

ABSTRAK

Generative AI saat ini masih didominasi pendekatan *single-pass* yang bergantung pada instruksi tunggal tanpa mekanisme internal untuk perencanaan multi-langkah, kontrol, dan evaluasi terintegrasi, sehingga media pembelajaran visual yang dihasilkan sering gagal memenuhi kecocokan tingkat kognitif pembelajar serta prinsip pedagogis seperti *Cognitive Load Theory* dan *Dual Coding Theory*. Penelitian ini bertujuan merancang dan mengevaluasi arsitektur *Agentic AI* berbasis sistem multiagen yang mampu melakukan dekomposisi konseptual secara adaptif dalam satu siklus generasi representasi visual edukatif. Arsitektur dibangun menggunakan metodologi rekayasa perangkat lunak *Prometheus* yang diadaptasi untuk agen berbasis *Large Language Model* (LLM). Sistem mendistribusikan tugas kepada agen terspesialisasi mencakup analisis materi, dekomposisi konseptual, penyusunan *framing slide*, hingga generasi konten visual, dengan audit gate pedagogis di tengah *pipeline* untuk mencegah kesalahan sejak dini. Evaluasi dilakukan secara multi-lapis, meliputi validasi ahli serta pengukuran otomatis menggunakan *FKGL*, *ROUGE-N*, *Groundedness Score/Ratio*, dan *Mermaid render rate*, ditambah studi ablasi internal dan eksternal. Studi ablasi arsitektur menunjukkan bahwa granularitas agen Per fase (tiga agen per fase) merupakan konfigurasi paling optimal, mencetak *groundedness ratio* 100% dan tingkat keberhasilan *render* diagram 100%, sekaligus paling efisien dari sisi komputasi dan latensi dibanding penggunaan agen yang terlalu banyak. Studi ablasi eksternal membuktikan arsitektur multiagen secara signifikan mengungguli pendekatan *single-pass* dengan model LLM yang identik, kesesuaian isi terhadap buku referensi (skor *ROUGE F1*) hampir tiga kali lipat lebih tinggi, dan keandalan representasi visual meningkat drastis dari 28,6% menjadi 100%. Secara keseluruhan, arsitektur *Agentic AI* ini terbukti mampu menutupi kekurangan pendekatan generatif *single-pass*, menghasilkan proses otomatisasi materi ajar dan dapat dipertanggungjawabkan secara pedagogis.

Kata Kunci : *Agentic AI*, Evaluasi Pedagogis, *Large Language Model*, Media Edukasi Visual, *Multi-Agent Systems*,

ABSTRACT

Generative AI is currently still dominated by single-pass approaches that rely on a single instruction without internal mechanisms for multi-step planning, control, and integrated evaluation; as a result, the visual learning materials produced often fail to align with learners' cognitive levels and pedagogical principles such as Cognitive Load Theory and Dual Coding Theory. This research aims to design and evaluate an Agentic AI architecture based on a multi-agent system capable of performing adaptive conceptual decomposition within a single cycle of educational visual representation generation. The architecture was built using the Prometheus software engineering methodology, adapted for agents based on Large Language Models (LLMs). The system distributes tasks to specialized agents, covering material analysis, conceptual decomposition, slide framing, and visual content generation, with pedagogical gate audits midway through the pipeline to prevent errors early on. Evaluation was conducted in multiple layers, including expert validation and automated metrics using FKGL, ROUGE-N, Groundedness Score/Ratio, and Mermaid render rate, along with internal and external ablation studies. Architectural ablation studies show that a per-phase agent granularity (three agents per phase) is the most optimal configuration, achieving a 100% groundedness ratio and a 100% diagram rendering success rate, while also being the most efficient in terms of computational resources and latency compared to using too many agents. External ablation studies demonstrate that the multi-agent architecture significantly outperforms the single-pass approach using an identical LLM model, with content alignment to the reference book (ROUGE F1 score) nearly three times higher, and the reliability of visual representations increasing dramatically from 28.6% to 100%. Overall, this Agentic AI architecture has proven capable of addressing the shortcomings of single-pass generative approaches, resulting in an automated process for creating instructional materials that is pedagogically sound.

Keywords: *Agentic AI, Large Language Model, Multi-Agent Systems, Pedagogical Evaluation, Visual Educational Media*