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HCAI-Based Adaptive Merdeka Learning: A Needs Analysis for 21st-Century Competencies.

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A B S T R A K

Educational transformation in the Society 5.0 era requires the implementation of the Merdeka Curriculum supported by Artificial Intelligence (AI) to strengthen 21st-century competencies. Although teachers demonstrate positive attitudes toward AI, its use remains largely limited to administrative tasks rather than supporting adaptive, data-driven learning. This study aimed to conduct a needs assessment for developing the Adaptive Merdeka Learning (AML) model by integrating the Merdeka Curriculum, Human-Centered AI, Adaptive Learning, Learning Analytics, and Competency-Based Education. The study represents the first phase of Design-Based Research (DBR) using a descriptive quantitative approach. The research was conducted in vocational high schools in West Sumatra, Indonesia, selected purposively based on their implementation of the Merdeka Curriculum, AI readiness, differentiated learning practices, and learning analytics capacity. Participants included school principals, teachers, and students. Data were collected through questionnaires, observations, semi-structured interviews, and document analysis. Instrument validity and reliability were established using Aiken's V and Cronbach's Alpha, respectively. The findings indicate that teachers have a good understanding of the Merdeka Curriculum and positive perceptions of AI; however, challenges remain in implementing differentiated instruction, AI-supported diagnostic assessment, personalized learning, and learning analytics. These findings reveal a gap between current instructional practices and the pedagogical demands of the Merdeka Curriculum. The study concludes that the development of the Adaptive Merdeka Learning (AML) model is essential to support learner-centered, AI-enhanced education and strengthen 21st-century competencies. The proposed framework provides a theoretical foundation for integrating the Merdeka Curriculum, Human-Centered AI, Adaptive Learning, Learning Analytics, and Competency-Based Education into a comprehensive pedagogical model.

INTRODUCTION

The learning paradigm in education has changed in the Society 5.0 age. It has moved from teacher centered to student centered with the aid of smart technology (Chigbu & Makapela, 2025; Rohayati & Nurjanah, 2026; Supriya et al., 2024). AI advancement opens up new possibilities for learning ecosystems to provide more flexible, data-driven, and customized educational experiences. Artificial intelligence can increase the quality of learning by providing individualized resources, adaptive assessment, real-time feedback and analysis of student learning progress (Weforum, 2025) Recommendation for Generative AI in Education and Research). However, UNESCO argues that the successful deployment of AI in education is not simply a question of technological sophistication,

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but rather a question of the capacity of educational institutions to incorporate AI into learner-centred pedagogical designs, while keeping teachers as the decision-makers in learning (UNESCO, 2023).

In the light of these advances, twenty-first-century competencies have been a main goal of contemporary education systems by numerous international organizations (Era et al., 2022; Fauzi & Hidayat, 2021; M. L. Pratama & Utama, 2023). In the face of fast social, economic and technological change, students need to acquire the abilities of critical thinking, creativity, communication, cooperation, electronic literacy, and problem-solving (OECD, 2023a). Meanwhile, automation, AI and big data will change the job structure in the next years (Report, 2016, The Future of Jobs Report 2025 released by the World Economic Forum). Hence education systems have to generate graduates with flexible capabilities, who can adjust to the technology and be ready for the dynamics of the future workplace. The results show that learning transformation is a strategic must to create competitive human resources. In addressing the challenges, the Indonesian government attempts to overcome them through the implementation of the Independent Curriculum which improves differentiated learning, builds the Pancasila Student Profile, and improves 21st-century competencies (Nabilah Alfania Hendrayani 2024; Mangka and Yani 2026; Sofianti, and Dewi Nirmala 2025). The independent curriculum encourages the use of digital technology in learning and provides teachers with tools to customize lessons based on student characteristics (Alifah et al., 2025; Kompetensi & Kurikulum, 2025; Mumtaz Ali Ridha Al Munawar, Nayla Ikhsani Azyan, Stephanie Aurelia, and Sulis Indriani, 2024). eachers are challenged to identify the learning needs of the students, design adaptive learning strategies, provide timely feedback, and utilize learning outcomes to make pedagogical decisions (Andikos, 2024). But, several assessments show that the application of differentiated learning is not successful (Dirman , Widya Kusumaningsih, 2025; Latif et al., 2025; Supriyanti et al., 2026). In contrast, the results of the Program for International Student Assessment (PISA) show that Indonesian students still need to improve in terms of numeracy, literacy and problem-solving skills. (OECD, 2023b) hese outcomes show that the learning transformation has yet to be completed entirely in terms of 21st century competencies improvement.

These challenges become more difficult as AI matures. Administrative duties, information retrieval, and the creation of learning materials are increasingly being utilized by Generative AI systems. Nevertheless, these diverse applications are beginning to be employed by both teachers and pupils (Andrew & Wijaya, 2023; M. Aris Akin, Ulfiani Rahman, 2026; Vail, 2024). Diagnostic tests, adaptive learning, tailored materials, analytical learning and data-driven feedback have not been consistently used in the pedagogical process. Artificial intelligence as a technology that can assist in the implementation of the Independent Curriculum has not been maximized. This issue shows that there is a disparity between the development of educational technology and the ways of learning that are employed in schools.

Preliminary observations in several Vocational High Schools (SMK) indicate that most educators are well aware of the fundamentals of the Independent Curriculum and are supportive of the use of AI in teaching (Adit et al., 2025). There is a need for systematic guidance on the use of AI in differentiated learning. In addition, the diagnostic assessment procedure is still done manually, learning profile mapping does not permit thorough data analysis, and monitoring of student learning progress is still based on conventional recording. By comparison, pupils are very interested in technology-based learning. They want a more personalized and interactive learning experience based on their learning characteristics. Figure 1.

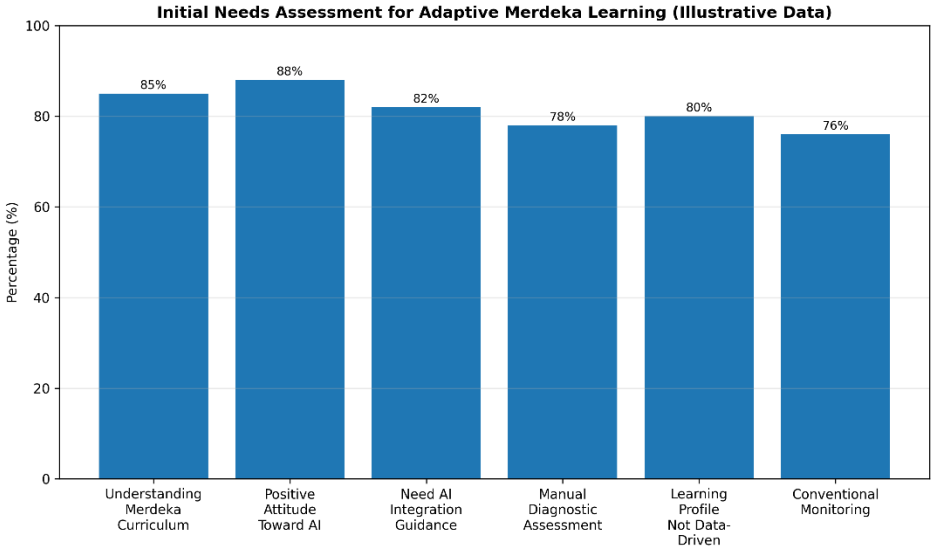

Figure 1 displays preliminary data

Figure 1 displays preliminary data concerning the readiness of teachers to adopt the AI-based Independent Curriculum in vocational high schools. In general, observations show that 85% of instructors have a strong comprehension of the fundamentals of the Independent Curriculum, and 88% of teachers reported that they favor the use of AI in the learning process. The findings suggest that teachers are conceptually ready to adopt AI-based improvements in learning, but not yet successfully implemented. 82% of teachers responded that there is still a need for formal instruction on how to implement AI in differentiated learning based on student characteristics. This means that the main challenge is not the acceptance of the technology but the lack of learning models that enable the application of AI in the learning approach.

Besides, it has been noticed that 78 % of the teachers still do diagnostic assessments manually. It takes a reasonably long period to identify students' learning readiness, starting abilities and specific needs. Consequently, the evaluation data are not used efficiently to generate differentiated learning, the characteristic of the Independent Curriculum.

In addition, about 80% of educators have not yet used holistic data analysis to develop their students' learning profiles. Learning profiles are often built via instructor observations, without the aid of an analytics system that can process many sources of learning data. Thus, teachers cannot know each student's interests, traits and learning needs in an objective and ongoing way. Therefore, the process of customized education cannot be fully realized.

Other results indicate that 76% of teachers still track student learning progress through traditional recordkeeping. Manual observation increases the administrative workload of teachers and makes it difficult to monitor students' learning progress in a timely manner. In turn, feedback and learning interventions are typically delayed making the learning process less effective.

Early results from the observation show a difference between teachers' willingness to embrace technological innovation and their capacity to apply AI in learning in general. Teachers believe in AI but they do not have a learning model for integrating AI with learning analytics, personalised learning, diagnostic assessment and differentiated learning. Results show the relevance of development of an adaptive independent learning model (AML). AML aims to combine the foundations of the Independent Curriculum with the potential of AI to develop adaptive, data-driven learning to improve 21st century skills.

Research on the independent curriculum has been found in previous studies to be focused mostly on implementation techniques, teacher preparedness, stakeholder perceptions and evaluation

of curriculum implementation. Meanwhile, research on Artificial Intelligence in education has concentrated more on the usefulness of certain AI applications, such as chatbots, intelligent tutoring systems, or generative AI, but has not fully embedded them in learning design (Davar et al., 2025; Setiawati et al., 2026). There is also substantial growth in research on adaptive learning and personalization, but usually done independently of the implementation of the Independent Curriculum. Hence, there is scope for future research. For example, there is no comprehensive learning model that combines AI, adaptive learning, individualized learning, the independent curriculum, and learning analytics into an empirically verified pedagogical model.

Considering these theoretical and practical differences, a requirements analysis is an important stage in the development of an independent adaptive learning (AML) model. This analysis is not just to find out problems related to the implementation of the autonomous curriculum and readiness of schools to apply artificial intelligence. It also seeks to compare the needs of teachers, students and educational units with the features of the learning model sought. Therefore the results of the needs analysis are intended to give a solid conceptual basis for the development of an effective artificial intelligence-based learning model to improve the implementation and contextual relevance. The results of the analysis will be utilized to design the components, syntax, learning tools and implementation techniques of Adaptive Independent Learning.

METHODS

This study employs a mixed-methods approach with a quantitative orientation, utilizing needs analysis as the initial stage in the Design-Based Research (DBR) process to develop the Adaptive Merdeka Learning (AML) model. Needs analysis was conducted to obtain empirical evidence regarding the actual conditions of the implementation of the Merdeka Curriculum, the level of readiness and utilization of artificial intelligence (AI) in learning, the implementation of differentiated instruction, the use of learning analytics, as well as the needs of teachers and students for the development of an adaptive learning model. Quantitative data served as the primary data source to describe the levels of implementation, readiness, and needs in measurable terms, while qualitative data obtained through semi-structured interviews, classroom observations, and document analysis were used to provide contextual explanations, deepen the quantitative findings, and perform triangulation. Therefore, this study is not categorized as purely descriptive quantitative research but rather as a needs analysis using a mixed-methods approach dominated by quantitative data, as the qualitative data serve as supporting evidence to explain and validate the conditions identified through the survey.

The research was conducted at a public vocational high school (SMK) in West Sumatra Province, which was selected using purposive sampling. The target schools are typically located in urban areas or rapidly developing regions with adequate technological infrastructure. Several criteria were used to select these schools, including: implementation of the Merdeka Curriculum; relatively stable internet access; possession of educational technology devices; institutional readiness to utilize AI in learning; implementation of or initiation of differentiated instruction; and a system or practice for managing learning data that enables learning analytics. These criteria were deliberately established because the primary purpose of the needs analysis is not to identify problems related to limited technological infrastructure but to determine the pedagogical, instructional, institutional, and learning design needs required for the development of the AML model. Selecting schools with reasonably adequate technological foundations allows the research to better focus on how AI, differentiated instruction, and learning analytics can be integrated into the implementation of the Merdeka Curriculum.

The research respondents included 117 school principals (representing 117 schools), 80 teachers, and 1,200 students, for a total of 1,397 respondents. The principals provided insights on school policies, the institution's readiness, support from leadership, and the organizational status regarding the use of AI for learning. Teachers were the primary respondents regarding professional aspects because they are directly involved in the implementation of the Merdeka Curriculum, lesson planning, differentiated instruction, assessment, the use of technology, and instructional decision-making. Meanwhile, the study participants were engaged to gather information about their actual learning experiences, perceptions toward the use of AI, adaptive learning needs, and expectations regarding a learning model that could adapt instruction to their characteristics and needs. Figure 1 shows the distribution of respondents and the contribution of each group to the needs analysis.

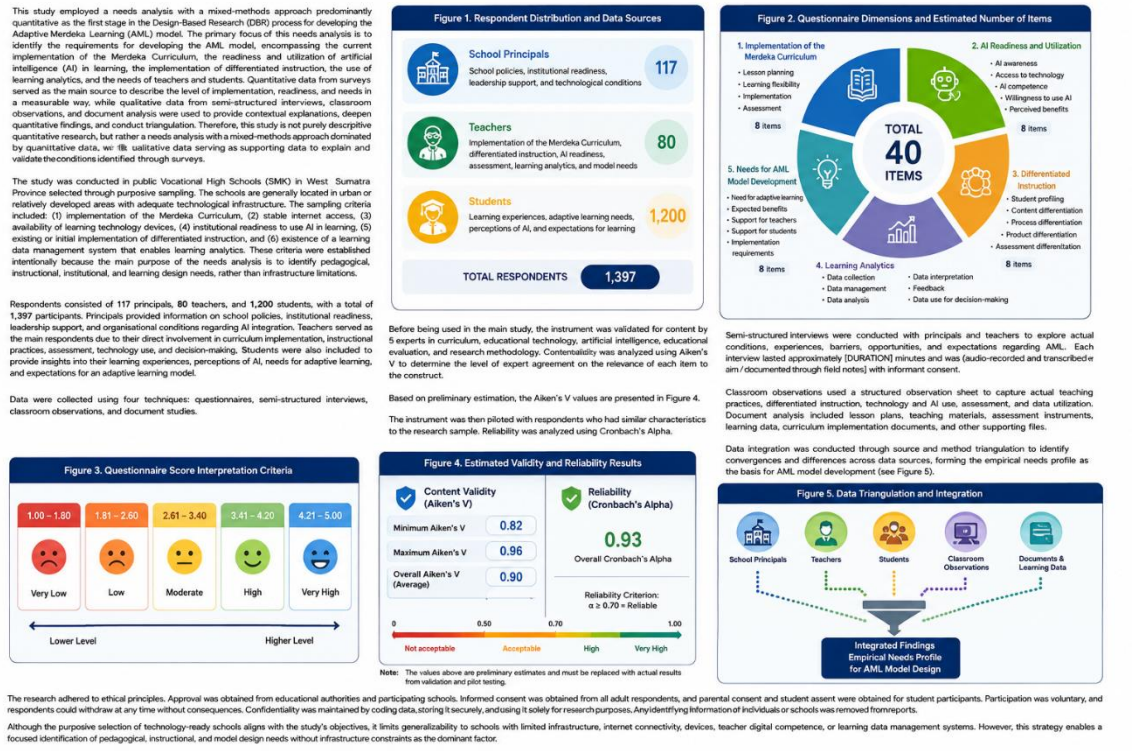

Figure 1-5. Academic Contributions and Conceptual Framework

Data collection was conducted using four complementary techniques: questionnaires, semi-structured interviews, classroom observations, and document analysis. The questionnaire served as the primary tool for collecting quantitative data and was designed based on the key components of the AML model and the needs to be identified. This questionnaire instrument covers five dimensions: implementation of the Merdeka Curriculum, AI readiness and utilization, differentiated instruction, learning analysis, and needs for AML model development. The implementation of the Merdeka Curriculum encompasses the dimensions of instructional planning, instructional flexibility, instructional delivery, and assessment. The AI readiness dimension includes knowledge and awareness of AI, access to technology, competence in using AI, readiness and willingness to use AI, and perceptions of the benefits of AI in learning. The differentiated learning dimension includes the identification of student characteristics, as well as differentiation of content, processes, outcomes, and assessment. The learning analytics dimension consists of the collection of learning data, analysis of data, interpretation of data, delivery of feedback, and use of data to make learning decisions. Meanwhile, the AML development needs dimension covers the need for adaptive learning, expected benefits, support for teachers and students, and model implementation requirements. The breadth of the construct measured suggests that the questionnaire is likely to have 40 items, with 8 items per

dimension, as shown in Figure 1. The questionnaire used a five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = somewhat/partially agree, 4 = agree, and 5 = strongly agree. Higher scores reflect a greater degree of implementation, readiness, capacity, or need, as appropriate to the construct being measured. Quantitative data analysis was performed by calculating frequency, percentage, mean, and standard deviation. The level of each indicator and dimension was determined using the mean value, while percentages were used to facilitate comparisons between indicators. Scores were interpreted using five categories: 1.00–1.80 was classified as very low, 1.81–2.60 as low, 2.61–3.40 as moderate, 3.41–4.20 as high, and 4.21–5.00 as very high. Before being used in the main study, the research instrument was validated by five experts with expertise in curriculum development, educational technology, artificial intelligence, educational evaluation, and research methodology. The content validity of the instrument was assessed using Aiken's V to determine the level of agreement among the experts regarding the relevance of each item to the construct being measured. Based on the initial simulation used as the basis for drafting the instrument, Aiken's V values were estimated to fall within the range of 0.82–0.96, with an overall average Aiken's V of approximately 0.90. This range indicates a high level of expert agreement regarding the relevance of the instrument's items. The V Aiken measure is indeed used to assess expert consensus on the relevance of items in an ordinal rating scale; therefore, the true values must be calculated from the scores assigned by each validator.

The instrument was then tested on respondents with characteristics similar to the study population, though they were not part of the main study sample. The instrument's reliability was analyzed using Cronbach's Alpha. Based on initial estimates for an instrument with 40 items and five construct dimensions, Cronbach's Alpha was estimated at 0.93, indicating excellent internal consistency. This value exceeds the minimum threshold of 0.70 used in the study as a criterion for accepting reliability. The value of 0.93 is considered a provisional/estimated value and must be replaced with the coefficient obtained from the actual pilot test data before the article is submitted. The use of actual values is crucial because the reliability coefficient is a characteristic of the scores generated in a specific sample and is not a fixed value inherent to the instrument.

Qualitative data was collected to clarify and deepen the findings of the quantitative survey. Semi-structured interviews were conducted with school principals and teachers who had direct experience with the implementation of the Merdeka Curriculum, differentiated instruction, the use of technology, the application of AI, and/or the management of learning data. The interviews focused on the actual conditions of the Merdeka Curriculum's implementation, teachers' experiences with differentiated instruction, the extent of AI utilization, the use of learning data, barriers to implementing adaptive learning, the need to improve teachers' competencies, expectations regarding the AML model, and the institutional support required within the framework of the model's implementation. Interviews, recorded and transcribed verbatim or documented via field notes after obtaining the informants' consent.

Observations were conducted directly on the learning process using structured observation guidelines. The observations were designed to gather evidence regarding actual teaching practices, student engagement, the implementation of differentiated instruction, the use of digital technology and AI, the administration of assessments, and the use of learning data to provide feedback and determine instructional strategies. These observations were crucial for comparing the practices reported by teachers through questionnaires and interviews with those actually occurring in the classroom. In addition, a study was conducted to document teaching modules, learning tools, teaching materials, assessment instruments, Merdeka Curriculum implementation documents, learning data, and other supporting documents. This documentation aims to verify the information obtained from

questionnaires, interviews, and observations while also providing an overview of schools' administrative and pedagogical readiness for the implementation of AML.

Based on the characteristics of each data source, data analysis was conducted both quantitatively and qualitatively. Quantitative data were analyzed descriptively using frequency, percentage, mean, and standard deviation at the indicator and dimension levels. The results of the data analysis were used to determine the level of implementation of the Merdeka Curriculum, AI readiness, the application of differentiated instruction, the use of learning analytics, and the need for the development of the AML model. Qualitative data were analyzed through the process of organizing data, coding, grouping categories, identifying themes, and synthesizing. The themes that emerged primarily relate to learning needs, teacher competencies, learner needs, technology readiness, institutional support, implementation barriers, supporting factors, and the desired characteristics of the AML model.

Data collection was conducted using source triangulation and technique triangulation. Quantitative results were used first to identify indicators showing high or low levels of readiness, implementation, or needs. The findings were then compared with results from interviews, observations, and documentation to understand the underlying context. For example, if the questionnaire results indicate a high level of teachers' readiness for AI, these results are confirmed through interviews and observations to determine whether that readiness has been implemented in teaching practices. The same process applies to the high perception of differentiated learning compared to teaching modules, assessments, and observation results to determine whether differentiated learning has been carried out systematically or if it is merely a matter of teachers' perceptions and expectations. Information from principals is also cross-referenced with teachers' data to assess the alignment of policies and institutional support with classroom-level teaching practices. Findings that are consistent across sources are used as evidence to strengthen the credibility of the analysis results, while discrepancies among sources are analyzed within their specific contexts to understand the gap between perceived and actual conditions. The results of integrating different data sources are then used to develop an empirical needs profile as the basis for developing the AML model. This needs profile serves as the foundation for determining the priority components of the model, including mapping student profiles, designing adaptive learning pathways, utilizing AI as a learning assistant, implementing differentiated instruction, utilizing learning analytics, providing formative feedback, supporting teachers' decision-making, and establishing model implementation mechanisms. Therefore, the needs analysis in this study not only describes the school's current condition but also produces design requirements that form the empirical basis for the development of an Adaptive Merdeka Learning model in the next DBR stage.

This research was conducted in accordance with the principles of research ethics. Research permission was obtained from the educational institution and the school serving as the research site. All adult participants were informed about the purpose of the research, data collection procedures, data usage, the voluntary nature of participation, and their right to refuse or withdraw from participation without penalty. Prior to distributing the questionnaires and conducting the interviews, informed consent was obtained from the school principal and teachers. For students who had not yet reached the age of legal consent, the research procedures followed the institution's policies regarding parental/guardian consent and student consent. Codes were used to maintain the confidentiality of respondents' identities and the schools' identities during data processing and reporting. Questionnaire data, interview transcripts, observation notes, and supporting documents were stored securely and used solely for research purposes. Learning data was managed in accordance with the principles of confidentiality and responsible use of educational data, and information that could identify students was not included in the publication. Although the research objective involved

the purposive selection of schools with relatively adequate technological conditions, this strategy resulted in limitations on generalizability. This study does not focus on schools' limitations regarding infrastructure, internet connectivity, digital devices, teachers' technological competencies, and learning data management systems. Therefore, the results of the needs analysis cannot be generalized to all vocational high schools in West Sumatra, particularly those located in areas with limited technology. The results of this needs analysis specifically represent the needs of schools that already have a relatively adequate technological foundation. However, this strategy allows the study to isolate and identify pedagogical, instructional, and AML model design needs more clearly, without letting infrastructure issues dominate. This approach enables the results of the needs analysis to serve as a more focused empirical basis for the development of the AML model, which is then tested, validated, and refined during the DBR development phase.

RESULTS AND DISCUSSION

RESULTS

The analysis demonstrates that the paradigm shift in education has been more student centric due to the implementation of the Independent Curriculum. However, in reality teachers confront so many problems that hinder them to execute differentiated learning effectively (Aprida , Arta, 2026; Supriyanti et al., 2026). The majority of teachers stated that they had difficulty in evaluating the learning needs of each student, preparing teaching materials adjusted to their abilities, and delivering fast and constant feedback (Hanifaa & As'ad, 2025; Muchammad, 2025; G. C. Pratama et al., 2025). The first step in the development of the Adaptive Independent Learning (AML) model is needs analysis. The aim of this analysis is to find conditions, in which Independent Curriculum may be implemented, the amount of use of AI and the requirement for adaptive learning for teachers and students. The analysis was done by means of interviews with teachers and principals, observations of the learning process, and questionnaires given to instructors and students on Teacher Needs Analysis, Student Needs Analysis, Learning Implementation and Gaps. The results of the needs analysis are presented in the table below.

Table 1. Teacher Needs Analysis

Dimension	Current Condition	Educational Implication
Merdeka Curriculum Implementation	Teachers demonstrate a sound understanding of the Merdeka Curriculum; however, differentiated instruction has not been implemented consistently across classrooms.	A structured pedagogical framework is required to facilitate effective implementation of differentiated learning.
Artificial Intelligence Integration	AI is mainly utilized for lesson preparation and information retrieval rather than instructional delivery.	AI should be integrated into pedagogical practices to support adaptive and personalized learning.
Diagnostic Assessment	Student readiness assessments continue to rely on conventional manual procedures.	AI-assisted diagnostic assessment is required to provide timely and accurate learner profiling.
Personalized Learning	Learning pathways remain uniform and have not yet been personalized based on students'	Data-driven adaptive learning pathways should be developed to enable personalized learning experiences.

	characteristics and learning needs.	
Learning Analytics	Learning data are not systematically analyzed to support instructional decision-making.	Learning analytics should be implemented to monitor students' progress and provide evidence-based feedback for continuous improvement.
Dimension	**Current Condition**	**Educational Implication**

Table 1 illustrates that teachers comprehend the Independent Curriculum philosophy. However, its implementation is currently focused on improving the learning tools and has not yet achieved comprehensive differentiated learning. Artificial Intelligence is also still utilized as an administrative tool, such as looking for learning references, formulating questions and making instructional modules. No teachers are using AI to analyze student characteristics, generate customized learning courses or provide automatic feedback. This issue shows that teachers require a learning model that can systematically integrate AI into the learning process to accomplish the aims of the Independent Curriculum. Table 2 presents an analysis of student needs.

Table 2. Student Needs Analysis

Dimension	Current Condition	Educational Implications
Interest in Digital Learning	Students demonstrate a high level of interest in technology-enhanced learning environments.	This provides a strong foundation for implementing AI-supported instructional practices.
Student Learning Engagement	Student engagement remains relatively low in conventional teacher-centered learning environments.	Interactive, student-centered, and AI-assisted learning strategies should be adopted to enhance engagement.
Learning Pace	Students exhibit varying learning paces and achievement levels.	Adaptive learning pathways should be designed to personalize learning according to individual needs and progress.
Digital Literacy	Students possess adequate digital literacy skills for technology-enhanced learning.	Digital literacy competencies should be leveraged to promote meaningful, responsible, and self-directed learning.
Learning Feedback	Feedback is not provided in a timely or continuous manner during the learning process.	AI-powered formative assessment and real-time feedback mechanisms are needed to improve learning outcomes and support evidence-based instructional decisions.
Dimension	**Current Condition**	**Educational Implications**

As seen in Table 2, students are well prepared for technology-based learning. As digital media interest continues to expand, it shows that AI may be involved in the learning process. However, uniform learning cannot suit the demands of individuals because pupils have various capacities and learning speeds. Also pupils want quicker feedback on their learning outcomes so they can see and improve what they need. The results of the student needs analysis for Learning Implementation are

presented in Table 3 below which reveals the need for a learning model that can give a more personalized, adaptable, and responsive learning experience to each student's needs.

Table 3. Learning Implementation

Educational Dimension	Current Practice	Desired Practice
Student-Centered Learning	Student-centered learning has been introduced but is not yet consistently implemented across instructional activities.	Student-centered pedagogy should be systematically embedded throughout the entire learning process.
Differentiated Instruction	Differentiated instruction has not been implemented effectively or consistently.	Instruction should be personalized based on students' learning profiles, readiness, interests, and learning preferences.
Artificial Intelligence Integration	AI is primarily used for limited instructional support and administrative tasks.	AI should be seamlessly integrated into instructional planning, delivery, assessment, and learning support.
Assessment Practices	Assessment remains largely summative with limited use of diagnostic and formative approaches.	AI-assisted diagnostic and formative assessment should be adopted to support personalized and data-informed learning.
Feedback Mechanism	Learning feedback is often delayed and generalized.	AI-enabled real-time, personalized, and continuous feedback should be provided to improve learning outcomes.
Learning Progress Monitoring	Student progress is monitored using conventional manual procedures.	Learning analytics should be employed to provide continuous monitoring and evidence-based instructional decision-making.

The observation of the implementation of learning shows that the learning process has developed into a learner-centered approach yet the implementation of differentiated learning is still inconsistent. Each student has individual learning qualities, yet teachers for the most part employ the same learning strategy for each student. Moreover, the assessment procedure cannot offer a timely report on student learning progress because it is based on summative assessments at the conclusion of the course. Furthermore, because monitoring of learning outcomes is still done manually, it takes a large amount of time to examine. These situations highlight the necessity for AI. This will allow teachers to conduct diagnostic tests, establish learning profiles and continuously monitor learning progress using learning analytics. Table 4 illustrates a considerable discrepancy between the existing learning conditions and the ideal conditions envisaged for the implementation of the Independent Curriculum, based on the observation results of the Teacher Needs Analysis, Student Needs Analysis, and Learning Implementation.

Table 4. Gap analysis

Existing Challenges	Target Learning Environment	Adaptive Merdeka Learning (AML) Solution
Instruction is predominantly uniform and does not adequately address students' diverse learning needs.	Adaptive and personalized learning experiences tailored to individual learner characteristics.	**Adaptive Learning Pathway** that dynamically adjusts learning content, activities, and difficulty levels based on students' learning profiles.
Diagnostic assessment relies primarily on conventional manual procedures.	Continuous, data-driven diagnostic assessment to identify students' readiness and learning needs.	**AI-Based Diagnostic Assessment** that automatically analyzes learner performance and generates individualized learning profiles.
Teachers face challenges in designing personalized instruction for students with diverse abilities and learning preferences.	Personalized instruction informed by students' readiness, interests, and learning progress.	**AI Recommendation System** that recommends appropriate learning resources, activities, and instructional strategies.
Learning feedback is delayed, generalized, and lacks personalization.	Immediate, continuous, and personalized formative feedback.	**AI Feedback Engine** that provides real-time feedback and adaptive learning recommendations.
Monitoring student progress depends on manual documentation and periodic evaluation.	Continuous monitoring supported by learning analytics and evidence-based instructional decision-making.	**Learning Analytics Dashboard** that visualizes students' learning progress, predicts learning risks, and supports data-informed instructional decisions.
Existing Challenges	**Target Learning Environment**	**Adaptive Merdeka Learning (AML) Solution**

The gap analysis in Table 4 shows significant discrepancies in learning differentiation, assessment, feedback and the use of learning outcome data. Teachers still struggle to pinpoint students' learning requirements quickly and properly. Thus learning is not fully adaptable. Hence, this study presents an Adaptive Merdeka Learning (AML) system which uses AI to assist diagnostics, learning customisation, automatic feedback and the usage of learning analytics. This incorporation is expected to accelerate the implementation of the Merdeka Curriculum and help the development of 21st century capabilities.

These findings are in line with UNESCO's view that AI has great potential to improve the quality of evaluation and deliver instant feedback. Moreover, the OECD Learning Compass 2030 underscores that adaptive learning environments are vital for the sustainable development of 21st-century abilities. The results of the needs analysis show that the adoption of the Merdeka Curriculum in the targeted schools has changed the paradigm of education to be more student-centred learning. The core tenets of the Independent Curriculum, especially those relating to diagnostic assessment, competency development, and differentiated learning in the 21st century, are familiar to most teachers (Jamludin et al., 2022; Ulfha et al., 2025). But these steps have not yet been fully implemented. Based on the data from the questionnaire and observations, teachers still have difficulties in identifying the learning needs of all students, designing learning strategies that are

customized to the characteristics of individuals, and using assessment results to make decisions in learning. This issue shows that the curriculum modifications have not been adequately reflected in the changes in the teaching practices of the classroom.

In addition, research demonstrates that AI is still quite new in the learning applications (Firdaus, 2026; Hatibu & Utami, 2026; Rohman et al., 2025; Syawaludin, 2025). AI is still hardly used to provide diagnostic evaluation, adaptive learning, customized learning, and analysis of learning progress. But most teachers utilize technology to help develop learning aids, look for reference resources, or create instructional materials (Asbara et al., 2024; Syamdani Syamdani et al., 2025) The results of the interview show that this constraint is not a lack of adoption of technology by teachers. The issue is not this. Instead, there are no learning models available that allow for the educational use of AI. Teachers have voiced the need for a learning framework that can incorporate technology with the ideas of the Independent Curriculum. This way you may use AI not only for administrative things, but also to actually support the learning process.

Classroom observations are revealing that differentiated learning is starting to be implemented. In practice, however, the differentiation of content still dominates and the distinction of process and result has not been adequately addressed. Teachers frequently utilize the same strategy to learning with various groups of students. Moreover, since diagnostic evaluations are still completed manually, it takes a lot of time to find out students' readiness for learning. This has prevented the efficient use of assessment results to develop flexible and customized instruction.

Additional findings reveal that the mapping of student learning profiles is based only on instructor observations, and not supported by the examination of full data. Traditional record-keeping also influences monitoring of learning progress, making it difficult for teachers to continuously check their students' development. This has implications for feedback loops and teachers' capacity to make timely learning interventions. However, adaptive learning requires precise data on each student learning progress to alter the learning tactics dynamically.

Meanwhile, on the employment of digital technology in learning, pupils gave good responses. They anticipated learning experiences to be engaging, flexible and customized to their specific learning needs. Students also wanted to receive feedback on learning outcomes faster so they could quickly improve their understanding and improve their skills. These findings indicate that student needs are consistent with the AI-based adaptive learning features that can offer a more personalized and responsive learning. The results of the research prove the idea that the application of AI in education depends on the availability of technology, especially the pedagogical design applied.

DISCUSSION

The gap analysis in Table 4 shows significant discrepancies in learning differentiation, assessment, feedback and the use of learning outcome data. Teachers still struggle to pinpoint students' learning requirements quickly and properly. Thus learning is not fully adaptable. Hence, this study presents an Adaptive Merdeka Learning (AML) system which uses AI to assist diagnostics, learning customisation, automatic feedback and the usage of learning analytics. This incorporation is expected to accelerate the implementation of the Merdeka Curriculum and help the development of 21st century capabilities.

These findings are in line with UNESCO's view that AI has great potential to improve the quality of evaluation and deliver instant feedback. Moreover, the OECD Learning Compass 2030 underscores that adaptive learning environments are vital for the sustainable development of 21st-century abilities. The results of the needs analysis show that the adoption of the Merdeka Curriculum in the targeted schools has changed the paradigm of education to be more student-centred learning. The core tenets of the Independent Curriculum, especially those relating to diagnostic assessment,

competency development, and differentiated learning in the 21st century, are familiar to most teachers (Jamlludin et al., 2022; Ulfha et al., 2025). But these steps have not yet been fully implemented. Based on the data from the questionnaire and observations, teachers still have difficulties in identifying the learning needs of all students, designing learning strategies that are customized to the characteristics of individuals, and using assessment results to make decisions in learning. This issue shows that the curriculum modifications have not been adequately reflected in the changes in the teaching practices of the classroom.

In addition, research demonstrates that AI is still quite new in the learning applications (Firdaus, 2026; Hatibu & Utami, 2026; Rohman et al., 2025; Syawaludin, 2025). AI is still hardly used to provide diagnostic evaluation, adaptive learning, customized learning, and analysis of learning progress. But most teachers utilize technology to help develop learning aids, look for reference resources, or create instructional materials (Asbara et al., 2024; Syamdani Syamdani et al., 2025). The research results point out that the use of technology as an aid to learning is not enough for the integration of AI in the autonomous curriculum. What we don't need is a pedagogical model that connects technology with learning objectives. Differentiated, customized instruction and learning analytics are embedded in a systematic learning framework to address this demand. This model is in line with the principle of the Merdeka Curriculum by making students the center of learning, and using artificial intelligence to make data-based pedagogical decisions.

Previous studies only discuss the deployment of Merdeka Curriculum or the application of AI exclusively. The results of this investigation further these findings. The research shows that there can be a bigger impact of AI when it is applied in a properly structured learning model. In this context, AI is not a substitute for instructors but an intelligent learning assistant that helps teachers to organize classes, monitor student progress, deliver quick feedback and develop learning techniques depending on learning objectives.

This research theoretically contributes to the construction of a new learning model by integrating Merdeka Curriculum theory, constructivism theory, adaptive learning, individualized learning, and AI. In contrast, the Adaptive Merdeka Learning model provides guidance on how teachers might use AI-based learning more efficiently, ethically, and in accordance with the characteristics of their students. Therefore, this model can be an alternative learning innovation that can help change Indonesian education into a smart, flexible learning ecosystem to improve 21st-century capabilities in the period of Society 5.0 (Jamlludin et al., 2022; Ulfha et al., 2025). But these steps haven't been properly implemented yet. Based on the data of the questionnaire and observation result, the instructor still has difficulties in identifying all the learning needs of students, designing learning strategies that are relevant to the characteristics of students, and applying the assessment result in making judgments about learning. The scenario shows that improvements in curriculum have not been completely paralleled by changes in classroom teaching approaches.

Moreover, research suggests that the usage of AI is still extremely new in the domain of learning (Firdaus, 2026; Hatibu & Utami, 2026; Rohman et al., 2025; Syawaludin, 2025). The use of AI to support diagnostic evaluation, adaptive learning, customized learning, and learning progress analysis is still quite limited. However, most teachers use technology to help in making learning tools, look for reference resources, or produce instructional materials (Asbara et al., 2024; Syamdani Syamdani et al., 2025). The results of the interview show that this constraint is not because of teachers' not accepting technology. The difficulty is not the technology, but the lack of appropriate learning models that would allow pedagogical application of AI. Teachers said they need a learning framework that can marry technology to the ideas of the Independent Curriculum. That would allow AI to transcend beyond administrative issues and really be of support in the learning process.

The results of the study show that technology as a learning tool is not adequate to integrate AI in the Independent Curriculum. What is needed is a pedagogical model linking technology to learning goals. To address this demand, a systematic learning framework is proposed that incorporates differentiated, adaptive, individualized learning and learning analytics. This paradigm underpins the principle of the Independent Curriculum, which places students at the centre of learning and uses artificial intelligence to support data-driven educational decision making.

Academically, this study contributes to the development of adaptive learning theory and design by integrating the Merdeka Curriculum, constructivist learning, differentiated instruction, individualized learning, learning analytics, and Artificial Intelligence (AI) into a single systematic learning framework through the Adaptive Merdeka Learning (AML) model. This study differs from previous research, which tended to examine the implementation of the Merdeka Curriculum and the use of AI separately. This study broadens the perspective by positioning AI not only as a supporting technology for creating learning materials or resources but also as an intelligent learning assistant that supports diagnostic processes, mapping of student characteristics, personalization of learning pathways, feedback, monitoring of learning progress, and data-driven pedagogical decision-making. The main contribution of this study is the development of a conceptual relationship between the principles of flexibility and student-centeredness in the Merdeka Curriculum and AI-based adaptation mechanisms and learning analytics, thereby resulting in a learning framework that is more responsive to diverse learning needs.

The results of the needs analysis indicate that changes in curriculum policy have not been fully accompanied by changes in teaching practices particularly regarding teachers' ability to identify students' individual needs, design differentiated learning strategies, provide timely feedback, and utilize learning outcome data to determine instructional interventions. Thus, AML contributes theoretically by bridging the gap between learner-centered curriculum principles and data-driven and adaptive learning practices. In this context, AI is not presented as a replacement for the teacher, but as a technology that enhances the teacher's professional capacity to understand learners' circumstances and respond to learning needs more quickly, personally, and based on evidence. Thus, this research contributes to the body of knowledge on AI in education by offering a perspective that the effectiveness of AI in education is not merely defined by the presence of technology but rather by the quality of pedagogical design that integrates technology with learning objectives, learner characteristics, assessment, feedback, and teacher decision-making. Conceptually, AML can serve as the foundation for developing a smarter, more flexible, personalized, and learner-centered learning ecosystem to support the transformation of Indonesian education and meet the demands of 21st-century competencies in the Society 5.0 era.

CONCLUSION

This research discovered a discrepancy between the idealistic values of the Independent Curriculum and the actual implementation in Vocational High Schools. Despite the existence of fairly adequate technological infrastructures in the targeted schools, teachers' positive attitudes toward AI and students' interest in technology-supported learning, the use of AI and adaptive learning practices has not been systematically embedded into classroom pedagogy. In particular the needs analysis points to ongoing issues with the implementation of differentiated learning, diagnostic assessment, responsiveness to individual learner characteristics, timely feedback and the use of learning result data for pedagogical decision-making. The results reveal that the main problem is not simply access to technology but rather the lack of a suitable pedagogical framework that integrates the existing technologies with the learner-centered concepts of the Independent Curriculum.

The results offer a empirical foundation for the creation of the Adaptive Merdeka Learning (AML) model based on Human-Centered Artificial Intelligence (HCAI). The suggested line of development of AML highlights the integration of learner profile, adaptive learning paths, differentiated instruction, AI-powered learning help, learning analytics, formative feedback and teacher decision-making in a coherent pedagogical framework. In this perspective, AI is conceived as an aid and a learning helper centered on the human being and not as a substitute for teachers. It seeks to build teacher capacity to detect learner needs, interpret learning evidence, provide timely feedback and adapt instructional tactics, while keeping teacher agency and pedagogical responsibility.

The present study makes an academic contribution thru the clarification that the integration of AI in the Independent Curriculum is not limited to the supply or adoption of digital resources. AI-supported learning should be integrated in a pedagogical model that considers the diversity of learners and that makes evidence-based instructional decisions. This perspective extends the current discourse on AI in education by linking human-centered AI with differentiated, adaptive, and data-informed learning in the particular context of Indonesian vocational education. At the same time, the findings give a conceptual framework for conceptualizing AML as a possible connection between curriculum flexibility, learner-centered pedagogy, and intelligent educational technologies.

From a practical point of view, the findings give instructors and schools evidence about the areas that need to be improved before the successful implementation of AI enabled adaptive learning. They include teacher ability for interpreting learner data, systematic implementation of differentiated learning, meaningful use of assessment information, responsible application of AI, and establishment of institutional systems for managing learning data. The implications for curriculum developers and educational institutions are that there is a need for implementation guidelines and professional-development programs that address not only AI literacy but also pedagogical integration of AI in curriculum planning, assessment, feedback, and instructional decision-making.

However, the findings of this study must be understood in light of its needs-analysis design and selective sampling strategy. The schools were purposely picked as they had pretty good technology conditions. The findings are thus essentially representative of the demands and constraints of schools with sufficient technology capability and cannot be immediately transferred to vocational schools with fundamentally differing infrastructure, connectivity or institutional conditions. Furthermore, the present study establishes the need and design rationale for AML but does not establish the validity, practicality or effectiveness. Subsequent stages will thus need to empirically validate claims about the effect of AML on learning outcomes and 21st-century capabilities.

Future study should systematically explore the development, expert validation, limited implementation, refining and efficacy evaluationof the AML model within a Design-Based study framework. Further research should assess the validity, practicality, feasibility and efficacy of the suggested approach in promoting differentiated learning practices, data-informed pedagogical decision-making, learner engagement and 21st-century capabilities. It will be crucial to test the model across schools with various levels of technological preparedness and varied educational contexts to understand the transferability and boundary conditions. Thus, the current work should be seen as an empirical starting point for the development and rigorous testing of AML, not as evidence that the model has already been validated.

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Hatibu, H., & Utami, U. (2026). *Analisis Pemanfaatan Artificial Intelligence dalam Pembelajaran IPS SD pada Mahasiswa Pendidikan Guru Sekolah Dasar Jurusan Pendidikan Guru Sekolah Dasar , Universitas Negeri Makassar Surel : hardiyanti.hatibu@unm.ac.id PENDAHULUAN Perkembangan teknologi digital telah mendorong transformasi signifikan dalam berbagai sektor , termasuk pendidikan . Salah satu inovasi yang berkembang pesat adalah Artificial Intelligence (AI), yang mampu mengolah data , memberikan rekomendasi , serta menghasilkan respons secara adaptif (Suresh & Sasidharan , 2025). Dalam konteks pendidikan , AI tidak hanya berfungsi sebagai alat bantu teknis , tetapi juga berpotensi menjadi sarana untuk menciptakan pembelajaran yang lebih fleksibel , personal , dan interaktif Artificial Intelligence dalam pendidikan tidak hanya terbatas pada penggunaan chatbot berbasis teks , tetapi juga berkembang dalam bentuk media visual interaktif , sistem adaptif , virtual learning assistant , dan pengembangan bahan ajar digital . Dalam konteks pembelajaran IPS SD , AI berpotensi membantu peserta didik memahami konsep abstrak melalui visualisasi , simulasi , dan media pembelajaran interaktif yang lebih kontekstual . Penggunaan AI yang terintegrasi secara pedagogis dapat meningkatkan keterlibatan siswa , memperkuat pengalaman belajar , serta mendukung pembelajaran yang berpusat pada peserta didik (Holmes & Tuomi , 2022 ; Kasneci Implementasi Artificial Intelligence (AI) dalam pendidikan memiliki potensi besar dalam mendukung personalisasi pembelajaran , otomatisasi asesmen , serta pengembangan sistem pembelajaran adaptif yang mampu menyesuaikan kebutuhan dan karakteristik peserta didik secara individual (Farhood et al ., 2025 ; Holmes & Tuomi , 2022 ; Zawacki- Richter et al ., 2019). Sementara itu , (Kasneci et al ., 2023) menegaskan bahwa generative AI seperti ChatGPT dapat membantu peserta didik dalam eksplorasi masalah , tetap memerlukan pengawasan*

pedagogis agar penggunaannya tidak bersifat pasif dan mekanis . dalam pembelajaran semakin luas , terutama dengan hadirnya teknologi chatbot generatif yang memungkinkan pengguna memperoleh penjelasan secara instan dan kontekstual (Fenta , 2025 ; Lai , 2024). Teknologi ini memberikan peluang bagi peserta didik untuk belajar secara mandiri sesuai dengan kebutuhan dan gaya belajar masing-masing . Selain itu , AI juga mampu meningkatkan efisiensi pembelajaran melalui akses informasi yang cepat dan beragam (Kasneci et al ., 2023 ; Zawacki-Richter …. 10(3), 102–114.

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