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Systematic Literature Review: The Influence of Intelligence Variation in Adaptive Learning Design

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ABSTRACT

As adaptive learning systems are increasingly implemented to support personalized education, concerns have emerged regarding their tendency to rely on narrow and reductionist intelligence models. This study aims to analyze the influence of intelligence variations in adaptive learning design through a systematic literature review. Using the PRISMA 2020 protocol, fifteen empirical articles from the period 2010–2025 were critically reviewed. The results show the dominance of rule-based approaches with static profiles that rely on the linguistic, logical, mathematical dimension as the default parameter, ignoring the potential of other dimensions such as naturalist and existential. Artificial intelligence integration offers dynamic personalization potential but poses pedagogical and ethical dilemmas. Empirical evidence in Indonesia confirms the effectiveness of multiple intelligences-based adaptive learning on reading literacy and science creativity, despite constraints related to infrastructure and teacher capacity. The findings lead to three design principles: multimodal flexibility, cultural calibration of measurement instruments, and technology–pedagogical balance. This study recommends the development of hybrid prototypes and ethical standards for the use of cognitive data to realize an inclusive learning ecosystem. The implications of this review indicate that adaptive learning design should move beyond single-intelligence models by adopting culturally calibrated, multimodal, and pedagogically guided adaptation strategies. These implications provide a concrete framework for educators, designers, and developers to design more inclusive and context-responsive adaptive learning systems.

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Introduction

Gardner's theory of multiple intelligences (MI) emphasizes that intelligence consists of diverse cognitive capacities, highlighting individual differences in how learners process information and demonstrate understanding. This perspective has important implications for educational practice, particularly in the development of adaptive learning designs that support personalized and flexible learning experiences (Gardner, 1983). In learning practice, recognition of intelligence variations is often manifested through personalization strategies ranging from modification of activities, presentation of materials, to forms of assessment. However, the application of such differentiation still tends to be intuitive and manual, especially at the conventional grade level. The development of educational technology, especially adaptive learning systems based on learning analytics and artificial intelligence, offers opportunities to improve the precision and scalability of adaptation based on students'

cognitive profiles. This kind of system not only diagnoses early intelligence tendencies, but also dynamically adjusts the learning trajectory based on the user's responses and progress.

In Indonesia, interest in the application of multiple intelligences (MI) theory in instructional design continues to grow, particularly within competency-based curricula and scientific approaches. Studies indicate that while teachers who understand students' MI profiles tend to be more creative in designing learning activities, the implementation of such approaches remains largely manual and constrained by limited time, training, and institutional resources (Abdiyah & Subiyantoro, 2021). Similar findings highlight a gap between teachers' theoretical understanding of intelligence variation and their technical capacity to design genuinely adaptive learning environments (Putra et al., 2024). Although early efforts to develop MI-based adaptive learning systems have shown promise in increasing student engagement, their effectiveness remains dependent on consistent and accurate calibration of learners' cognitive profiles (Syaifullah, 2025). These limitations suggest that current personalized learning approaches are not yet scalable or precise, underscoring the potential of AI-powered adaptive learning systems to enable more accurate, dynamic, and scalable adaptation based on students' cognitive profiles.

These findings indicate that the potential for integrating intelligence variation into adaptive learning designs has not been optimally utilized. Most initiatives still focus on linguistic and logical-mathematical intelligence, while dimensions such as naturalist, existential, or interpersonal are often overlooked in adaptive systems architectures. In addition, there has been no comprehensive effort to map how various intelligence models of not only MI, but also Sternberg's triarchist theory or cognitive style-based approach have been operationalized in a responsive digital learning environment.

This study aims to conduct a systematic literature review to identify, analyze, and synthesize the latest empirical evidence regarding the influence of intelligence variation in adaptive learning design. Its main focus is to understand how intelligence profiles are measured, integrated, and utilized as adaptation parameters, as well as uncover challenges and opportunities in their application in various educational contexts. The results of the study are expected to enrich the theoretical framework for the development of personalized learning systems, as well as provide empirical guidance for educators, instructional designers, and educational technology developers in creating a more inclusive and equitable learning ecosystem.

Methods

Literature search and synthesis were conducted using a systematic literature review (SLR) approach following the PRISMA 2020 protocol to ensure transparency, traceability, and minimal selection bias. Each stage of the PRISMA process Identification, Screening, Eligibility, and Included was systematically labelled and documented in the selection chart. The research questions were formulated using the PECO framework, consisting of Population (students at the primary to higher education levels), Exposure (the use of intelligence variation profiles, such as multiple intelligences, triarchist theories, or cognitive styles, as the basis for learning adaptation), Comparison, and Outcome (indicators of learning effectiveness, including achievement, motivation, engagement, and perception). The comparison component was not mandatory across all included studies, as many studies on adaptive learning and intelligence variation employed non-comparative designs, such as system development, design-based research, or exploratory implementations. When applicable, comparison involved contrasts between adaptive and non-adaptive learning conditions, different intelligence-based adaptation strategies, or pre- and post-intervention learning outcomes. The search period was limited to publications from January 2010 to October 2025, as this period marks the acceleration of technology-driven adaptive learning systems and the first substantial cross-cultural validation of intelligence measurement instruments.

The literature search was conducted across five international academic databases (e.g., Scopus, Web of Science, ERIC) in parallel with Google Scholar to ensure comprehensive coverage. Structured keywords were grouped into three categories: (1) intelligence (multiple intelligences, triarchic intelligence, cognitive style), (2) adaptive learning (adaptive learning, intelligent tutoring systems, personalized instruction), and (3) design (learning design, instructional adaptation). Keywords within and across categories were combined using Boolean operators (AND, OR), phrase searches (e.g., "multiple intelligences" AND "adaptive learning" AND "learning design"), and truncation where applicable. To capture empirical evidence from the Indonesian context, additional searches were conducted in SINTA using localized keywords, including compound intelligence, cognitive style, adaptive learning, and personalized learning design. This strategy aligns with contextual inclusion practices in

cross-cultural systematic literature reviews, as demonstrated in the development of MI-based adaptive systems in secondary education (Kusumaningtyas et al., 2017).

Inclusion criteria encompassed quantitative, qualitative, and mixed-method empirical studies that explicitly described how intelligence profiles were measured, classified, and integrated into adaptation mechanisms, such as modifications of learning content, activities, or feedback based on intelligence indicators. Studies were included if they were published in reputable journals indexed in SINTA (levels 1–5) and available in full-text format. Exclusion criteria applied to conceptual articles, review papers without primary analysis, and studies that referenced intelligence only as a theoretical foundation without operationalization in learning design. Additionally, articles were commonly excluded during the review stage if they lacked sufficient methodological detail, did not focus on adaptive learning, or were inaccessible in full text. The selection process involved two independent reviewers conducting blind screening at the title, abstract and full-text evaluation stages. Disagreements were resolved through discussion or consultation with a third reviewer. Inter-rater reliability analysis yielded a Cohen's Kappa coefficient of 0.86, indicating an excellent level of agreement.

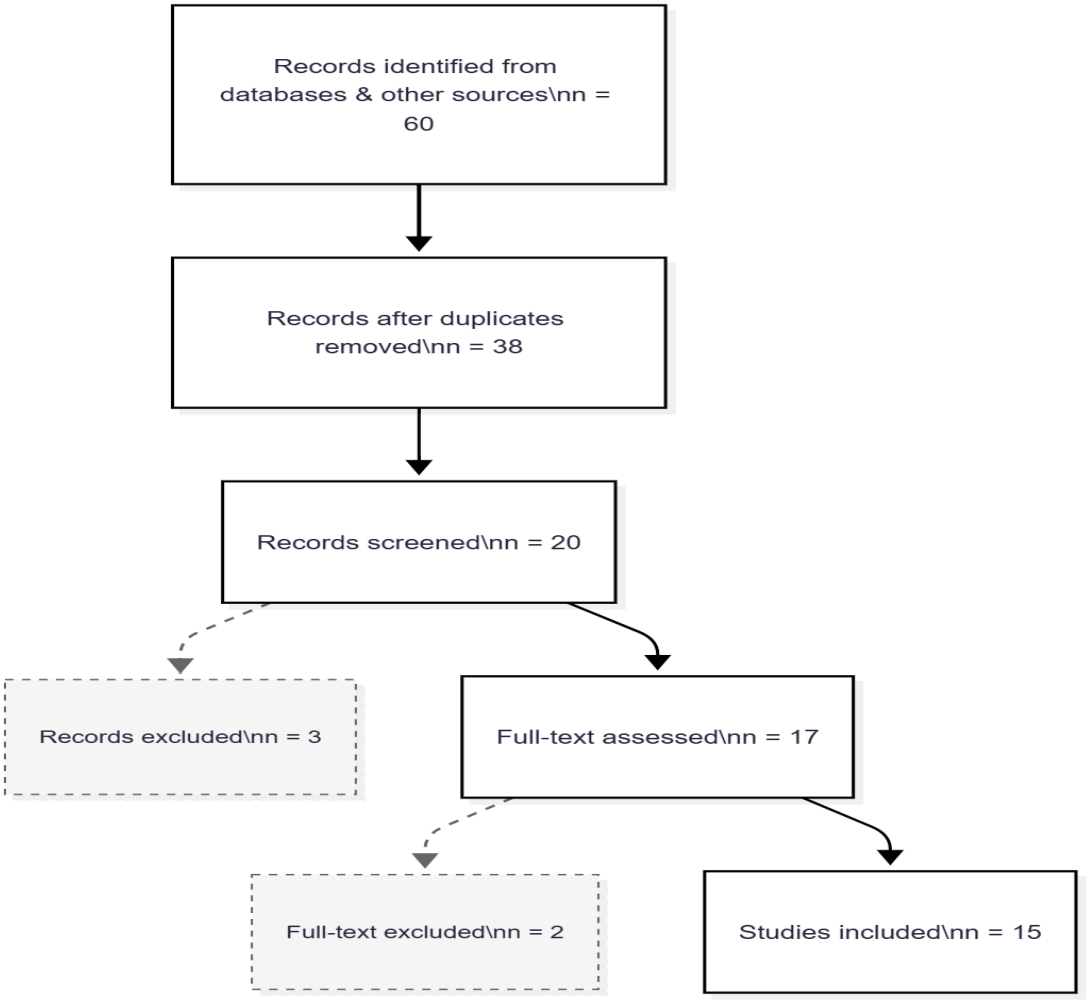

Figure 1 PRISMA Flow Diagram

Data extraction was carried out using a structured form that included the identity of the study, the context of the participants, the intelligence theories used, the measurement instruments (including local adaptations such as the MI questionnaire version of (Rahadian., et al 2024), the type of adaptive system (rule-based, AI-driven, or hybrid), adaptation parameters, research design, and key findings. The methodological quality of each study was assessed using the 2018 version of the Mixed Methods Appraisal Tool (MMAT). Analysis is carried out through

narrative thematic synthesis: the findings of each study are openly coded, grouped into repetitive conceptual themes (e.g.: the dominance of linguistic-logical intelligence in system design, adaptation mechanisms based on classroom observation, the gap between theoretical profiles and real learning responses), and then integrated across studies to uncover patterns, contradictions, and design implications. The validation of MI instruments in the Indonesian context as reported by Firza (2024) through confirmatory factor tests on the adaptive scale of science is a critical consideration in assessing the transferability of cross-cultural findings.

Results and Discussion.

The results of this study are presented through a mapping of key findings from various studies that discuss the relationship between students' intelligence characteristics or learning styles and the implementation of adaptive learning systems. A literature synthesis shows that adaptive learning approaches, whether based on multiple intelligences, cognitive styles, or learner profiles, are increasingly developing along with the use of intelligent technology and artificial intelligence. In general, previous research results indicate that personalized learning through adaptive systems has the potential to increase learning effectiveness, although its success is highly dependent on the quality of the system design, the accuracy of student characteristic modeling, and the implementation context in the educational environment.

Table 1. Characteristics of Studies Meeting Inclusion Criteria in the SLR.

Author (Year)	Types of Intellegence	Adaptive System	Method	Main Findings
Martin, F., Chen, Y., Moore, R.L., & Westine, C. (2020)	Learning style	Adaptive learning platforms	Systematic review	Adaptations that incorporate learner characteristics (initial ability/style) tend to increase personalization, but effectiveness is highly dependent on the design and context of implementation.
Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019)	AI systems and learner characteristics	ITS, adaptive systems, and analytics	Systematic Review	Adaptive AI is widely used in HE, great potential, but there are ethical & pedagogical issues
Wang, X. (2025)	cognitive style / learner mode	Adaptive e-learning systems with AI & learner models	Systematic review of learner modelling techniques	ML techniques for modeling learners are improving; model quality & data are crucial for effective adaptation; gap on generalizations and ethical issues.
Alvarez-Icaza, I. (2024)	Learning Styles, Cognitive & Thinking Skills	User profiling strategy	Systematic Literature Review (Scopus/WoS search)	User profiles (cognitive profiles) improve the quality of adaptation; It takes dynamic profiles to capture competency changes.
Kumar, A., Singh, N., & Ahuja, N. J. (2017)	Learning model (visual/Verbal)	Conversation-Based Smart Tutoring System That Is Able to Predict Students' Learning Styles.	Empirical studies review / system design studies	Students' learning styles can be predicted from interaction trace data, and ITS can use these predictions to adjust the delivery of material adaptively
Tzu-Chi Yang et. al (2019)	Model kognitif FSLSM (Felder–Silverman Learning Style Model)	Adaptive learning systems that integrate learning	Developmental study / system	Developmental study / system implementation & evaluation

		styles and cognitive styles	implementation & evaluation	
Amini, A. (2025)	Multiple Intelligences (Gardner	Learning management strategies & adaptive activities berbasis MI	Sistematic literature review	MI-based instructional strategies can be combined with adaptive activities to optimize children's potential; empirical evidence is still mostly small studies/local implementations
Rustan Efendy et.al	Multiple Intelligence	Instructional adaptive design integrates MI into adaptive activities	Literature Review	Identification of MI → activity mapping → integration into adaptive learning design holds promise for personalization
Zerkouk, M. (2025)	Different learning models and backgrounds	AI-based ITS (beragam domain)	Comprehensive review (arXiv)	AIED/ITS often adjusts based on the characteristics of learners; Research Needs Towards Pedagogical Integration & Ethics
Fariani, R. I. (2022)	Learning model	adaptive learning management system (ALMS)	Systematic review	Cognitive style can be considered by ALMS to tailor the material; Evidence of effectiveness varies between studies
Gligorea, I. et.al (2023)	cognitive style & learner preferences	AI adaptive e-learning systems	Literature review	adaptive AI systems exploit a lot of cognitive features & preferences; Problem: Cognitive load and instructional design need to be balanced
Afnan, M. Z. (2025)	Multiple Intelligences (MI-based pedagogy)	The use of AR/VR in conjunction with AI-based adaptive learning is recommended to support the Multiple Intelligences-Based learning approach.	Systematic Review	integration of MI-based pedagogy and adaptive AI technology is promising for individualized learning in elementary schools; Longitudinal study needed
Hilmiyati (2024)	A teaching approach that adjusts strategies, activities, and materials based on the variety of students' intelligence, so that learning becomes more personalized and effective.	How cognitive technology affects students' thinking ability profiles.	Reviews	Real-time cognitive and adaptive technology can strengthen students' understanding of special needs; demanding adaptive instructional design.
Khabib Sholeh et.al (2025)	Multiple Intelligences	MI-based reading activities integrated in reading instructions	a combination of quantitative (pre-post test,	Multiple Intelligences-based reading instruction has been proven to improve students' literacy comprehension , significantly shape students' character values , and can be

			IRT/Bayesian IRT) and qualitative (class observations, interviews)	an equal and effective educational strategy in the context of Indonesian education, supporting character and literacy reform
Sasmita et al. (2024)	Linguistics, Kinesthetics, Visual	Variety of learning approaches	Observations, interviews	Intelligence variations strengthen students' creativity through adaptive learning.

The main findings show that the operationalization of intelligence variation in adaptive design is still dominated by a rule-based approach with a static profile, although technological developments are beginning to lead to dynamic models. Eight of the fifteen studies (Martin et al., 2020; Alvarez-Icaza, 2024; Wang, 2025) identifies adaptive systems' dependence on linguistic-logical-mathematical intelligence as the default parameter. This dominance creates a bias in the architecture of the system, ignoring dimensions such as naturalist or existential that are precisely relevant in the context of contextual learning (Amini, 2025; Rustan Efendy et al.). This gap is exacerbated by the lack of validation of cross-cultural measurement instruments. Firza (2024) found that the adaptation of MI questionnaires in Indonesia requires a recalibration of confirmatory factors to avoid profile distortion, while Khabib Sholeh et al. (2025) proved the effectiveness of MI integration in reading literacy through local calibration involving classroom observation and in-depth interviews. These findings confirm that intelligence profiles need to be updated in real-time based on learning responses, not just initial scores (Alvarez-Icaza, 2024).

The integration of artificial intelligence (AI) and learning analytics shows significant potential in improving the scalability of personalization, but poses multidimensional challenges. Six studies (Zawacki-Richter et al., 2019; Zerkouk, 2025; Afnan, 2025) reports that AI-based systems are able to predict learning preferences through machine learning from students' digital footprints, such as click patterns or interaction duration. However, Gligorea et al. (2023) warn of the risk of excessive cognitive load when adaptation too aggressively accommodates cognitive preferences without considering instructional design principles. In Indonesia, Syaifulloh (2025) noted an increase in learning engagement using a prototype of an MI-based adaptive system, but the effect on cognitive outcomes was only moderate due to the misalignment between the adaptation algorithm and the national curriculum. A similar finding was put forward by Putra et al. (2024), who highlighted the gap between the technical capacity of system developers and teachers' understanding of intelligence variations. The ethical dilemma also emerged in three studies (Wang, 2025; Zerkouk, 2025; Fitri Hilmiyati, 2024), especially related to data privacy and the potential for stereotyping of cognitive profiles that hinder the development of students' holistic competencies.

Empirical studies in Indonesia reveal the potential for adaptive learning transformation based on intelligence variations, although its implementation is still constrained by infrastructure and resource capacity. Khabib Sholeh et al. (2025) proved that MI-based adaptive reading strategies improve the literacy of comprehension and character of junior high school students through multisensory activities (kinesthetic, musical, visual). Similar results were reported by Sasmita et al. (2024) in science learning in elementary schools, where a variety of activities according to the MI profile triggered students' creativity. However, two studies (Abdiyah & Subiyantoro, 2021; Putra et al., 2024) criticized the implementation that is still intuitive and fragmented. Teachers often have difficulty mapping MI profiles to activity design due to limitations of technical training and affordable diagnostic tools. This condition increases the risk of instructional over-adaptation, where learning activities are designed to follow cognitive preferences without sufficient consideration of instructional sequencing and cognitive load management. As a result, students may experience excessive cognitive demands, which can reduce learning efficiency and negatively affect comprehension and retention, particularly in complex subject matter. From a learning theory perspective, effective learning requires not only personalization of content but also careful alignment with pedagogical principles that support meaningful engagement and manageable cognitive demands. The conceptual framework presented in Learning and Teaching highlights the central role of structured instructional strategies, motivation, and contextualized learning experiences in facilitating deeper understanding and retention, suggesting that adaptive systems should integrate these pedagogical considerations alongside technological adaptation (Evitarini et al., 2025).

Fariani (2022) added that the adaptive learning management system (ALMS) in Indonesia has not systematically accommodated differences in cognitive styles, resulting in inequality of access for students with special needs.

Cross-study analysis yielded three critical principles for intelligent variation-based adaptive learning design. First, multimodal flexibility is necessary to avoid cognitive reductionism. The ideal system must combine various visual, auditory, and kinesthetic modalities in an integrated manner, rather than simply choosing one path according to the dominant profile (Amini, 2025; Afnan, 2025). Second, cultural calibration is a prerequisite for the validity of adaptation. Intelligence measurement instruments need to be revalidated in a local context, as Rahadian et al. (2024) did through the modification of the MI questionnaire for secondary schools in Garut. Third, the technological-pedagogical balance must be maintained to prevent ethnocentrism. Adaptive technology should serve as a reinforcement of proven pedagogical strategies, not a substitute for the role of teachers (Zerkouk, 2025; Fitri Hilmiyati, 2024). This principle is in line with the findings of Kumar et al. (2017), who showed that intelligent tutoring systems are most effective when adaptation algorithms are designed in conjunction with pedagogues and educational psychologists.

The findings of this review highlight the need for an adaptive learning design paradigm that is dynamic, multimodal, and contextually grounded. Adaptive systems should move beyond static intelligence profiles derived from initial assessments and instead incorporate continuous learning-response data to update adaptation parameters in real time. Multimodal flexibility is essential to prevent cognitive bias and over-reliance on dominant intelligence dimensions. Rather than matching learning activities rigidly to a single intelligence profile, effective adaptive systems should integrate visual, auditory, and kinaesthetic modalities in a pedagogically sequenced manner. This approach helps manage cognitive load while maintaining instructional coherence. Importantly, these findings reposition teachers as co-designers within adaptive learning ecosystems. Teachers contribute pedagogical judgment, curricular alignment, and contextual knowledge that cannot be fully captured by algorithms alone. In practice, this may involve teachers validating adaptive recommendations, adjusting activity sequencing, or refining feedback strategies generated by AI-based systems. Such collaboration helps ensure that technological adaptation reinforces rather than replaces sound instructional principles.

These findings confirm the initial hypothesis that intelligence variation has a significant influence on the effectiveness of adaptive learning, but that influence is mediated by technical, pedagogical, and cultural factors. The dominance of the single intelligence paradigm in the architecture of educational technology systems needs to be challenged through multidisciplinary collaboration between AI developers, instructional designers, and field practitioners. At the policy level, national standards for the validation of diagnostic instruments and ethical frameworks for the use of cognitive data are needed. Further research is suggested to focus on the development of prototypes of hybrid adaptive systems that combine artificial intelligence with teacher intervention, as well as longitudinal studies to measure the long-term impact on the development of students' multidimensional competencies.

The limitations of this study lie in the dominance of qualitative studies and small-scale implementation in the reviewed literature, so the generalization of findings needs to be done carefully. Most of the empirical evidence comes from research in developed countries with adequate educational technology infrastructure, while the Indonesian context still faces challenges of access, teacher capacity, and alignment with the national curriculum. Future research is suggested to develop a prototype of a hybrid adaptive system that combines artificial intelligence with teacher intervention, as well as conduct longitudinal trials to measure the long-term impact on the development of students' multidimensional competencies. The development of ethical standards for the use of cognitive data and a cross-cultural instrument validation framework is also a critical agenda in efforts to realize an inclusive and equitable adaptive learning ecosystem.

Conclusion

The findings of this systematic literature review confirm that intelligence variation has a significant influence on the effectiveness of adaptive learning; however, this influence is mediated by the complexity of theoretical operationalization, the availability of responsive technologies, and the cultural context of implementation. An analysis of fifteen empirical studies reveals the dominance of a reductionist paradigm in the utilization of intelligence profiles, where adaptive systems tend to rely primarily on linguistic-logical-mathematical intelligence as default adaptation parameters. This approach contrasts with Gardner's theoretical framework, which conceptualizes intelligence as a constellation of relatively autonomous but interacting dimensions. While Gardner emphasizes the need to recognize diverse intelligence profiles holistically, many adaptive systems operationalize intelligence in a narrow and static manner, limiting adaptation to a small subset of cognitive strengths. As a result,

learners with non-dominant intelligence profiles, such as naturalist, interpersonal, or existential—are less optimally supported within current system architectures. In the Indonesian context, empirical evidence demonstrates meaningful potential for transformation through locally calibrated intelligence measurement instruments and multisensory integration in instructional design. Studies reviewed indicate improvements in students' reading literacy, creativity, and character development when adaptive learning is grounded in Multiple Intelligences-based principles that align with cultural and curricular realities.

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