes or personalize instruction accordingly (Humammi et al., 2024). Globally, the development of adaptive platforms is often driven by performance metrics and remains insufficiently adapted to cultural contexts, limiting their applicability in multicultural societies such as Indonesia. (Tan et al., 2025).

As a result, there is a pressing need for a unified and systematic conceptual framework that integrates diagnostic assessment, content modularization, and socio-cultural contextualization within a single adaptive learning platform. Therefore, this study seeks to address the following three research questions: 1) What are the defining characteristics of adaptive learning innovations currently implemented in SMP and MTs in Indonesia? 2) To what extent have these adaptive systems integrated individual diagnostic assessments with socio-cultural contextualization? and 3) How can conceptual models of adaptive learning be structured to simultaneously support personalized learning and local cultural relevance?

The objectives of this study are: 1) To identify innovative practices in digital adaptive learning in SMPs and MTs across Indonesia; 2) To analyze the limitations and potentials of integrating diagnostic and cultural-contextual approaches; and 3) To develop a conceptual model for adaptive instructional design that is responsive to the specific cultural and pedagogical contexts of secondary education in Indonesia.

The results of this study are expected to offer both theoretical and practical contributions. Theoretically, this study enriches the academic discourse on adaptive learning by foregrounding culturally responsive pedagogical design. Practically, its findings may serve as a reference for digital platform developers, educators, and policymakers seeking to create inclusive, community-based adaptive learning ecosystems. Meanwhile, as for policy, the results of this study can be considered as a

basis and material for the development of national regulations on curriculum design, teacher training, as well as for the integration of local content in digital education platforms.

In addition, this study also offers an empirical and theoretical proposition through the development of what it is called the *Diagnostic-Modular-Culture (DMC)* adaptive learning model. This integrative framework encompasses three key components, namely individualized diagnostic assessment, modularized instructional pathways, and the incorporation of socio-cultural values within digital learning environments. Theoretically, the DMC model extends current algorithm-driven adaptive learning paradigms by incorporating affective and cultural dimensions that contribute to a more meaningful and holistic personalization of learning. Empirically, this study synthesizes data from eight educational institutions, which are four SMPs and four MTs, that exhibit varied adaptive innovations, including the use of AI, value-based instructional modules, and perception-based approaches. The proposed adaptive learning model of DMC offers a scalable and contextually relevant blueprint for schools seeking to design digital learning platforms that are inclusive, adaptive, and culturally responsive to the diverse educational realities of Indonesian learners.

2. METHODS

This study employs a qualitative, case-informed literature review approach, which combines conceptual synthesis with empirical illustrations drawn from selected case studies (Snyder, 2019). It is involving four Junior High Schools (SMP) and four Religious Junior High Schools (Madrasah Tsanawiyah/MTs) in Indonesia. The case-informed literature review, as conceptualized by Snyder, seeks to enrich theoretical discussions by anchoring them in documented field practices (Snyder, 2019). This method integrates theoretical frameworks with context-specific empirical evidence that make it differ from traditional systematic reviews that often emphasize abstraction and generalization. Thus, by conducting a case-informed literature review approach, this study enables theoretical generalization with contextual grounding, namely the development of theoretical framework that align with the field dynamic so that it is practically relevant and, at the same time, academically valid (Boell & Cecez-Kecmanovic, 2015; Snyder, 2019)

The data for this study were drawn from both primary and secondary sources, including peer-reviewed journal articles (national and international), conference proceedings, scholarly books, institutional reports, and documented case studies. Empirical illustrations are derived from eight educational institutions, they are SMP Negeri 1 Beringin (North Sumatra), SMP Negeri 1 Gading Rejo (Lampung), SMP Muhammadiyah Al-Kautsar (Yogyakarta), SMP Wahid Hasyim (Malang), MTsN 2 Asahan (North Sumatra), MTsN 1 Makassar (South Sulawesi), MTs Khozinatul Ulum (Blora), and MTs Mukhtar Syafa'at (Banyuwangi). The data were collected through publicly available documentation, including research publications, institutional websites, government databases, and educator testimonies as published in journal articles.

The selection of these eight institutions was guided by the principle of maximum variation sampling (Patton, 2015), ensuring a representative diversity across institutional types, geographical locations, socio-cultural settings, and technological practices. The diversity covers four key dimensions, namely: 1) Institutional type, covering both public and private, secular and religious institutions; 2) Geographical distribution, involving schools from Java, Sumatra, and Sulawesi to reflect regional variation; 3) Cultural context, including urban-rural distinctions, pesantren (Islamic boarding school) environments, and religious communities; and 4) Adaptive learning innovations, ranging from AI-based diagnostics to culturally grounded content strategies.

This methodological orientation enables the uncovering and understanding of the implementation of adaptive learning at various educational and socio-cultural settings in Indonesia. Furthermore, it supports the construction of a conceptual framework integrating three crucial dimensions of adaptive learning, they are student diagnostics, modular content pathways, and contextual-cultural inserting. The rationale for selecting each school is elaborated as shown in Table 1:

Table 1. The Rationale for Selecting Each School

No.	School and Location	Rationale
1.	SMP Negeri 1 Beringin (Deli Serdang, North Sumatra)	represents a public institution recognized for its advanced use of artificial intelligence (AI) in diagnostic learning tools, serving as the basis for the "individualized diagnostics" component
2.	SMP Negeri 1 Gading Rejo (Pringsewu, Lampung)	exemplifies a school that employs the *Merdeka Mengajar* platform for differentiated learning, aligning with national educational reform efforts
3.	SMP Muhammadiyah Al-Kautsar (Yogyakarta)	a private religious school, integrates Islamic values within its proprietary learning management system (LMS), contributing to the cultural contextualization of digital learning
4.	SMP Wahid Hasyim (Malang, East Java)	adopts a humanistic, perception-based approach, emphasizing student engagement and relational learning
5.	MTsN 2 Asahan (North Sumatra)	This state MTs is distinguished by its ICT-based learning management system, offering comparative insights into adaptive capabilities in religious schooling
6.	MTsN 1 Makassar (South Sulawesi)	This state MTs is notable for its responsive online learning system that reflects the socio-economic and cultural context of the local community
7.	MTs Khozinatul Ulum (Blora, Central Java)	a private MTs, represents structured academic data integration into learning differentiation strategies via its internal school database
8.	MTs Mukhtar Syafa'at (Banyuwangi, East Java)	offers exemplary practices in embedding cultural narratives and religious values into its digital learning modules, reinforcing the contextual-cultural node of the conceptual model

For the analysis process and interpreting the data, this study uses three foundational theories, namely. 1) Adaptive Learning Theory; This theory is rooted in constructivist pedagogy and differentiated instruction. This theory advocates tailoring educational strategies to the specific needs, pace, and profiles of learners (Rosa et al., 2024; Tomlinson, 2014). In the digital realm, adaptive learning is operationalized through tools such as LMSs, AI-based engines, and recommendation systems that facilitate personalized learning pathways (Tan et al., 2025; Turnbull et al., 2020); 2) Instructional Diagnostic Theory; This theoretical component highlights the need for initial learner readiness assessments to inform targeted interventions. Techniques include pre-assessments, competency gap analyses, and learning histories, all of which contribute to a non-generic, data-informed instructional design (Winarno, 2012); 3) Contextual-Cultural Theory in Education; Drawing from culturally responsive pedagogy and place-based education, this theory suggests that effective learning must be attached to the local values and cultural identities of students. In Indonesia's multicultural context, integrating linguistic, religious, and socio-cultural narratives into instructional content can significantly enhance students' emotional and cognitive engagement with the material (Aeschlimann et al., 2024; Gay, 2018; Slimi et al., 2025). To ensure analytical reliability, the study employed document triangulation by comparing case documentation with official curriculum and policy guidelines (e.g., *Kurikulum Merdeka*), peer-reviewed academic studies, and institutional self-reports and implementation records.

3. FINDINGS AND DISCUSSION

3.1. Innovation in Adaptive Learning Platforms in Junior High School (SMP)

The adaptive learning innovation at SMP Negeri 1 Beringin Deli Serdang, North Sumatra, centers on the implementation of an AI-based digital learning platform with real-time assessment capabilities. This public secondary school has adopted artificial intelligence (AI) to dynamically adjust instructional materials and assessment types according to students' performance in real time. One of the platform's standout features is its ability to automatically categorize students based on diagnostic results, enabling

the development of differentiated learning trajectories—ranging from remedial and standard to enrichment pathways. This approach not only enhances the personalization of digital instruction but also significantly improves pedagogical efficiency by allowing teachers to tailor instruction with greater precision (Putri & Maharani, 2023).

At SMP Negeri 1 Gading Rejo, Pringsewu, Lampung, the principal innovation lies in the integration of the Independent Teaching Platform (*Platform Merdeka Mengajar*) with differentiated content design. This platform is particularly utilized in the Islamic Religious Education (PAI) curriculum to address varying levels of student readiness. By leveraging the platform's adaptive features—such as the question bank and flexible content tools—teachers can adjust the complexity and depth of instructional materials, offering customized learning routes for both students requiring remedial support and those needing enrichment. This approach reflects a policy-aligned yet context-sensitive implementation of adaptive learning (Humammi et al., 2024).

SMP Muhammadiyah Al-Kautsar in Yogyakarta exemplifies innovation through the development of an internal Learning Management System (LMS) and the integration of Islamic values into the learning experience. The school has designed its LMS to support adaptive learning principles, allowing teachers to construct digital learning modules based on formative assessments and student feedback. Uniquely, the system integrates religious values and Muhammadiyah's educational philosophy into the pedagogical narrative. This results in an adaptive platform that is responsive not only in technical dimensions but also in its alignment with institutional ethos. The LMS also supports tiered learning strategies, where students demonstrating slower progress receive scaffolded reinforcement modules, while advanced learners engage in independent projects or inquiry-based tasks (Syahid & Pembangunan, 2024).

Distinct from schools employing high-tech digital tools, SMP Wahid Hasyim Malang has adopted a student-perception-based model of instructional adaptation. Rather than relying solely on AI or automated analytics, the school conducts student surveys to assess learning preferences, emotional engagement, and perceived challenges. The data obtained are then used to adjust teaching methods, media, and instructional content, creating a highly responsive learning environment attuned to the subjective experiences of students. This innovation illustrates a human-centered adaptive learning model, grounded in affective understanding and participatory evaluation, demonstrating that meaningful adaptation can be achieved through relational strategies (At Thaariq et al., 2024).

Reflecting on these four institutional cases, it becomes evident that adaptive learning at the secondary level in Indonesia is manifesting through diverse approaches, shaped by institutional vision, technological capacity, and pedagogical philosophy. From AI-powered diagnostics to national platform utilization, and from internal LMS development to perception-based instructional design, these practices indicate a shift from purely technical personalization towards more integrative, contextually grounded models of adaptive learning. This evolution suggests a growing recognition that true adaptability in education must balance technological efficiency with cultural, emotional, and humanistic dimensions.

3.2. Innovation in Adaptive Learning Platforms in Madrasah Tsanawiyah (MTs)

At MTsN 2 Asahan, the key innovation lies in the transformation of ICT-based digital learning management systems. This state madrasah has demonstrated notable progress in adopting an adaptive learning model through the development of the *Sistem Pembelajaran Elektronik* (SPeL), a digital platform designed to accommodate individualized student learning needs. The system enables teachers to monitor student progress online and differentiate instructional materials based on students' cognitive profiles. By embedding adaptive features within a digital infrastructure, MTsN 2 Asahan fosters both instructional flexibility and data-driven personalization, laying a measurable and integrated foundation for adaptive learning within the institutional ecosystem (Butar et al., 2024).

The innovation at MTsN 1 Makassar is distinguished by the creation of a socio-culturally responsive distance learning platform. Developed during the COVID-19 pandemic, this initiative

reflects a commitment not only to the continuity of education but also to its contextual relevance. The platform incorporates interactive learning strategies that align with the local cultural background and address the emotional and logistical challenges faced by students. Teachers utilize two-way communication via online groups, enabling real-time engagement and feedback, particularly for learners with limited access to digital resources or home learning support. This model highlights the role of cultural sensitivity and relational pedagogy in adaptive education (Idris & Rais, 2022).

At MTs Khozinatul Ulum, Blora, Central Java, the focus of adaptive innovation is the integration of academic information systems (SIA) with digital instructional platforms. This integration provides teachers with real-time data on student learning progress, allowing for timely adjustments to instructional materials. The platform facilitates individualized content adaptation, enabling tailored interventions for students demonstrating either accelerated or delayed progress. While the institution still faces challenges in teacher professional development and contextual content creation, it has laid essential groundwork by leveraging digital tools for adaptive instruction through data-informed decision-making (Jaya, 2024).

MTs Mukhtar Syafa'at, Blokagung, Banyuwangi, East Java, stands out for its development of a contextually grounded digital module aimed at fostering social resilience and digital literacy. This initiative integrates local socio-cultural narratives, including the stories of respected community figures, social themes, and media literacy content, into the school's online learning materials. The objective is to enhance students' critical thinking, digital independence, and emotional connection to learning, while anchoring the educational experience in pesantren values and community life. This approach demonstrates how adaptive learning can function not only as a pedagogical strategy but also as a vehicle for local identity formation and value internalization (Nisa & Aimah, 2024).

Across these four madrasahs, it becomes evident that adaptive learning innovations vary in emphasis, reflecting divergent institutional priorities, technological capacities, and socio-cultural orientations. MTsN 2 Asahan and MTs Khozinatul Ulum emphasize technological infrastructure and data-driven differentiation, whereas MTsN 1 Makassar and MTs Mukhtar Syafa'at adopt a humanistic and context-sensitive approach, addressing cultural, emotional, and community-based dimensions of education. Despite these differences, all four institutions converge toward a shared direction: the pursuit of instructional differentiation, personalized learning pathways, and the contextualization of content in alignment with the educational and cultural realities of Islamic schooling in Indonesia.

3.3. Advantages and Limitations in Adaptive Learning Platform Innovation in SMP and MTs

This section addresses two important issues identified in the study, namely the limitations of adaptive learning platforms that rely predominantly on individual diagnostic data, and the lack of contextual-cultural integration in adaptive learning platform (ALP) designs. At SMP Negeri 1 Beringin, the implementation of an AI-based adaptive platform marks a significant step forward in addressing the absence of pre-assessment systems in traditional educational models. The technology enables the real-time grouping of students based on diagnostic performance, allowing teachers to tailor instructional pathways, remedial, standard, or enrichment, according to individual needs (Putri & Maharani, 2023). While effective in enhancing cognitive personalization, this innovation does not incorporate local culture, regional language, or community narratives. Consequently, it remains detached from students' affective and cultural identities (Slimi et al., 2025; Tan et al., 2025).

The use of the Independent Teaching Platform at SMP Negeri 1 Gading Rejo allows for manual formative assessments and basic diagnostic surveys that inform differentiated content development. Though beneficial, the system lacks technological automation and longitudinal analytics to support deep personalization (Humammi et al., 2024). Moreover, the platform's orientation remains aligned with the national curriculum, with little evidence of localized content or religious-cultural contextualization, despite Pringsewu's semi-rural setting, which presents opportunities for integrating local wisdom (Mardiati et al., 2024).

At SMP Muhammadiyah Al-Kautsar, an internally developed LMS supports the structuring of learning paths based on formative assessment data. The system provides remedial modules for underperforming students and independent research tasks for advanced learners. Although diagnostic assessments are still conducted manually, this LMS stands out for its integration of Muhammadiyah's religious values and Yogyakarta's cultural narratives into its content and learning strategies (Syahid & Pembangunan, 2024). This addresses critiques by Slimi et al. (2025) and Aeschlimann et al. (2024) regarding the lack of student identity representation in digital learning environments (Aeschlimann et al., 2024; Slimi et al., 2025).

SMP Wahid Hasyim in Malang presents an uncommon but valuable innovation through the development of affective diagnostics based on student perception surveys. These diagnostics allow teachers to adjust content, methods, and media in response to students' preferences and emotional states (At Thaariq et al., 2024). While this is not a traditional academic diagnosis, it aligns with humanistic learning principles. However, the absence of localized content from Malang's cultural or pesantren context limits its potential for deeper contextual adaptation (Alqudah & Khasawneh, 2024).

At MTsN 2 Asahan, the introduction of the SPeL digital learning management system enables differentiated instruction through continuous online monitoring. Although the system is responsive to learning outcomes, it lacks predictive or initial diagnostic capabilities, such as student learning profiles or style assessments (Butar et al., 2024). Additionally, it does not incorporate regional cultural content or community values, making the learning experience universal rather than rooted in local identity (Black & Wiliam, 1998; Slimi et al., 2025; Yuwanita et al., 2020).

At MTsN 1 Makassar, a distance learning platform developed during the COVID-19 pandemic enabled socio-emotional and accessibility-responsive instruction. Although not based on algorithmic diagnostics, its relational and observation-based responsiveness—including adaptation to students' emotional needs and cultural context—demonstrates a meaningful form of social-affective adaptation. The incorporation of local languages and narratives from Makassar's urban-rural community makes this platform a notable example of contextual-cultural integration (Idris & Rais, 2022; Slimi et al., 2025).

MTs Khozinatul Ulum in Blora utilizes an integrated academic information system that provides real-time performance data for content adjustments. However, this system remains reactive rather than predictive, relying on formative rather than diagnostic assessments. Moreover, there is no indication that the digital content reflects Blora's cultural context, with the platform still based on national standard content. This disconnect potentially reduces the relevance and authenticity of the learning experience for students (Alqudah & Khasawneh, 2024; Jaya, 2024).

At MTs Mukhtar Syafa'at, innovation is centered on developing contextual digital modules that incorporate local narratives, socio-political issues, and pesantren values. Although not tailored to individual learning diagnostics, the modules are culturally responsive and emotionally resonant. This approach provides a strong cultural anchor for the learning experience, even if it lacks algorithmic personalization (Judijanto et al., 2024; Nisa & Aimah, 2024; Slimi et al., 2025).

Discussion

Diagnostic-Modular-Culture (DMC) Based Adaptive Learning Platform

The evolution of educational technology needs instructional designs that are both cognitively adaptive and rooted in individual learner diagnostics and culturally responsive frameworks. Such a model is particularly relevant in Indonesia, where socio-cultural diversity and student heterogeneity, both in learning abilities and cultural backgrounds, are prominent across both SMP and MTs. A comparative analysis of innovative practices at four SMPs and four MTs reveals complementary institutional strengths. While SMPs typically excel in technological integration, particularly with AI-based adaptive systems and real-time performance diagnostics (Putri & Maharani, 2023), MTs demonstrate strong engagement with local values, religious identity, and cultural narratives embedded in instructional design (Idris & Rais, 2022; Nisa & Aimah, 2024). However, both face notable limitations:

SMPs often overlook contextual and cultural dimensions, whereas MTs typically underutilize systematic diagnostic data to personalize learning trajectories.

Table 2. The Comparison of Adaptive Learning Platform Innovation in SMP and MTs

No.	Aspect	Junior High Schools (SMP)	Madrasah Tsanawiyah (MTs)
1.	Innovation Focus	Emphasis on digital technologies (AI, LMS, national platforms, student perceptions)	Combination of ICT systems, academic data platforms, and contextual-cultural values
2.	Diagnostic Approach	Primarily formative and AI-based; some affective diagnostics via student surveys	Mostly formative and teacher-observation-based; stronger emphasis on social-affective adaptation
3.	Availability of Modular Paths	Remedial, regular, and enrichment modules exist, though not fully automated	Differentiated content available; lacks automation or AI-based trajectory generation
4.	Cultural Context Integration	Generally weak, except in value-based institutions (e.g., Muhammadiyah)	Stronger presence, especially in community-based MTs (e.g., MTs Mukhtar Syafa'at)
5.	Religious and Value Integration	Limited to certain schools; not mainstreamed	Inherently present in most MTs; often central to content design and delivery
6.	Platform Personalization	Technology-centric with advanced diagnostics; lacks local narrative embedding	Teacher-student relational approach; socially adaptive but not yet algorithmic
7.	Key Challenges	Limited cultural integration; low teacher readiness for AI and Merdeka platforms	Limited digital training; scarce local content that aligns with student realities

Table 2 illustrates that SMP and MTs are progressing along different innovation trajectories in adaptive learning. SMPs tend to excel in technological sophistication and cognitive personalization, often utilizing AI, LMS platforms, and real-time data analytics to construct individualized learning experiences (Humammi et al., 2024; Putri & Maharani, 2023). However, their integration of local cultural narratives and community values remains limited, especially in public schools aligned rigidly with national curricula (Slimi et al., 2025). Meanwhile, MTs institutions emphasize cultural and religious contextualization, as seen in platforms developed by MTs Mukhtar Syafa'at and MTsN 1 Makassar (Idris & Rais, 2022; Nisa & Aimah, 2024). These platforms effectively represent students' social identities, although they often lack advanced digital diagnostics or AI-based adaptability.

Based on the data, SMP must work towards enriching digital platforms with local culture and identity-based narratives, ensuring that personalization does not compromise cultural relevance. At the same time, MTs need to invest in early diagnostics and data-driven personalization to support differentiated learning pathways systematically (Strielkowski et al., 2025; Tan et al., 2025). If conceptually integrated, the complementary strengths of these two education models could yield a more holistic and inclusive adaptive learning framework, one grounded in diagnostic precision and cultural narrative alignment.

To address disparities between technological advancement and contextual relevance in adaptive education, this study proposes an integrative framework termed the Diagnostic–Modular–Culture (DMC) model. This model synthesizes technological precision with cultural responsiveness into a cohesive adaptive learning design. It is structured around three interdependent dimensions: individual diagnostics, modular adaptive pathways, and socio-cultural contextualization. By integrating these components, the DMC model seeks to ensure that personalization is not limited to algorithmic adjustment but also reflects learners' identities, values, and lived realities.

Adaptive learning begins with systematic early-stage diagnostics that map students' academic readiness and learning profiles. Foundational research emphasizes that formative assessment plays a crucial role in identifying learner needs and guiding instructional adjustment (Black & Wiliam, 1998). Contemporary adaptive systems expand this diagnostic scope to include learning styles, pace, media preferences, and modality alignment (Cahyono, 2023; Prakash et al., 2024). Core diagnostic elements therefore encompass visual, auditory, and kinesthetic tendencies; baseline literacy and numeracy competencies; preferences for instructional media such as video, audio, text, or simulations; and inclinations toward synchronous or asynchronous learning modes. Empirical observations indicate partial implementation of such diagnostics in Indonesian secondary schools. For example, segmentation supported by real-time AI analytics has been introduced at SMP Negeri 1 Beringin, although comprehensive learning-style mapping remains underdeveloped (Putri & Maharani, 2023). At MTs Khozinatul Ulum, diagnostic data tends to be used post-instructionally, thereby limiting its proactive personalization potential (Jaya, 2024). Strengthening adaptive precision therefore requires embedding structured digital pre-assessment tools—such as Google Forms surveys or Moodle analytics plugins—into early learning stages to enable data-driven differentiation (Tan et al., 2025).

Following diagnosis, learners are directed into differentiated modular pathways aligned with their identified profiles. Adaptive modularization prevents homogenized "one-size-fits-all" instruction and promotes equitable engagement by tailoring content complexity and instructional strategies (Black & Wiliam, 1998; Brusilovsky, 2001). The DMC framework conceptualizes three progressive modules: remedial modules designed for students below minimum competency standards (KKM), enriched with visual scaffolding, instructional videos, and interactive drills; standard modules aligned with baseline curricular expectations; and enrichment modules targeting high-achieving learners or those with specialized interests and competencies. Evidence from SMP Gading Rejo and SMP Muhammadiyah Al-Kautsar indicates that modular differentiation is gradually emerging through teacher observation and performance-based grouping (Humammi et al., 2024; Syahid & Pembangunan, 2024). In science instruction, for instance, students requiring remediation engage with animated respiratory-system tutorials, whereas advanced learners undertake inquiry-based projects exploring local air pollution. Such differentiated pathways illustrate how modular structuring can simultaneously support mastery and intellectual extension.

The third dimension of the DMC model underscores the integration of socio-cultural context into adaptive design. Effective personalization must extend beyond cognitive optimization to foster identity affirmation, emotional resonance, and cultural belonging. Instructional materials should therefore reflect students' social environments, religious values, regional narratives, and linguistic traditions. At MTs Mukhtar Syafa'at, locally grounded stories of community leaders and pesantren-based wisdom are incorporated into learning modules, strengthening critical reflection alongside social resilience (Nisa & Aimah, 2024). Similarly, SMP Wahid Hasyim employs student perception surveys to adapt pedagogical strategies to psychosocial realities and community contexts, demonstrating intentional contextual alignment even in the absence of automated systems (At Thaariq et al., 2024). These examples illustrate that adaptive learning attains deeper transformative potential when technological differentiation is harmonized with cultural authenticity.

In synthesis, the DMC framework advances adaptive education by uniting diagnostic precision, modular flexibility, and cultural contextualization into an integrated model. Such an approach moves personalization beyond technical customization toward holistic responsiveness, ensuring that adaptive systems cultivate not only academic achievement but also meaningful engagement rooted in learners' sociocultural identities.

Table 3. Framework for the Diagnostic–Modular–Culture (DMC) Adaptive Learning Model

No.	Component	Description	Current Implementation (SMP / MTs)
1.	Individual Diagnosis	Pre-assessment to identify learning styles, readiness, media preferences, pace	Present in AI-based SMPs (e.g., SMP Beringin); underdeveloped in most MTs
2.	Modular Adaptation	Differentiated learning pathways (Remedial, Standard, Enrichment) based on data	Initiated at Gading Rejo SMP and MTs Khozinatul Ulum
3.	Cultural Contextualization	Integration of community narratives, regional language, religious values	Strong at MTs Mukhtar Syafa'at and MTsN 1 Makassar

Based on the synthesis above, the DMC model offers an interactive framework in which each node informs and enhances the others. Individual diagnostics serve as the foundation for targeted differentiation. Modular learning pathways respond to diagnostic outputs, enabling tailored content and activities. Meanwhile, the socio-cultural integration dimension embeds learning in students' lived realities, reinforcing identity and emotional connection to content.

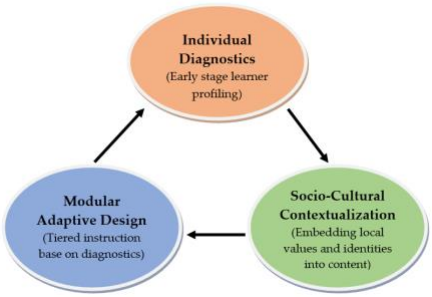

Figure 1. Diagram of Diagnostic–Modular–Culture (DMC) intersection

The diagram illustrates bidirectional interactions among all three core components, indicating that diagnostic assessment is not a linear process but one that evolves in response to feedback from both modular pathways and cultural context. Modular design, in turn, must respond not only to cognitive data but also to localized cultural values. Likewise, cultural contextualization should be informed by learner profiles and serve to enrich the overall instructional design. Thus, the DMC model is not merely a technical or cultural intervention, but a holistic adaptive learning system that responds meaningfully to the diverse educational realities of Indonesian students.

This model is a bridge between technology and cultural relevance, and is a strategic link between algorithmic efficiency and humanistic pedagogy. The development and implementation of this DMC-based adaptive learning platform in Indonesian schools and madrasahs requires collaborative engagement among educators, instructional designers, and the developers of educational technology. Through this model of MDC, adaptive learning transitions from being merely data responsive to becoming deeply meaningful, culturally and locally rooted, and pedagogically inclusive. Thus, the DMC framework lays the foundation for a sustainable and contextually enriched adaptive learning system, one that is as responsive to data as it is respectful of diversity.

Challenges in Integration

Despite growing interest in adaptive learning platforms, current implementations at the secondary school in Indonesia reveal persistent challenges in integrating diagnostic precision, instructional modularity, and cultural contextualization into a coherent system. This fragmentation undermines the transformative potential of adaptive learning and limits its responsiveness to Indonesia's diverse educational realities.

One major challenge lies in the disconnection between performance diagnostics and socio-cultural adaptation. Schools equipped with AI-based platforms or LMS systems often succeed in automating formative assessments and tracking student progress. However, these systems typically operate on generic performance metrics, such as quiz scores or completion rates, without capturing learner identities, community values, or affective experiences. As a result, students are grouped and instructed based on academic output alone, which can exclude critical elements of motivation, cultural identity, and social belonging (Gay, 2018; Slimi et al., 2025).

Conversely, schools that emphasize cultural narratives, particularly many MTs, rarely link this content to student readiness data. Their approach tends to be rich in context but poor in differentiation, resulting in learning that is emotionally resonant but not tailored to individual competency gaps. This disconnect represents a structural weakness that prevents the formation of truly adaptive and inclusive learning environments.

The second challenge is the inconsistent application of modular instructional pathways across institutions. While some schools attempt to differentiate content through remedial, standard, and enrichment tracks, most do so informally or manually—often relying on teacher discretion rather than structured diagnostics. The absence of integrated decision-making tools within digital platforms limits the scalability and sustainability of modular design. Moreover, the lack of alignment between diagnostics and content delivery pathways contributes to inefficiencies and mis-targeted instruction.(Black & Wiliam, 1998; Tomlinson, 2014)

A third barrier is the fragmentation of digital infrastructure across regions and school types. While certain SMPs have access to AI-driven platforms and robust internet connectivity, many MTs, particularly those in rural areas, lack basic infrastructure or rely on minimal ICT support. This creates a two-tiered ecosystem, where the technological affordances needed to implement diagnostics and modularity are unevenly distributed. Furthermore, existing national platforms such as *Merdeka Mengajar* have yet to integrate localized diagnostics or dynamic content pathways that respond to learner diversity. As such, educators are often forced to rely on external platforms, improvised tools, or analog adjustments, limiting coherence in instructional delivery and widening the digital implementation gap.(Tan et al., 2025)

There is also a lack of alignment between adaptive learning frameworks and teacher training policies. Most pre-service and in-service programs focus on subject matter content and standardized assessment rather than diagnostic pedagogy or culturally responsive instruction. Consequently, even when platforms offer adaptive features, teachers may lack the pedagogical literacy to interpret diagnostic data or design culturally embedded content.(Aeschlimann et al., 2024)

The integration of diagnostics, modular learning, and cultural contextualization is hindered by four things, they are: 1) technological silos between LMS features and cultural design; 2) limited teacher capacity to interpret diagnostics or construct modular content; 3) infrastructure disparities that prevent platform consistency; and 4) Policy gaps that fail to support adaptive pedagogy systematically. Overcoming these challenges requires a coordinated approach involving platform developers, teacher educators, policymakers, and local communities, anchored in models like DMC that emphasize coherence, contextualization, and scalability.

Institutional Contrasts and Complementary Strengths

A core insight from this study lies in the contrasting ways that SMPs and MTs implement components of adaptive learning. While both school types are situated within the same educational ecosystem and face overlapping challenges, such as diverse learner profiles, limited infrastructure, and evolving curricular mandates, their institutional responses diverge markedly, reflecting different strengths, priorities, and traditions.

SMPs, particularly those linked to national and regional digital innovation programs, excel in deploying data-driven diagnostics. With AI-supported Learning Management Systems (LMS), perception surveys, and analytics dashboards, these schools effectively track student progress, group

learners by ability, and adjust instruction accordingly. This technical sophistication enables real-time personalization and scalable adaptation (Brusilovsky, 2001; Tomlinson, 2014).

In contrast, MTs rely more on affective and relational knowledge, grounded in close teacher-student interaction, religious practice, and communal life. This context fosters deep awareness of students' emotional and spiritual development, though such insights are rarely translated into formal diagnostic systems (Gay, 2018). While pedagogically rich, this embedded form of diagnosis remains underutilized in technical applications.

SMPs often adopt modular learning pathways—such as remedial, standard, and enrichment tracks, based on performance data. However, these modules are frequently detached from cultural and affective dimensions, resulting in content that is competency-aligned but contextually thin. MTs, conversely, integrate academic instruction with local stories, religious values, and community histories. Though lacking formal modularity, their approach offers continuity and narrative coherence, particularly valuable for adolescents navigating identity and moral development (Bruner, 1996).

These contrasts reveal complementary strengths, namely: SMPs provide technological structure and scalability, while MTs offer holistic, culturally resonant content. A synthesized model, such as the Diagnostic–Modular–Culture (DMC) framework, could leverage both, aligning data-driven personalization with socio-cultural grounding. Cultural integration further differentiates the two. MTs, especially in rural or pesantren settings, embed local language, values, and traditions into their pedagogy, enhancing emotional engagement and learner representation (Slimi et al., 2025). In contrast, SMPs often use standardized digital content, such as that provided by *Platform Merdeka Mengajar*, which, though technically sound, lacks sensitivity to local identity and context.

These differences should not be viewed as shortcomings but as complementary capacities. By uniting SMPs' modular precision with MTs' contextual depth, the DMC framework enables adaptive learning that is both personalized and culturally embedded. This integration supports a broader shift from viewing adaptive learning as a purely technical solution to embracing it as a human-centered, equity-driven paradigm responsive to Indonesia's educational diversity.

Teacher Agency and Professional Capacity

At the heart of any adaptive learning ecosystem lies a critical human factor, that is, the teacher. While technological infrastructure and platform design provide scaffolding for adaptive instruction, it is ultimately the agency, skill, and contextual awareness of educators that determine the success of implementation. Across both SMP and MTs contexts, this study finds that teacher capacity remains a double-edged determinant, both a driving force and a limiting constraint in the realization of the DMC model.

Although adaptive learning frameworks often rely on algorithmic differentiation and real-time data, their practical enactment, particularly in decentralized systems like Indonesia, rests heavily on teacher initiative. In several MTs, for instance, cultural integration is achieved not through preset platform functions, but through teacher-authored content such as moral narratives and local themes, rooted in lived community contexts.

This highlights the need to reconceptualize teachers not merely as implementers but as co-designers of adaptive learning (Fullan & Langworthy, 2014). Within the DMC framework, educators are expected to develop diagnostic tools (e.g., surveys, pre-tests), differentiate instructional materials, and embed cultural narratives into content delivery. However, many educators lack training in these key areas. Diagnostic pedagogy remains underdeveloped; while summative assessment is widely practiced, the use of formative or predictive diagnostics to map readiness and progression is limited. Similarly, though cultural awareness is present, its integration into structured instructional design is rarely supported by professional development initiatives.

This results in uneven implementation, where innovation is often driven by a few motivated individuals, while others rely on generic, centrally produced content with minimal localization. Addressing this gap requires a systemic approach to professional learning. This includes: (1) sustained

training in data use, modular sequencing, and contextual pedagogy; (2) mentoring models that encourage peer learning within schools and teacher networks; (3) collaborative spaces for co-creating culturally responsive modules; and (4) recognition systems that incentivize teacher-led innovation. Institutions such as *Pusdatin*, *Pusat Kurikulum dan Perbukuan*, and professional teaching associations have a vital role in facilitating workshops, curating resources, and disseminating best practices at scale.

To foster teacher agency, policy alignment and institutional flexibility are essential. Although *Kurikulum Merdeka* permits pedagogical innovation, many educators continue to operate within rigid accountability frameworks that emphasize compliance and standardized outcomes. Shifting toward adaptive and contextualized education requires reforming teacher appraisal systems to value instructional relevance and cultural responsiveness. It also entails embedding DMC principles into teacher certification programs and building cross-institutional platforms for sharing diagnostics, modular designs, and localized content.

The implementation of the DMC framework depends on both digital tools and empowering teachers as adaptive designers, cultural interpreters, and instructional strategists. When teacher agency is supported and professional capacity is expanded, adaptive learning can evolve into a human-centered, culturally grounded, and pedagogically inclusive practice.

The Relevance and Feasibility of the Integrative Model of DMC (Diagnostic-Modular-Culture) in SMP and MTs

The integrative model of an adaptive learning platform called DMC (Diagnostic–Modular–Culture), which combines individual diagnostics, modular instructional design, and socio-cultural contextualization, illustrates strong relevance for the secondary education context, both SMP and MTs, in Indonesia. Given the high degree of diversity among Indonesian learners, in terms of academic ability, learning styles, cultural backgrounds, and religious values, this MDC model encourages a shift in instructional design approaches from standardized to learner-responsive and culturally contextualized models.

Findings from eight case studies (four SMPs and four MTs) affirm the model's practical viability, highlighting its role not merely as a theoretical construct but as an actionable and scalable innovation. For instance, SMP Muhammadiyah Al-Kautsar Yogyakarta employs an internal Learning Management System (LMS) to track formative data; however, its implementation remains technically focused, lacking integration with affective and cultural dimensions (Syahid & Pembangunan, 2024). In contrast, MTs Mukhtar Syafa'at Banyuwangi incorporates pesantren values and local narratives into digital content, demonstrating robust cultural contextualization (Nisa & Aimah, 2024).

A key advantage of the DMC model is its ability to enhance learner engagement by presenting content that resonates with students' everyday environments, identities, and linguistic norms. Such contextualized personalization strengthens emotional and cognitive attachment to learning materials, making students feel "seen and represented" in their educational experiences (Slimi et al., 2025).

The diagnostic element of the DMC framework enables early identification of student needs and strengths, unlike conventional models that rely heavily on summative assessments. The AI-based platform at SMP Negeri 1 Beringin Deli Serdang, for example, groups students into tailored learning pathways using real-time performance data (Putri & Maharani, 2023). Though still limited in cultural integration, this case demonstrates the model's potential scalability through technology-driven design.

Equally important is the model's support for decentralized content development. Rather than reducing teachers to passive users of standardized platforms, DMC empowers them as co-designers of culturally relevant instructional content. This is evident in MTsN 1 Makassar and SMP Wahid Hasyim Malang, where teachers draw on student perception data and community narratives to inform instruction (At Thaariq et al., 2024; Idris & Rais, 2022). Such bottom-up innovation fosters democratic, identity-sensitive learning environments and strengthens collaboration between educators and technology developers (Aeschlimann et al., 2024).

The implementation feasibility of the DMC model, in sum, is highest in educational institutions with the following characteristics: 1) A strong community identity, such as pesantren-based MTs or value-oriented private schools; 2) High levels of teacher involvement in curriculum and content development; and 3) Curricular flexibility, particularly in schools adopting the *Kurikulum Merdeka*, which accommodates innovation in pedagogy and content design. The implementation feasibility of the DMC model:

Table 4. Applicability Matrix: DMC in SMP and MTs

No.	Component	Junior High Schools (SMP)	Madrasah Tsanawiyah (MTs)	Implications
1	**Individual Diagnostics**	AI-enabled in some cases (e.g., SMP Beringin), real-time grouping	Mostly absent or post-instructional (e.g., MTs Khozinatul Ulum)	Needs capacity building in MTs; strengthen predictive assessment
2	**Modular Design**	Structured but often informal (e.g., SMP Gading Rejo)	Emerging, often teacher-led (e.g., MTs Khozinatul Ulum)	Requires automation and consistent application
3	**Cultural Context**	Limited, except in value-based schools (e.g., Muhammadiyah)	Deeply embedded in most institutions (e.g., MTs Mukhtar Syafa'at)	SMPs need stronger cultural anchoring in design
4	**Infrastructure Support**	Generally better access to LMS, AI tools	Often constrained by ICT and training gaps	Policy focus needed to bridge digital inequity

However, the DMC model offers a transformative framework for advancing adaptive, inclusive, and culturally relevant learning. By bridging diagnostic precision, modular differentiation, and socio-cultural integration, it repositions adaptive learning not merely as a technological enhancement, but as a human-centered and sustainable educational paradigm.

Despite its potential, scaling the DMC model must proceed cautiously, particularly in resource-constrained environments. Implementation challenges include Limited ICT infrastructure, especially in remote MTs or rural SMPs, teacher readiness gaps, particularly around digital literacy and instructional design; and scarce access to curated, local content, especially in under-documented linguistic communities.

To mitigate these constraints, this paper strongly recommends phased pilot testing in selected schools with institutional readiness. Pilot trials should be evaluated based on diagnostic accuracy and personalization outcomes, student emotional and cultural engagement, teacher agency in content creation, and integration ease into existing school LMS and curricula. Such pilot-based scaling would ensure that DMC is implemented with contextual sensitivity, digital equity, and pedagogical coherence.

The DMC model presents a transformative blueprint for adaptive learning in Indonesia's secondary education system. By combining diagnostic intelligence, instructional modularity, and cultural contextualization, the framework moves beyond superficial personalization toward a deeply embedded, inclusive learning experience. The model encourages stakeholders, such as educators, policymakers, technology developers, and communities, to adopt a human-centered paradigm in digital education. It is not merely a technological upgrade, but a philosophical and pedagogical reorientation grounded in identity, diversity, and learner voice.

4. CONCLUSION

This study examined the implementation and development of adaptive learning platforms in Indonesian secondary schools (SMP and MTs), focusing on the relationship between individual diagnostics, modular instructional differentiation, and cultural-contextual integration, and subsequently proposed the Diagnostic–Modular–Culture (DMC) framework as an integrative model. The findings reveal a complementary divergence between institutional types. SMPs generally

demonstrate stronger technological infrastructure and data-driven personalization through AI-supported diagnostics and structured learning management systems; however, they often give limited attention to embedding cultural and religious contextualization within instructional content. In contrast, MTs institutions show a strong commitment to integrating local narratives, Islamic values, and socio-emotional dimensions into digital learning environments, yet they frequently lack systematic diagnostic mechanisms and algorithmic adaptability to personalize learning pathways effectively. These patterns highlight the need for a balanced framework that combines technological precision with cultural responsiveness. The proposed DMC model addresses this need through three interconnected components: digital pre-assessment to map learner profiles, differentiated modular pathways (remedial, standard, and enrichment), and contextual-cultural integration aligned with community values and the *Kurikulum Merdeka* framework. Nevertheless, this research is limited by its qualitative and conceptual orientation, reliance on institutional case descriptions, and the absence of large-scale empirical measurement of learning outcomes and identity development. Future studies should therefore implement experimental and quasi-experimental designs to evaluate academic impact, explore cultural adaptation through ethnographic approaches, conduct comparative rural–urban analyses, and undertake longitudinal research to assess sustainability and scalability. Such empirical advancement will strengthen the applicability of the DMC framework and support the development of inclusive, equitable, and culturally grounded adaptive education in Indonesia.

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