



AI-Based Metacognitive Model in Learning to Writing Scientific Papers: Transformation of Indonesian Language Education in The Digital Eramodel

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Abstract. The low metacognitive awareness of students and the limited feedback capacity provided by lecturers are challenges faced in learning to write scientific papers in higher education. This conceptual article aims to design a Metacognitive Model Based on Artificial Intelligence (AI) Technology that can be used as a transformative framework in learning Indonesian in the digital era. Through a systematic review of the latest literature in the period 2015-2026, this article identifies three main theoretical foundations, namely: (1) Flavell's metacognitive theory strengthened by Zimmerman's Self-Regulated Learning (SRL) model, (2) Sanulita's Metacognitive Writing Model (2023), and the development of AI utilization in higher education. The proposed model consists of five integrated components, namely AI-assisted adaptive planning, real-time feedback-based monitoring, meta-reflective reflection through digital journals, hybrid multilayered evaluation, and continuous self-regulation. This article emphasizes that AI integration is not just a tool, but a transformation agent that can change the paradigm of Indonesian language teaching towards a learning ecosystem that is personalized, responsive, and globally competitive.

Keywords: metacognitive model; artificial intelligence; write scientific papers; digital transformation



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1. Introduction

The skill of writing scientific papers is an important skill that students must master in college. Writing skills are a complex activity that requires a writer to use various skills simultaneously such as cognitive, metacognitive and affective skills. Apart from that, writing also includes social and contextual factors such as the environment and social interactions. However, various studies show that the majority of students in Indonesia still face significant difficulties in producing scientific writing that is coherent, argumentative and meets academic standards. The difficulties faced by these students are not only linguistic, but stem from low metacognitive awareness, namely the ability to plan, monitor and evaluate thinking and writing processes independently.

The research results also show that the relationship between metacognitive awareness and writing skills is in a very strong and positive category, so that students who have a high level of metacognitive awareness tend to produce quality scientific work. Therefore, metacognitive integration is needed in learning to write scientific papers in order to facilitate the strengthening of metacognitive knowledge. Metacognitive learning strategies are high-level executive skills that can help students become more independent, autonomous, and able to plan, monitor, and evaluate the learning process. Recent research in Indonesian universities shows that metacognitive strategies have contributed significantly to students' academic writing skills.

The metacognitive model includes eight main dimensions, namely declarative, procedural, and conditional knowledge, as well as regulation involving planning, monitoring, evaluation, information management, and improvement strategies (debugging). Through metacognitive awareness, writers are able to maintain the quality of their writing process from the idea planning stage to the final revision. This is very important in writing scientific papers because when writing, students must be able to organize complex ideas coherently and cohesively. The development of AI (artificial intelligence) technology has brought significant changes to language learning, particularly in writing skills. The presence of Large Language Models (LLM) such as ChatGPT, Grammarly, and various other writing platforms has brought major and fundamental changes to the writing learning process.

These technological developments enable students to obtain rapid and continuous feedback throughout the writing process. The integration of AI technology in language learning has been proven to provide more in-depth and useful feedback than conventional feedback. In addition, AI systems are also capable of analyzing argument structure and identifying various inconsistencies in written text. AI-based platforms can even accompany students interactively at every stage of writing, making the learning process more effective and focused. The use of artificial intelligence (AI) in higher education has significantly changed the academic writing process from a traditional cognitive activity to a complex interaction between humans and technology. The presence of AI can provide convenience to writers to help draft writing and correct grammatical errors in a more systematic and structured manner.

However, behind these benefits, new challenges will emerge in the form of writing anxiety and the risk of cognitive debt resulting from dependence on AI technology. Therefore, in this context, the development of metacognitive strategies and self-efficacy are important aspects needed by writers, especially students, to be able to maintain control of their thinking processes, creativity, and intellectuality during the writing process. Metacognitive strategies consisting of planning, monitoring, and evaluation have been shown to act as negative predictors of writing anxiety. Students who have good metacognitive regulation tend to be able to manage cognitive load better and more effectively by utilizing AI as a cognitive aid or assistant that supports the learning process, not as a substitute for their thinking abilities.

The current digital transformation is encouraging educators to begin utilizing artificial intelligence (AI) in various aspects of education, including language learning and academic writing. Systematic studies on AI in education show that the application of AI needs to be integrated with a strong pedagogical perspective so that technology does not merely function as a technical tool but is able to support meaningful learning processes. The presence of Generative AI opens up great opportunities to transform education through changes in learning processes and outcomes that are more adaptive to the challenges of the digital era. The implementation of AI as a metacognitive scaffolding provider can be an innovative alternative in learning to write because it can help students develop higher-order thinking strategies during the writing process.

Writing-based AI systems can be used to help students identify errors, improve sentence structure, and improve the quality of the resulting writing. Feriyanti, et.al. highlighted that AI is not only able to identify and correct technical errors such as grammar, spelling, and punctuation, but can also provide input on writing clarity, creativity, and originality. However, the use of AI in the context of Indonesian language education, especially for learning to write scientific papers, still lacks a systematic and contextual model framework. Therefore, a model is needed that is able to integrate the strengths of established metacognition theory with the pedagogical potential of AI technology. The demands of 21st-century learning require students to be able to manage their thinking processes consciously and independently. Based on this, a model is needed that pedagogically integrates metacognitive theory with AI technology.

Metacognitive theory has proven effective in developing the ability to plan, monitor, and evaluate the learning process, but its application is still hampered by the limited availability of personalized, continuous, and real-time feedback. To address these limitations, the integration of AI technology is needed to address these limitations through analysis of learning patterns, adaptive recommendations, and facilitation of self-reflection. An integrative model that positions

AI not as a substitute for thinking processes, but rather as a tool to strengthen metacognitive functions, thus facilitating a more personalized and independent learning process. The integration of metacognitive and AI must ensure that the use of AI in education strengthens students' thinking awareness, decision-making skills, and intellectual responsibility in constructing meaningful knowledge.

Based on this background, this article aims to: (1) identify the theoretical basis of an AI-based metacognitive model in learning to write scientific papers; (2) design integrative and applicable model components; and, (3) discuss the implications of the model for the transformation of Indonesian language education in the digital era. Through an interdisciplinary perspective that connects applied linguistics, educational psychology, and educational technology, this article is expected to be a meaningful conceptual contribution to the development of the science and practice of Indonesian language education.

2. Methodology

This article uses a systematic literature review (SLR) approach with a conceptual analytical design. This method is used because it is in accordance with the research objectives which are conceptual in nature, namely designing a theoretical model based on critical synthesis of the latest literature. The SLR approach allows researchers to identify, evaluate, and synthesize scientific evidence in a transparent and replicable manner. This study refers to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol as a reporting framework to ensure the quality, consistency, and accountability of the review process.

Data collection was carried out through a systematic literature search in reputable scientific databases, including Google Scholar, Scopus, ERIC, and the national journal portal Sinta, using keywords: "metacognitive model", "AI in academic writing", "self-regulated writing", "digital Indonesian language education", "artificial intelligence higher education". The search timeframe was limited to publications from 2015-2026 to ensure the relevance of the findings to the development of AI technology and contemporary educational practices. The screening process was conducted in stages based on inclusion criteria established prior to the search (a priori). The inclusion criteria consisted of: journal articles, proceedings, or book chapters from 2015–2026.

Discussing metacognition, SRL, AI in education, or academic writing, available in Indonesian or English, published in peer-reviewed journals, and relevant to the higher education context. Coding was conducted inductively and deductively using a layered thematic approach. This process refers to coding adapted from a systematic literature review. The coding stages consisted of:

1. Stage 1 (Deductive Coding): This stage involved initial coding derived from the established theoretical framework, namely: metacognitive theory (Flavell), the SRL Model (Zimmerman), the Metacognitive Model of Writing (Sanulita, 2023), and the Taxonomy of AI Utilization in Education.
2. Stage 2 (Inductive Coding): This stage included new codes emerging organically from the literature to capture previously unanticipated findings.
3. Stage 3 (Grouping Codes into Themes): Interrelated codes were grouped into major themes, which then served as the basis for designing model components, including: (1) adaptive planning, (2) real-time monitoring, (3) meta-reflective reflection, (4) hybrid evaluation, and (5) self-regulation.

The collected data was analyzed using thematic analysis techniques as developed by Braun & Clarke [19]. The analysis process included the following stages: (1) familiarization with the data, (2) generalization of data codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing analytical reports.

3. Results and Discussions

3.1 Theoretical Foundation: Synthesis of Primary Literature

A systematic review of the literature yielded a conceptual map linking three major theoretical clusters. Table 1 summarizes the primary sources that form the foundation of the model.

Table 1. Synthesis of Primary Literature

Source	Theme/Concept	Main Contribution	Relevance
Flavell (1979)	Metacognition Theory	Conceptual basis of cognitive monitoring	High
Zimmerman (2000)	Self-Regulated Learning (SRL)	Planning-monitoring-reflection cycle	High
Sanulita (2023)	Metacognitive Model of Writing	Indonesian academic context, metacognition model, reflective journal	High
Cope & Kalantzis (2009)	Multiliteracies & Technology	Integration of digital media in literacy	High
Roll & Wylie (2016)	AI in Education	Intelligent tutoring systems & metacognition	High
Zawacki-Richter et al. (2019)	Systematic Review AI-Education	AI supports personalization of learning	High
Godwin-Jones (2017)	Technology & Language Learning	NLP tools in learning to write	High
Lim et al. (2023)	ChatGPT & Higher Education	The potential & challenges of LLM for academics	High

The synthesis of the table above shows that: metacognition theory requires a technological medium to be operationalized effectively in the current higher education context. Flavell [20] asserts that metacognition includes knowledge of one's cognition and regulation of those cognitive processes. Zimmerman developed a SRL cycle consisting of three phases: planning, implementation, and self-reflection. These three phases align with AI's capabilities in providing learning scaffolding. To clarify the proposed model's position, Table 2 presents a comparison of three paradigms for learning to write scientific papers.

Table 2. Comparison of Paradigms for Learning to Write Scientific Papers

Aspect	Conventional Learning	Metacognitive Approach	AI-Based Metacognitive Model
Planning	Teacher-determined	Independent by students	AI helps with adaptive planning
Monitoring	Limited	Manual reflective journal	Real-time AI feedback
Evaluation	Summative only	Formative & summative	Data-driven, multi-layered evaluation
Feedback	Delayed	Time-limited	Instant and personalized
Scalability	Low	Medium	High

Source: adapted from Sanulita (2023), Roll & Wylie (2016), and Zawacki-Richter et al. (2019)

Table 2 confirms that the AI-Based Metacognitive Model represents a paradigmatic evolution, not simply a feature addition. The most important difference lies in the feedback capacity this model can provide: from delayed and limited to instant and personalized, and in its scalability, which allows for individualized learning, even in large classes.

3.2 AI-Based Metacognitive Model Design

Based on theoretical synthesis and comparative analysis, this article proposes an AI Technology-Based Metacognitive Model (AI-MMBT) consisting of five integrated components. This model is built on three main pillars, namely: (1) metacognitive pillar consisting of: awareness, regulation, and evaluation of thinking processes, (2) pedagogical pillar consisting of: scaffolding principles, differentiation, and meaningful learning (Vygotsky, in Sanulita, (3) technological pillar: AI as an adaptive tutor, feedback agent, and learning analytics system.

Table 3. Components of the AI Technology-Based Metacognitive Model

Components	Actors	Activities	Outputs
1. Adaptive Planning (AI-Assisted Planning)	Students, AI tutors	Goal setting, topic analysis, AI-assisted idea mapping	Structured and realistic writing plans
2. Real-Time Monitoring (AI Feedback Loop)	Students, AI, Lecturers	Automatic text analysis, cohesion suggestions, argument consistency	Data-driven incremental revision
3. Meta-Reflective Reflection (Digital Journal)	Students	Digital reflective journal, AI-assisted self-assessment prompts	Increased metacognitive awareness
4. Multi-Layer Evaluation (Hybrid Assessment)	Lecturers, AI, Peers	Digital rubric, peer review, AI analysis for plagiarism and coherence	Comprehensive and accountable assessment
5. Self-Regulation	Students	Personal progress dashboard, AI-based goal setting	Long-term learning independence

The MMBT-AI model operates in a five-phase cycle that is spiral and reflective, rather than linear. Here's an operational description of each phase:

Phase 1: Adaptive Planning

In this phase, students interact with an AI tutor to map out topics, identify writing objectives, and develop an argumentative framework. The AI analyzes the student's learning profile based on previous interaction history and provides personalized structure recommendations. The instructor acts as a facilitator, validating the initial plan.

Phase 2: Writing with Real-Time Monitoring

Throughout the writing process, AI provides incremental feedback on cohesion, coherence, accuracy of scientific terms, and strength of arguments. The Natural Language Processing (NLP) system detects logical inconsistencies and provides specific suggestions for improvement. Students learn to respond to this feedback as part of the metacognitive process, rather than as passive correction.

Phase 3: Meta-Reflective Reflection

During each writing session, students complete a digital reflective journal guided by AI prompts. The prompts are designed to encourage students to answer metacognitive questions such as: What was difficult for me today? What strategies worked? What do I need to change in the next session? This journal data is analyzed by AI to chart the longitudinal development of metacognitive awareness.

Phase 4: Hybrid Multi-Layered Evaluation

Evaluation is conducted in layers: (a) self-assessment using a digital rubric, (b) structured peer review facilitated by the platform, (c) AI analysis for plagiarism and discourse coherence, and (d) a final assessment by the lecturer. This combination produces a comprehensive assessment profile and reduces subjective bias.

Phase 5: Self-Regulation

The AI's personal dashboard displays the development of students' writing competencies over time. Students set new targets based on a gap analysis between their actual abilities and competency targets. The AI provides recommendations for additional learning resources tailored to each student's specific needs.

3.3 Implications of the Model for the Transformation of Indonesian Language Education

AI Based Metacognitive Model has transformative implications at three levels: micro (individual learning), meso (institutional), and macro (national policy).

3.3.1 Micro Level: Shifting Roles of Students and Lecturers

This model shifts the role of students from passive recipients to active agents responsible for their own learning process. Lecturers transition from being sole sources of knowledge to becoming learning environment designers and metacognitive mentors. This role

transformation aligns with the demands of the Independent Curriculum, which emphasizes student-centered learning [16].

3.3.2 Meso Level: Reconstruction of Study Program Curriculum

Indonesian Language Education study programs need to reconstruct scientific writing courses by integrating digital literacy competencies as an explicit learning outcome. The MMBT-AI model can be used as a reference in developing Semester Learning Plans (RPS) that are responsive to technological developments.

3.3.3 Macro Level: Contribution to National Education Policy

In the context of the Impactful Campus and Independent Curriculum policies, this model provides a concrete example of how AI technology can be pedagogically integrated, not simply through the adoption of tools. This model also contributes to strengthening Indonesian digital literacy as part of the nation's identity and competitiveness in the global era.

Discussions

The literature synthesis presented in Table 1 confirms that the theoretical foundation of the AI-Based Metacognitive Model (AI-MMBT) is rooted in three mutually reinforcing theoretical clusters: Flavell's metacognitive theory, Zimmerman's Self-Regulated Learning (SRL) model, and Sanulita's Metacognitive Model of Writing (2023). The interconnectedness of these clusters is not merely a conceptual alignment, but rather reflects an urgent epistemological need: a pedagogical framework capable of bridging the potential of technology with the depth of students' thinking processes. Flavell's pioneered metacognitive theory asserts that a person's awareness of their own thinking processes is a primary prerequisite for effective learning.

In the context of contemporary higher education, research by Okonkwo & Awonuga shows that students with high metacognitive regulation consistently produce more coherent and argumentative academic writing compared to their peers who rely solely on external feedback, thus metacognitive awareness is not merely a supporting factor, but a determining factor in the quality of scientific writing. This is in line with Broadbent's research in a systematic review of 32 studies found that students with high SRL capacity showed better academic performance and learning satisfaction in both online and offline environments.

Furthermore, the Sanulita Metacognitive Writing Model provides crucial local contextualization because this model is rooted in the socio-cultural dynamics of Indonesian language learning, so that MMBT-AI is not just a technological adaptation but a model that is contextual and responsive to the reality of Indonesian language learning. The adaptive planning phase in the MMBT-AI model is built on the assumption that planning at the beginning of the writing process greatly determines the quality of the resulting writing. This is reinforced by Chiu's findings, which state that the involvement of AI as a partner in compiling writing plans can be used to improve the quality of students' argumentative frameworks, especially in terms of analytical depth and logical consistency.

This is also reinforced by a systematic review conducted by Tlili, et.al. on the use of Chat GPT in higher education, which concluded that LLM is most useful when acting as a thinking partner in the planning stage, not as a content generator itself. This is in line with the MMBT-AI model, which positions AI as a planning facilitator, not a substitute for students' thinking processes, while lecturers play an important role as parties who validate the initial plan according to writing objectives and academic standards. The writing phase with real-time monitoring is an element that distinguishes MMBT-AI from conventional metacognitive approaches. Traditional metacognitive models have been hampered by the lack of instant, personalized, and continuous feedback, especially in large classes.

MMBT-AI is able to address these constraints by presenting an AI-based automated feedback system. This is reinforced by the SLR conducted by Cavalcanti, et.al. which shows that the AI-based automated feedback system can provide more specific, actionable, and timely comments than conventional lecturer feedback, especially regarding text cohesion and argument clarity. The Meta-Reflective Reflection phase through digital journals is the core of the MMBT-AI model, designed so that students not only assess their writing results, but also understand their own

thinking processes. This is in line with the views of Harsono, et.al who emphasized that the meta-reflective writing model is considered effective, practical, and relevant as a pedagogical approach to strengthen critical thinking in academic writing, although further refinement of the indicators at the pre-writing stage is still needed.

In MMBT-AI, AI acts as an adaptive reflective scaffolding that adjusts the complexity of the prompt based on the development of students' metacognitive awareness. The hybrid multi-layered evaluation phase combines self-assessment, peer review, AI analysis, and lecturer assessment. This phase reflects the view that the validity of assessment cannot rely on a single perspective. Noroozi, et.al. [28] found that the combination of structured peer review with automated AI analysis resulted in more accurate and comprehensive assessments than either method alone, where peer review trained critical evaluation while AI analysis contributed consistency and objectivity. This combination makes the MMBT-AI evaluation system both formative and summative. The self-regulation phase represents the long-term goal of MMBT-AI, namely to develop independent academic writers.

Farrokhnia et.al.'s concerns regarding cognitive debt resulting from excessive AI use are a key design consideration, so MMBT-AI adopts the principle of gradual release of responsibility so that AI support decreases as students' self-regulation capacity increases. As a conceptual article, MMBT-AI has not undergone empirical field testing, and this is an inherent limitation that needs to be explicitly acknowledged, so empirical validation through quasi-experimental or design-based research in various contexts of Indonesian Language Education study programs is an essential next step. Further research is also needed to examine the differential effectiveness of model components on various student characteristics, as well as to develop contextualized and validated metacognitive awareness measurement instruments in Indonesian.

4. Conclusions

This article produces a conceptual framework called the AI-Based Metacognitive Model (AI-MMBT), an integrative model that combines the theoretical foundations of metacognition with the capabilities of artificial intelligence technology in the realm of scientific writing learning in Indonesia. This model framework consists of five integrated components: adaptive planning, real-time monitoring, meta-reflective reflection, hybrid multi-layered evaluation, and self-regulation. These five components do not operate linearly, but rather form a dynamic spiral cycle so that each stage can influence and strengthen the learning process continuously. The MMBT-AI model addresses the conceptual gap between established academic metacognition theory and the rapidly evolving dynamics of AI technology in Indonesian language education.

By presenting a common ground between the two, this model is not only theoretical but also offers an operational framework that allows for direct implementation and further development in the context of higher education in Indonesia. The MMBT-AI model is considered both relevant and applicable to practitioners and educational stakeholders. A fundamental aspect that distinguishes this model from other educational technology approaches lies in its perspective on the role of artificial intelligence in the teaching and learning process, particularly in writing. The MMBT-AI model firmly positions AI not as a substitute for human cognitive abilities. AI is used solely as a tool, a learning partner that functions to strengthen students' metacognitive awareness while fostering their learning autonomy. With this perspective, the involvement of technology is directed at optimizing potential, not diminishing or replacing it.

The transformation of Indonesian language education in the digital era is essentially not simply a matter of adopting technological devices, but rather a comprehensive reconstruction of the learning paradigm. This paradigm places humans, with all their complex cognitive, affective, and cultural dimensions, at the center of every pedagogical reform. Within this framework, the MMBT-AI model presents a concrete contribution that can serve as both a conceptual and practical offering to realize the vision of a humanistic, adaptive, and competitive education amidst the ever-evolving digital landscape.

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