



A Methodological Review of Personalized and Conversational AI-Based Tutoring for Online Learning

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ABSTRACT :

While online learning platforms have democratized access to educational content, self-directed learners still face persistent challenges in structuring study materials, obtaining context-sensitive explanations, assessing comprehension, and monitoring mastery over time. Recent advancements in artificial intelligence address these limitations through personalized learning, intelligent tutoring systems (ITS), conversational agents, large language models (LLMs), retrieval-augmented generation (RAG), automated assessment, and learning analytics. This paper presents a methodology-focused review of 50 research studies charting the evolution of digital and self-directed learning toward personalized, conversational AI tutoring. We examine how learner profiles, adaptive mechanisms, conversational interaction, knowledge grounding, assessment routines, feedback generation, and learner-state tracking have been implemented and evaluated. Rather than classifying AI techniques in isolation, this review analyzes candidate methodologies based on their specific educational functions and architectural roles. Our synthesis indicates that while personalization, dialogue, grounding, assessment, and analytics are mature individual domains, their integration into an end-to-end, learner-centered tutoring loop remains limited. We formulate this gap as one of methodological fragmentation: curriculum grounding, contextual dialogue, learner-state modeling, assessment feedback, and longitudinal progress tracking are predominantly deployed as isolated modules. To resolve this fragmentation, we derive a set of methodological requirements for next-generation tutoring architectures—encompassing an LLM conversational layer, retrieval-based grounding, semantic content retrieval, a persistent learner model, adaptive assessment routines, targeted feedback, and cumulative progress tracking—establishing a traceable path from literature analysis to system design.

Index Terms—personalized learning, intelligent tutoring systems, conversational AI, large language models, retrieval-augmented generation, learner modeling, adaptive assessment, learning analytics.

I. INTRODUCTION

The rapid expansion of online education has shifted the primary role of the student from a classroom-bound participant to an autonomous consumer of digital instructional resources. Video platforms, learning management systems (LMS), open repositories, and AI assistants enable students to curate study materials, progress at individual paces, and solicit on-demand instructional support. Prior research on YouTube-based self-directed learning and YouTube-LMS learning analytics demonstrates that open video resources and learner interactions yield valuable instructional opportunities along with rich behavioral signals [1]–[5]. However, unassisted access to learning materials does not inherently guarantee conceptual understanding, nor does it ensure that students can accurately identify their own knowledge deficits. Consequently, research in artificial intelligence has moved beyond passive content dissemination toward personalized instruction and adaptive cognitive scaffolding. Early personalized learning environments leveraged static learner profiles, learning-style classification, algorithmic recommendation engines, domain knowledge graphs, and adaptive learning paths [6]–[15]. Intelligent tutoring systems (ITS) advanced this paradigm by detecting conceptual misconceptions and dynamically tailoring instructional interventions. More recently, educational platforms have incorporated conversational agents and LLMs to facilitate unconstrained natural language interaction, explanations, hints, feedback, and targeted problem-solving guidance [17]–[27]. While LLM-based tutoring provides conversational fluency and flexibility, it introduces significant challenges regarding factual reliability, contextual drift, and instructional hallucination. To mitigate these risks, recent literature increasingly couples LLMs with retrieval-augmented generation (RAG), vector databases, semantic retrieval, and curated pedagogical knowledge bases [28]–[37]. In parallel, research on LLM-driven question generation and formative assessment demonstrates that unstructured educational content can be automatically converted into diagnostic quizzes, targeted feedback, and interactive evaluation modules [38]–[47]. Furthermore, learning analytics and multimodal learner-state modeling demonstrate that behavioral and performance telemetry can dynamically steer learning trajectories [48], even as issues surrounding sparse performance data present persistent modeling challenges [49]. These converging trends justify a methodology-focused synthesis over a conventional technology survey. Rather than cataloging the popularity of specific AI algorithms, this review investigates how disparate methods across the literature can be holistically integrated to support an ongoing, self-directed learning workflow. Recent surveys similarly report rapid growth across AI-driven personalized learning and LLM-based ITS, while highlighting recurring bottlenecks in factual grounding, personalization fidelity, feedback quality, continuous student monitoring, scalability, and empirical evaluation. Work by [50] and related IEEE reviews further emphasize the necessity of examining these instructional capabilities in an integrated framework.

II. LITERATURE REVIEW

A. Online and Self-Directed Learning

Studies [1]–[5] establish the foundational context in which automated AI tutoring operates. Platforms such as YouTube allow independent learners to select learning resources autonomously, while integrated analytics capture granular engagement signals, including watch duration, playback trajectories, and view frequencies. Although these studies validate the utility of digital platforms and quantify user engagement, their primary analytical focus centers on resource curation and broad behavioral patterns rather than on sustained, individualized cognitive scaffolding. The literature highlights an initial baseline requirement: an effective tutoring methodology must interface with and structure pre-existing online educational materials rather than assuming that content delivery alone satisfies instructional needs.

B. Personalized Learning and Intelligent Tutoring Systems

Studies [6]–[17] show the progression from recommendation toward adaptive tutoring. Learning-style prediction, learner profiles, knowledge-point mastery, knowledge graphs, behavior detection, adaptive paths, and performance metrics have all been used to personalize learning. A recurring methodological principle is that personalization requires some representation of the learner. This representation may contain interests, prior knowledge, performance, learning behavior, or interaction history. The limitation is that many systems treat the learner model as a recommendation or adaptation component rather than as persistent state shared with a conversational tutor.

C. Conversational AI and LLM-Based Tutors

Studies [18]–[27] document the transition toward natural language tutoring interfaces. Modern chatbots and LLMs support dialogue-driven conceptual explanations, guided problem-solving, and adaptive responses. Comparative evaluations indicate that underlying model families exhibit substantial variation in reasoning accuracy, pedagogical depth, and answer consistency. Notably, investigations into Feynman-style pedagogical agents and self-regulated learning systems demonstrate that LLMs perform substantially better when constrained by structured pedagogical strategies rather than operating as open-ended question-answering systems. The literature reveals that an effective conversational tutor requires not only an underlying foundational language model, but also a systematically structured pedagogical interaction policy.

D. Retrieval-Augmented and Knowledge-Grounded Tutoring

Studies [28]–[37] address a critical failure mode of unconstrained LLM tutoring: the generation of syntactically plausible answers that are factually unsupported by or misaligned with the student's primary curriculum. RAG frameworks counteract this by querying authoritative knowledge repositories prior to answer generation. Educational implementations routinely employ dense text embeddings, vector databases, semantic indexing, conversation-history-aware retrieval, and localized course repositories to enhance factual precision and contextual relevance. Nevertheless, existing implementations typically ground outputs against static text documents or institutional course notes; few systems integrate contextual grounding with persistent student modeling and continuous formative assessment. In video-based learning environments, this challenge is compounded because semantic similarity alone is insufficient: retrieved evidence must also correspond to exact temporal coordinates within the source media.

E. Assessment, Feedback, and Learning Analytics

Studies [38]–[49] demonstrate advancements in automated assessment and feedback generation. LLMs and RAG pipelines are increasingly utilized to synthesize multiple-choice questions (MCQs), diagnostic quizzes, cognitively stratified assessment items, and video-derived evaluative prompts. Complementary formative-assessment frameworks emphasize evidentiary alignment, cognitive validation, and actionable diagnostic guidance. Furthermore, automated oral assessment and multimodal learning analytics extend the assessment paradigm beyond discrete quiz scoring. However, automated question generation remains largely evaluated as an isolated task. An unexploited methodological opportunity lies in routing real-time assessment outcomes directly back into the core learner model to steer subsequent conversational tutoring and instructional recommendations.

III. REVIEW METHODOLOGY

This review follows a systematic, methodology-oriented analytical protocol. The candidate corpus was assembled through structured scholarly database queries, verified primarily via IEEE Xplore, and supplemented by high-impact peer-reviewed external venues where specific methodological evidence was required. The synthesis focuses deliberately on recent literature to reflect the paradigm shifts introduced by modern LLM architectures. The resulting analytical set comprises 50 studies spanning online video learning, personalized learning environments, classical ITS, conversational agents, LLM tutors, RAG pipelines, automated assessment, and learning analytics.

A. Search Strategy

Representative search combinations included:

"personalized learning" AND "AI tutor"

"intelligent tutoring system" AND "conversational AI"

"large language model" AND tutoring AND education

"LLM" AND "AI tutor"

"retrieval augmented generation" AND education

"RAG" AND "intelligent tutoring system"

"video-based learning" AND AI tutor

"video" AND RAG AND education

"adaptive learning" AND learner modeling

"AI" AND quiz generation AND education

"AI" AND formative assessment AND education

B. Inclusion and Exclusion Criteria

Studies were included if they presented an empirical or methodological contribution to AI-driven instruction, intelligent tutoring, personalization frameworks, conversational interaction, factual knowledge grounding, automated assessment, pedagogical feedback, or student modeling. Publications were excluded if they discussed superficial enterprise software overviews, non-refereed commentaries, broad generic AI applications, or non-educational domains. Relevant non-IEEE publications were retained in the working set where they directly resolved an identifiable architectural gap; formal adherence to departmental citation guidelines will be coordinated with the project guide.

C. Data Extraction

Each selected paper was systematically cataloged across educational context, tutoring system classification, core AI methodology, evaluation framework, principal empirical results, noted architectural limitations, and methodological implications. The core objective of this data extraction was to synthesize

recurrent systemic limitations across disparate publications into an operational set of architectural requirements. This 50-study analytical matrix directly underpins the research-gap and methodology-selection frameworks.

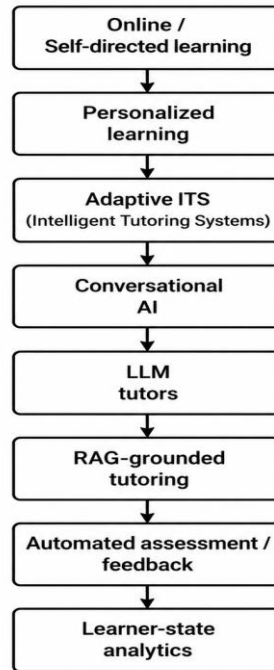
D. Analytical Procedure

The literature synthesis followed a four-phase workflow: (1) functional categorization of studies by educational objective and technical role; (2) thematic extraction of cross-cutting system capabilities and architectural failure points; (3) derivation of concrete methodological requirements addressing these recurrent limitations; and (4) comparative mapping of candidate technologies against these requirements. This progression ensures that the recommended technical architecture is directly grounded in empirical findings rather than retrofitted post hoc.

IV. RESULTS AND DISCUSSION

A. Evolution of the Research Area

The 50 studies reveal a progression rather than a set of unrelated technologies:



This technical progression reflects an evolving pedagogical challenge: moving from initial content accessibility to interactive dialogue, factual grounding, continuous diagnostic evaluation, and closed-loop personalization..

B. Cross-Study Findings

TABLE I. CROSS-STUDY RESEARCH FINDINGS AND METHODOLOGICAL REQUIREMENTS

Literature Finding	Observed Limitation	Requirement	Methodological Direction
Conversational tutors improve interaction	Responses may remain reactive or weakly pedagogical	Structured multi-turn tutoring	Pedagogically guided LLM
LLMs provide flexible explanations	Accuracy/hallucination remains a concern	Reliable knowledge grounding	RAG
RAG improves contextual relevance	Many systems use static documents	Content- and, where needed, time-aware retrieval	Semantic/timestamp-aware retrieval
Personalized systems use profiles/mastery	Learner model is often separate from dialogue	Persistent learner state	Learner profile/mastery model
Adaptive ITS uses assessment	Assessment and tutoring are often separate	Assessment-to-feedback loop	Integrated assessment + feedback
Quiz generation is increasingly automated	Generated questions are not always linked to learner weaknesses	Learner-state-aware assessment	Grounded adaptive assessment
Learning analytics captures behavior	Signals are not always fed back to the tutor	Continuous state update	Progress/mastery model
Video learning is widely used	Watching alone does not ensure mastery	Active support around content	Video-grounded tutoring
Integrated prototypes exist	Longitudinal learner-centered evaluation remains limited	End-to-end architecture + evaluation	Integrated tutoring loop

TABLE III. SUMMARY OF THE 50 REVIEWED STUDIES

Ref .	Year / Paper / Venue	Learning Context / Tutor Type / AI Method	Main Finding	Limitation / Gap	Methodological Implication
1	2022 Choosing YouTube Videos for Self-Directed Learning IEEE Access	YouTube/self-directed Video selection —	Top-ranked choices did not predict problem-solving; conceptual learning needs thoughtful strategies.	Passive/self-directed video learning needs additional support.	Video learning context
2	2021 Learning Analytics of YouTube Videos Linked to LMS Moodle MIPRO	YouTube + Moodle Learning analytics —	Watch time, views and viewing patterns can be analyzed.	Analytics is not integrated with tutoring.	Learner activity signals
3	2023 Relationship Between Cognitive Features and Social Media Engagement: An Analysis of YouTube Science Videos IEEE TEM	YouTube science Video engagement —	Segmenting/signaling relate to engagement.	Engagement analysis is not personalized tutoring.	Video/context features
4	2024 Exploring Digital Learning Pathways: Student Use of Online Information Resources and the Role of AI WEEF-GEDC	Google/YouTube/AI Self-directed learning AI tools	Heavy reliance on digital tools can cause information overload/superficial understanding.	Need deeper, guided learning.	Grounded learning support
5	2024 Investigating YouTube's Educational Videos: Patterns, User Conduct and Suggestion Techniques ICESIC	YouTube Recommendation Content/collaborative filtering	Educational-video recommendation can improve resource discovery.	Recommendation is not tutoring/mastery.	Recommendation layer
6	2022 AI-Based Learning Style Prediction in Online Learning for Primary Education IEEE Access	Online portal Personalized recommendation Collaborative filtering + learning-style prediction	Learning-style-based recommendations improved learning performance.	Focuses on style, not conversation/mastery.	Learner model
7	2022 Personalized Learning Resource Recommendation Based On Learner Profile IUCC/CIT/DSCI/SmartCNS	Online platform Resource recommendation KNN + learner profile	Profile combines interests and knowledge-point mastery.	No conversational tutor.	Learner profile/mastery
8	2021 A Framework of AI-based Intelligent Adaptive Tutoring System ICCSE	ITS Adaptive tutoring Knowledge graph + DNN + behavior detection	Detects learner weaknesses and adapts resources.	Limited conversational/LLM integration.	Learner model + adaptation
9	2022 The Design and Development of an Adaptive Intelligent Tutoring System Based on Constructive Alignment and Cognitive Theories JCSSE	ITS Adaptive learning Adaptive paths + assessment	Adaptive paths and regular assessment support personalization.	Not conversational/content-grounded.	Assessment-driven adaptation
10	2024 The Design of Guiding and Adaptive Prompts for Intelligent Tutoring Systems and Its Effect on Students' Mathematics Learning IEEE TLT	Mathematics ITS Adaptive prompts Guiding/adaptive prompts	Adaptive prompts improved posttest and completion time.	Prompt adaptation alone does not solve grounding/mastery.	Pedagogical prompting
11	2023 An Intelligent Serious Game for Digital Logic Education to Enhance Student Learning IEEE	Digital logic Personalized scaffolding AI-based tutoring	Timely personalized scaffolding supports learning.	Game-specific and not necessarily conversational.	Timely intervention
12	2023 An Intelligent Tutoring System Proposal Based on Chatbot and Learning Styles to the Project Management Study IEEE	Project management Conversational ITS Chatbot + learning styles	Combines chatbot interaction with personalization.	Limited modern LLM/RAG grounding.	Conversational + personalization
13	2025 Adaptive Versus Non-adaptive Mathematics Tutoring by Social Robots in Tanzanian Primary Schools RO-MAN	Mathematics Adaptive tutoring Adaptive vs non-adaptive	Adaptive tutoring showed slightly higher knowledge gains/engagement.	Robot-specific setting.	Adaptive tutoring
14	2026 Intelligent Adaptive Tutor with Career Recommendations IGNITE	Educational platform Integrated adaptive tutoring ML + NLP + student model	Architecture includes student model, adaptive content, assessment/feedback and analytics.	Career component is outside tutoring; verify detailed metadata.	Integrated learner model
15	2024 Research on Intelligent Recommendation Algorithm of Online Learning Platform Based on Artificial Intelligence EEBDA	Online platform Personalized recommendation Deep learning + data mining	Uses history, interests and subject level for learning paths.	Recommendation separate from tutoring.	Learner history
16	2025 Generative AI for Personalized Learning and Education ICISS	Education Personalized GenAI Generative AI	Synthesizes GenAI personalization approaches.	Review rather than primary experiment.	GenAI personalization
17	2024 A Generative Artificial Intelligence Based Tutor for Personalized Learning SmartBlock4Africa	Education Generative AI tutor Custom GPT + API + repository	Combines tutor, content repository, learner profiles and performance.	Preliminary implementation.	LLM + repository + learner profile

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18	2023 Challenging the Confirmation Bias: Using ChatGPT as a Virtual Peer for Peer Instruction in Computer Programming Education FIE	Programming Conversational AI ChatGPT	ChatGPT virtual peer improved some outcomes/engagement; abstract problems remained difficult.	Conversation alone does not ensure grounding.	Pedagogical conversation
19	2024 Analyzing the Impact of AI-Driven Chatbots as Virtual English Tutors on English Language Learning and Engagement ICAIQSA	English learning Conversational tutoring LSTM chatbot	Supports learning/engagement and personalized paths.	Older chatbot architecture; limited general grounding.	Conversational tutoring
20	2025 Personalization capabilities of current technology chatbots in a learning environment Education and Information Technologies	Higher education Personalized chatbot ChatGPT	Evidence of content adaptation and feedback customization.	Needs broader validation and mastery integration.	Dialogue-based personalization
21	2024 WIP: Beyond Code: Evaluating ChatGPT, Gemini, Claude, and Meta AI as AI Tutors in Computer Science and Engineering Education FIE	CS/engineering LLM tutor evaluation ChatGPT/Gemini/Claude/Meta AI	Evaluates accuracy, persuasiveness and depth.	No persistent learner model.	Multidimensional tutor evaluation
22	2023 Exploring Students' Perceptions of ChatGPT: Thematic Analysis and Follow-Up Survey IEEE Access	Higher education LLM academic support ChatGPT	Useful/easy/motivating, but accuracy limitations exist.	Perception does not prove mastery.	Reliability evaluation
23	2024 Learn Like Feynman: Developing and Testing an AI-Driven Feynman Bot TALE	Learning Conversational tutor LLM + LangChain + RAG	Feynman-style dialogue + RAG produced higher learning gains in a small study.	Small sample.	Active conversation + grounding
24	2025 Designing a Large Language Model Agent to Support Programming Problem Solving Based on Self-Regulated Learning ICET	Programming LLM agent LLM + SRL stages	Uses SRL stages and interaction records.	Needs broader outcome validation.	Pedagogical LLM agent
25	2025 AI Powered Academic Assistant Using Conversational AI ICAECA	Higher education Conversational assistant Conversational AI + retrieval	Context-specific support, document retrieval and analytics.	Broader academic assistant rather than mastery tutor.	Context retrieval + analytics
26	2024 Large Language Model in Higher Education: Leveraging Llama2 for Effective Academic Advising ATC	Higher education Domain LLM Fine-tuned Llama 2	Domain adaptation supports academic advising.	Advising differs from tutoring.	Domain adaptation
27	2023 Exploration and Practice of Applying Large Language Models in Home Education Guidance ICISE-IE	Home education LLM guidance LLM + knowledge base + memory filtering	Knowledge base and memory/prefix filtering reduce hallucination.	Narrow context.	Grounding + memory
28	2024 OpenRAG: Open-source Retrieval-Augmented Generation Architecture for Personalized Learning ICAIRC	Online learning RAG tutoring RAG architecture	Modular retrieval/generation architecture for personalized learning.	Limited learner-model evaluation.	RAG architecture
29	2024 An Interactive Question-Answering System Using Large Language Model and Retrieval-Augmented Generation in an Intelligent Tutoring System on the Programming Domain ICAICTA	Programming RAG conversational ITS LLM + RAG + history-aware retriever	History-aware retrieval supports contextual programming QA.	Small/qualitative evaluation; no mastery tracking.	Conversation + RAG
30	2025 Intelligent Tutoring Agent with Retrieval-Augmented Generation: A Case Study of Quality Management System Course ICCECE	Quality management RAG tutor Vector retrieval + LLM	Grounded explanations and practice questions.	Limited generalization.	Course-grounded tutoring
31	2025 Accessible and Reliable AI Coding Tutors: Augmenting Large Language Models with Retrieval-Augmented Generation for Java Programming EDUCON	Java programming RAG coding tutor RAG + Gemma	RAG improved performance on medium/high difficulty tasks.	Domain-specific evaluation.	Reliable domain grounding
32	2026 Combining RAG, LLMs, Vector Databases and Semantic Search in Intelligent Tutoring Systems ICSCSS	Education Integrated RAG ITS RAG + LLM + vector DB + semantic search	Combines tutoring, flashcards and quizzes with RAG.	Needs stronger learning-outcome validation.	Integrated RAG + assessment
33	2025 Retrieval-Augmented Generation for Scalable, Context-Aware Educational Tools NKCon	Education RAG tools RAG	Supports flashcards, questions, FAQs and interactive chat.	Continuous learner model not central.	Context-aware generation
34	2025 Aduvia: A Multi-Purpose AI-Powered Learning Management System (LMS) NILES	Education AI LMS OCR + embeddings + FAISS + RAG + Llama 3.3	Integrates chat, quiz and feedback; strong retrieval metrics reported.	Longitudinal mastery limited.	Integrated content/RAG/assessment

Ref .	Year / Paper / Venue	Learning Context / Tutor Type / AI Method	Main Finding	Limitation / Gap	Methodological Implication
35	2025 Design and Implementation of a Personalized AI Tutor for University Education Using RAG Redžur	University Personalized RAG tutor RAG + vector DB + prompt engineering	Proposes personalized tutoring and future knowledge-gap adaptation.	Metadata/evaluation needs final verification.	RAG + learner gaps
36	2026 From Surface Learning to Deep Understanding: A Grounded AI Tutoring System for Moodle arXiv	Moodle Grounded Socratic tutor RAG + Socratic tutoring	Grounded dialogue aims at deeper understanding.	Preprint/preliminary.	Grounding + pedagogy
37	2026 Retrieval-Augmented Tutoring for Algorithm Tracing and Problem-Solving in AI Education ACL BEA	AI education RAG tutor Intent-aware Socratic + multimodal RAG	Combines retrieval with pedagogical response strategy.	Very recent; verify final metadata.	Intent-aware RAG
38	2024 MCQGen: A Large Language Model-Driven MCQ Generator for Personalized Learning IEEE Access	Education Personalized assessment LLM + RAG + self-refinement	Generates misconception-aware personalized MCQs.	Assessment often separate from tutoring.	Grounded assessment
39	2024 Enhancing Engineering Education Through LLM-Driven Adaptive Quiz Generation: A RAG-Based Approach FIE	Engineering Adaptive quiz generation LLM + RAG + embeddings + vector DB	RAG-based adaptive quiz generation.	Limited long-term learner modeling.	Adaptive assessment
40	2025 Quiz Generation and Chat Interaction with LLMs: A Design and Implementation of an AI-Based LMS SoftCOM	Education LLM LMS Conversational LLM + RAG	Combines chat, quiz generation and RAG.	Very small study.	Chat + assessment integration
41	2025 Research on Automatic Question Generation Methods for Niche Subjects Based on Large Language Models ICEIT	Niche subjects Question generation Domain LLM + prompt tuning	Knowledge enhancement/data augmentation improve domain question generation.	AQG rather than tutoring.	Domain assessment
42	2025 Real-Time Question Generation from Educational Video Lectures using Deep Learning WCONF	Video lectures Video question generation Whisper + Flan-T5	Generates questions from lecture speech; reported BERTScore 88.94.	No tutoring/mastery loop.	Video → assessment
43	2025 Comparative Analysis of Large Language Models for Automated Question Generation From Video-Based Learning Content IEEE TAI	Video learning Video question generation 10 LLMs	Compares LLMs for question generation from video content.	Generation rather than learner adaptation.	Video-grounded assessment
44	2024 Automatic Question Generation for Cognitive Domain of Outcome-Based Education System ICIT	OBE Assessment generation DistilBERT + Transformers	Targets cognitive levels using course outcomes.	Limited conversation.	Assessment alignment
45	2025 A Three-Stage Framework for Large Language Model-Assisted Formative Assessment and Actionable Feedback in Teacher Education ICAITE	Teacher education Formative assessment Observe–Align–Coach	Connects evidence acquisition, target alignment and actionable feedback.	Needs learner-facing continuous tutoring.	Feedback loop
46	2025 Personalized Assessment in Education: Enhancing MCQ Generation Using Advanced AI and Contextual Learning Models CCUBE	Education Personalized assessment RAG + prompt engineering + self-refinement	Improves relevance/difficulty/diversity etc.	Quality metrics are not mastery outcomes.	Contextual assessment
47	2026 EvalIA: Towards a Hybrid AI-Supported Platform for Oral Performance Assessment EDUCON	Education Oral assessment Multimodal AI + human judgment	Supports oral performance assessment.	Separate from continuous tutoring.	Viva/oral signal
48	2025 Large Language Model-Based Multimodal Learning Analytics and Intelligent Path Planning ICISE-IE	Online learning Learning analytics/path planning LLM + multimodal analytics	Uses text/video/audio/clickstream to plan personalized paths.	Complexity and infrastructure.	Learner-state analytics
49	2025 Data Augmentation for Sparse Multidimensional Learning Performance Data Using Generative AI IEEE record	ITS performance data Learner modeling Generative AI augmentation	Addresses sparse/missing learner-performance observations.	Exact metadata needs final verification.	Robust learner-state data
50	2025 Exploring the Efficacy of ChatGPT in an Undergraduate Electronics Course through Comparative Analysis of Circuit Problem Solving iSTEM-Ed	Electronics LLM-assisted learning ChatGPT	Efficiency/UX benefits but accuracy/misinformation concerns.	Needs stronger grounding.	Grounded LLM requirement

C. Research Gap

The compiled literature demonstrates that standalone implementations of conversational LLMs, RAG frameworks, automated quiz generators, and learning analytics systems are well-documented. Rather, the central open challenge is methodological fragmentation. Individual studies consistently establish successful architectures for isolated instructional tasks; however, these functional modules are rarely integrated into a coherent, bidirectional tutoring loop. Existing literature displays a marked scarcity of architectures that simultaneously guarantee content grounding, conduct natural language dialogue, update persistent student models based on dialogue and test performance, produce actionable feedback from that internal state, and dynamically adapt downstream instructional materials.

Consequently, this review identifies the following research gap: while personalized AI tutoring, conversational LLMs, retrieval-grounded instructional systems, automated assessment engines, and learning analytics have each individually validated their utility, their integration into a unified, content-grounded, assessment-informed, and learner-state-aware tutoring methodology remains fragmented and insufficiently evaluated.

D. Methodological Requirements Derived from the Gap

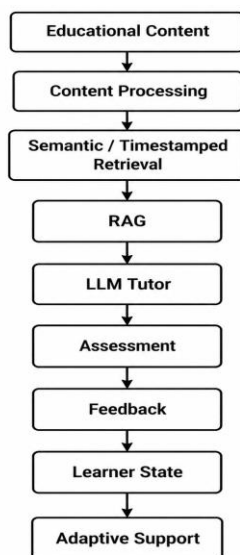
TABLE II. METHODOLOGICAL REQUIREMENTS DERIVED FROM THE LITERATURE

Requirement	Candidate methodological component
Natural interaction	LLM/conversational agent
Reliable educational answers	RAG and trusted knowledge sources
Relevant learning-content retrieval	Embeddings + semantic/vector retrieval
Personalization	Persistent learner profile/state
Adaptation to performance	Assessment-driven learner-state updates
Automated assessment	Grounded quiz/MCQ generation
Actionable feedback	LLM feedback using assessment evidence
Long-term progress	Learning analytics/mastery tracking
Video-specific support	Timestamp-aware representation when source location matters

E. Path Toward Method Selection

The synthesized literature indicates that resolving this fragmentation requires a modular, multi-tier system architecture rather than a monolithic algorithm. The requirement for dynamic pedagogical dialogue necessitates a generative LLM interface. Addressing factual precision and curriculum alignment requires a RAG pipeline. Scalable, fine-grained information retrieval requires dense vector embeddings and semantic search. Sustained personalization requires a dedicated learner modeling layer capable of persisting historical interactions and topic mastery estimates. The assessment literature demonstrates that contextually relevant diagnostic items can be generated from grounded source materials, while formative-assessment frameworks confirm that diagnostic outputs must feed structured feedback back to the student. Finally, learning analytics modules must consume these assessment signals to recalibrate the learner model and expose knowledge gaps.

The resulting methodological chain is:



F. Proposed Methodological Direction for Future Research

Based on this synthesis, future research should prioritize an integrated, learner-centered pipeline over isolated conversational agents. The foundational content layer must index validated educational source media; the retrieval layer must surface semantically and temporally relevant instructional segments; the conversational layer must leverage an LLM governed by pedagogical scaffolding prompts; the learner modeling layer must persist interaction logs, cognitive states, and mastery histories; and the assessment layer must continuously evaluate concept acquisition. Telemetry from the assessment and learner layers must directly govern subsequent dialogue strategies and learning-path recommendations. When applied to video-based curricula, the indexing tier must preserve fine-grained temporal markers so that conversational explanations can link directly back to specific instructional segments. This design direction is strongly corroborated by recent literature published beyond the core 50-study corpus. A 2025 IEEE review of AI-powered ITS identifies an industry-wide transition toward LLM backbones coupled with adaptive frameworks, while highlighting ongoing challenges in algorithmic transparency and system scalability. A 2025 IEEE Access systematic review evaluating 46 engineering-education ITS platforms similarly underscores the critical necessity of unified personalization, formative feedback, and student monitoring. Furthermore, recent IEEE studies investigating RAG-driven personalized learning confirm that retrieval constraints significantly improve factual reliability while preserving instructional flexibility. These

complementary findings substantiate the architectural conclusions derived from our 50-paper corpus.

V. CONCLUSION

This methodological review synthesized 50 studies across the domains of online learning, personalized instruction, intelligent tutoring systems, conversational AI, LLM-based tutoring, RAG, automated assessment, instructional feedback, and learning analytics. The evidence reflects substantial maturation across individual capabilities: online learning research establishes the utility of behavioral telemetry in self-directed environments; personalized learning underscores the centrality of learner profiles; conversational AI literature demonstrates the efficacy of natural language pedagogical interfaces; RAG systems provide an established framework for factual grounding; assessment engines successfully automate diagnostic generation; and analytics frameworks support continuous learner tracking.

Critically, the central impediment identified in this review is not the absence of specific AI algorithms, but rather widespread methodological fragmentation across these components. To advance the state of the art, next-generation tutoring architectures must integrate content grounding, conversational scaffolding, dynamic student modeling, automated assessment, and diagnostic feedback into a closed, continuous loop. These conclusions provide an empirical, traceable rationale for combining an LLM conversational layer, RAG-driven curriculum grounding, semantic retrieval mechanisms, persistent student state tracking, and adaptive diagnostic assessment into a unified methodology. Future implementations must empirically validate whether this multi-tier integration demonstrably improves retrieval precision, output reliability, learner engagement, assessment scores, and long-term subject mastery.

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