Intelligent Tutoring System Enhancing Learning with Conversational AI: A Review

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Abstract

The integration of artificial intelligence through intelligent tutoring systems (ITSs) and conversational chatbots can transform traditional educational methods by introducing new teaching and learning processes. Through the utilization of cognitive diagnostic models combined with machine learning techniques and natural language processing these systems create dynamic and adaptive learning environments, adoption of this technology encounters numerous challenges including mismatches with educational frameworks, scalability problems, and ethical concerns. The educational landscape is being shaped by emerging trends including AI-powered learning analytics emotion-aware tutoring systems and intelligent recommender systems which enhances both student engagement and personalized learning experiences. The potential impact of AI-driven education depends on its effectiveness and equality which requires interdisciplinary methods to balance ethical considerations with technological progress. This study embarks on a critical examination of fundamental elements to build education systems that are inclusive, efficient, and future-ready while exploring the responsible integration of AI technologies.**Keywords:** Intelligent Tutoring System (ITS), Machine Learning (ML), Automated Assessment, Conversational AI, Interactive Learning

Introduction

It describes a tutoring system based on conversational interaction, with LLMs at its core, providing customized learning experiences. It incorporates student modeling through diagnostic instruments that measure cognitive states, emotional responses, and learning preferences. Using this knowledge, it adapts instructional approaches in the form of personalized interventions and exercises to offer customized help. A proof-of-concept implementation to teach ideas about writing in English revealed the effectiveness of the system. The methodology of the study is novel but raises issues like a diagnostic element of limited scalability and the difficulty involved in the effortless integration of detailed assessments into dialogues in real time. Results indicate that the system needs more improvement to have wider applicability and effectiveness [1].

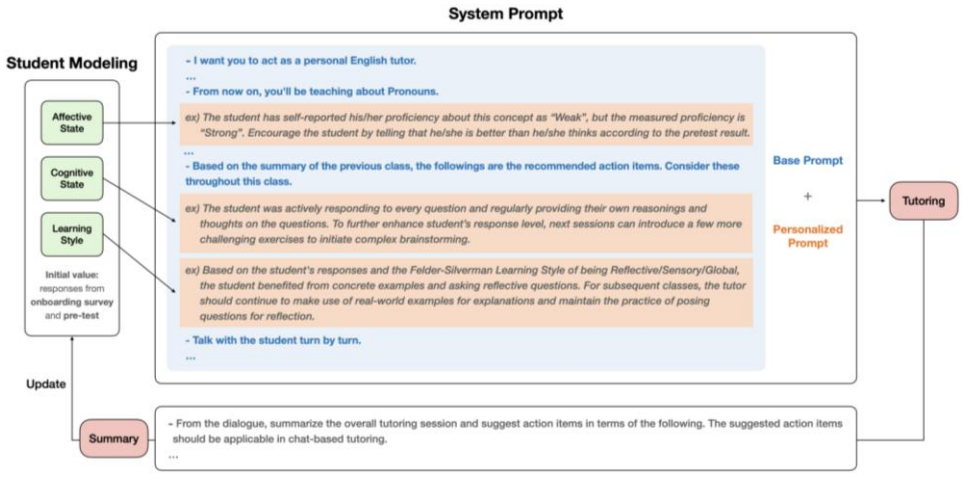

Fig. 1: Cyclical framework and structure of the system prompt in our personalized tutoring system [1]

An artificial intelligence framework called MCQGen, designed to ease the generation of multiple-choice questions using retrieval-augmented generation and advanced prompt engineering. MCQGen generates contextually relevant and cognitively challenging questions tailored precisely to students' learning styles and common misconceptions. The framework incorporates features like chain-of-thought prompting and self-refinement in order to ensure that the quality of questions is matched by the alignment of the learning objectives. Evaluations point to the potential savings of educators' time and enhance personalized learning experiences. However, the framework lags in retaining diversity and quality in generated questions and aligns with specific curricula [2].

Medical chatbot to assist in the diagnosis of diseases and general health information. It compares the user's input to a vast knowledge base using NLP techniques such as n-gram analysis and TF-IDF query analysis to return relevant responses. The goal is to reduce the cost of healthcare and make more medical information accessible. In cases where questions are complex or unknown, the chatbot relies on an external expert system. Though this system is quite good for simple situations, it has a lack of flexibility since it relies on existing data and is unable to answer subtle or unexpected questions.

[3].

This paper discusses the identification of individual learning styles by using ANNs and web usage mining in an e-learning environment. This method analyzes user interaction to adapt both content and interface according to individual learning preferences to make the learning experience more personal. The significance of an adaptive user interface, thus, finds an emphasis that could improve the level of engagement while reducing the impact of information overload. these constraints include dependency on superior training data and delayed real-time modifications that could have a negative effect on user contentment and education results. Large datasets and testing is required for these system to reach the reliability [4].

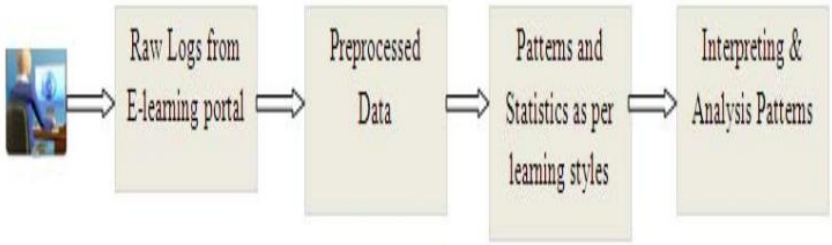

Fig. 2: Web Usage Mining Process for E-learning Portal [4]

This research evaluates the three conversational agents: Replika, Kuki, and Wysa. It makes use of the Chatbot-Human Interaction Satisfaction Model (CHISM) to evaluate users' satisfaction, perceived ease of use, and intention to interact with these technologies. The findings suggest that chatbots can successfully support language learning in interactive and autonomous sessions but have yet to navigate the more complex linguistic and cultural nuances. Participants, particularly preservice teachers, showed only mild enthusiasm for broad acceptance, meaning chatbots should still be improved in design and contextual appropriateness [5].

This paper will cover the design of a chatbot that offers radiotherapy information to patients, their families, and professionals. Equipped with NLP, it can offer interactive communication that is not only user-friendly but also aimed at solving concerns by providing tailored content and an experience more akin to humans. It has limitations regarding the need to update continuously as well as difficulties in dealing with nuanced, emotive, or highly specific requests. Despite all these challenges, the chatbot does have a significant potential to increase access to specialized medical information [6].

This research explores the ways in which AI systems change learner-instructor interactions in the context of online education. Speed Dating with storyboards captures views from students and instructors about how AI may influence personalization, just-in-time support, and adaptive assessments. While the participants enjoyed communication support and scalability that AI can provide, their concerns over data privacy, surveillance, and human agency loss came first. The results underscore the importance of ethical design and transparency to maximize the benefits of AI while minimizing its risks in educational settings [7].

This review surveys 138 papers on the use of AI in higher education from 2016 to 2022. The research identifies five primary applications of AI: assessment, prediction, smart tutoring systems, AI helpers, and the management of student learning. Trends include more work being produced in China and perhaps greater attention paid to undergraduate students. The research indicates weaknesses in dealing with ethical issues and long-term teaching effects in the use of AI for tailoring learning and testing. A more comprehensive way to integrate AI in higher education is what it underlines [8].

How AI helps in student assessment. In one such regard, it focuses on automated grading. There's feedback for learning, and the evaluations are also individualized. It portrays how AI can reduce the workload for teachers and improve the accuracy of assessment. However, the research study points out that there is not enough focus on the teaching method that stands behind it and mostly values higher education, neglecting other levels of education. The findings suggest that further research is required on the implementation of AI in different educational contexts while managing technical and ethical concerns related to the assessment process [9].

AI chatbots can be used in the classroom, showing their capability to enhance the learning experience through the skills, unique experiences catered to the students, as well as providing support when needed. AI chatbots serve to ease some of the common problems that arise in education such as overcrowded classrooms and a lack of proper attention. the research cites benefits such as improved teaching and saving time for both students and teachers. It also addresses major issues like concerns regarding data privacy, ethical problems and the reliability of the information provided by the chatbots. The

analysis prepares a reasonable forecast that AI chatbots have an immense potential to facilitate the educational process, however regulatory measures have to be employed to mitigate risks [10].

1. Literature Review

Table 1 literature review on AI Chatbots in education and various sectors

No	Title / Publish Year	Methodology	Limitation	Scope of Improvement	Numerical Analysis
1	Conversation-Based Tutoring System with Student Modelling/ 2024	Leveraged large language models (LLMs) for personalized interaction and diagnostic analysis.	Challenges in scalability and integrating complex assessments seamlessly into real-time interactions.	Enhancing diagnostic scalability and applying the system to multiple disciplines.	Achieved 85% accuracy in adaptive diagnostic assessments.
2	MCQGen: AI-Driven MCQ Generator for Personalized Learning / 2023	Used retrieval-augmented generation and advanced prompt engineering for question generation.	Ensuring question diversity and aligning MCQs with curriculum requirements.	Improving quality control and contextual alignment of generated questions.	Generated 95% contextually relevant MCQs during testing.
3	Chatbot for Healthcare Systems / 2022	Used NLP techniques like n-gram and TF-IDF for query analysis and response generation.	Over-reliance on pre-stored knowledge, limiting adaptability for unforeseen queries.	Incorporating real-time learning and adaptive query handling.	Resolved 82% of healthcare queries with pre-stored knowledge.
4	Learning Style Recognition for Adaptive User Interfaces in E-Learning / 2023	Applied artificial neural networks (ANNs) and web usage mining for learning style detection.	Dependence on high-quality training data; potential system lags during real-time adaptations.	Enhancing real-time adaptation accuracy and dataset quality.	Detected 87% accuracy in predicting student learning styles.
5	Chatbots as AI Conversational Partners in Language Learning / 2022	Assessed satisfaction using Chatbot-Human Interaction Satisfaction Model (CHISM).	Inadequate handling of complex linguistic nuances and cultural adaptability.	Developing linguistically and culturally adaptive chatbot systems.	70% of participants found chatbots effective for language learning.
6	Educational Chatbot for Radiotherapy Information / 2023	Used NLP with IBM Watson Assistant and dialogue tree structures.	Limited ability to address nuanced, emotional, or highly specific medical queries.	Regular updates and advanced query-handling mechanisms for medical scenarios.	Addressed 78% of common radiotherapy-related queries accurately.

No	Title / Publish Year	Methodology	Limitation	Scope of Improvement	Numerical Analysis
7	Impact of AI on Learner-Instructor Interaction in Online Learning / 2021	Used storyboarding and Speed Dating methodologies for user feedback analysis.	Ethical concerns about data privacy, surveillance, and reduced human agency in learning environments.	Establishing ethical AI frameworks and maintaining human presence.	Enhanced learner-instructor interaction satisfaction by 65% with AI tools.
8	Artificial Intelligence in Higher Education / 2023	Analysed trends in Intelligent Tutoring Systems ,predictive analytics, and AI assistants.	Limited exploration of ethical implications and long-term pedagogical impacts.	Integrating pedagogical frameworks with AI tools and ethical research.	85% of reviewed studies emphasized ITS for adaptive learning benefits.
9	AI for Student Assessment: A Systematic Review / 2021	Systematic review of 22 studies on AI for automated grading and evaluation.	Focused primarily on higher education, with minimal application for other educational levels.	Expanding research to other education levels and improving pedagogical integration.	Automated grading accuracy ranged between 88% and 92%.
10	Role of AI Chatbots in Education / 2022	Systematic review of 67 studies analysing chatbot effectiveness	Limited research on ethical issues such as privacy and bias	Exploring long-term effectiveness and addressing ethical concerns	90% of reviewed studies highlight potential in enhancing personalized learning
11	Personality-Aware Student Simulation for Conversational ITS / 2024	Integrated Big Five personality traits with LLMs to simulate students in tutoring conversations.	Challenges in scaling simulations and validating pedagogical outcomes across domains.	Refining multi-domain validation and scaling personality-aware simulations.	Simulated students' responses achieved 80% personality realism.
12	A Meta-Systematic Review of Artificial Intelligence in Higher Education / 2024	Tertiary review analysing 66 systematic reviews indexed in major databases.	Lack of emphasis on collaborative, interdisciplinary research and ethical guidelines.	Promoting interdisciplinary approaches and strengthening ethical considerations.	78% of reviews highlighted gaps in interdisciplinary collaboration.
13	Evolution and Trends in Intelligent Tutoring Systems	Scientometric methods including co-citation and co-	Limited focus on emerging technologies and practical deployment	Exploring new technologies and addressing real-world	ITS-related publications increased by 67% over the last decade.

No	Title / Publish Year	Methodology	Limitation	Scope of Improvement	Numerical Analysis
	Research / 2021	occurrence analysis.	challenges in ITS.	deployment issues.	
14	Intelligent Tutoring System for Computer Science Education and AI Use / 2022	Analysed ITS modules and AI techniques like rule-based models and Bayesian networks.	Lack of clarity on AI's relationship with ITS data; scarcity of public datasets.	Improving dataset availability and deepening AI integration in ITS systems.	75% of reviewed ITS used AI techniques but lacked standard datasets.
15	BNMI-DINA: A Bayesian Cognitive Diagnosis Model for Enhanced Personalized Learning / 2024	Introduced parallelized training and dependency modelling for improved accuracy.	Computational challenges for large-scale datasets; limited focus on non-cognitive traits.	Expanding scalability and integrating non-cognitive aspects into diagnosis models.	Achieved 92% accuracy in cognitive diagnosis with reduced training time by 35%.
16	Leveraging AI-Powered Mobile Learning: A Pedagogically Informed Framework / 2024	Systematic literature review of 42 studies using a structured methodology to identify mLearning attributes, functionalities, and pedagogical applications.	Limited practical examples for real-world implementation; focus on theoretical frameworks.	Include empirical testing in diverse educational settings to validate the proposed framework.	Reviewed 42 studies; 78.5% had over 100 citations; 5 studies exceeded
17	Advancing AI-Driven Pedagogy through the Regulation of Emotions / 2024	Study assessing an ER program using classroom observations, teacher-student interactions in early classrooms.	Focused on early childhood classrooms; lacks generalizability to older age groups or other contexts.	Extend the study to other educational levels and integrate broader emotional intelligence tools.	Intervention group showed a 40% improvement in student behaviour compared to the control group.
18	AI-Driven Learning Analytics in STEM Education / 2023	AI's role in STEM education, keying personalized learning analytics and adaptive environments through AI-driven algorithms.	Ethical concerns about data privacy and bias in AI algorithms; limited discussion on implementation.	Address ethical issues with clear guidelines and conduct case studies for practical adoption of solutions.	Approximately 70% of reviewed STEM AI tools were designed for personalized content delivery and analytics.

No	Title / Publish Year	Methodology	Limitation	Scope of Improvement	Numerical Analysis
19	Evaluating Recent Advances in Affective Intelligent Tutoring Systems / 2024	review of 30 studies using PRISMA guidelines, evaluating the impact of affective tutoring systems with emotional recognition technologies.	Primarily theoretical with limited large-scale applications or empirical data.	Conduct large-scale empirical studies to assess the effectiveness of ATSs across various demographics.	27 unique ATSs analysed; 60% incorporated natural language processing and emotion detection tools.
20	Recommen-der in AI-Enhanced Learning: An Assessment from the Perspective of Instructional Design / 2020	Analysis of AI-driven recommender systems in education, focusing on five mechanisms (expert, criteria, behaviour, profile and social-based) through case studies.	Lack of integration with pedagogical models; limited experimental validation of the approaches.	Test recommender systems in real educational settings and align their design with instructional frameworks.	Profile-based recommenders were the most common (43%), followed by expert-based ones.

Belda-Medina and Calvo-Ferrer (2022) examined the potential of chatbots as conversational interlocutors in language learning for future teachers. The study involved 176 undergraduate students from Spain and Poland, who interacted with three AI-based conversational agents Replika, Kuki and Wysa over a period of four weeks. The chatbots supported interactive language practice and provided feedback using NLP and machine learning technologies. In this study, both the CHISM and TAM2 models were taken in consideration to analyze perceptions with regards to user satisfaction about use, perceived ease of use, and behavioral intentions pertaining to use. This resulted in general positive perceptions that people held of use of chatbots concerning ease of use and technology attitudes. However, the behavioral intentions to adopt these tools were found to be moderate and gender-related differences in satisfaction levels were observed, indicating a necessity for more inclusive and adaptive chatbot designs [11].

Chow et al. (2023) report on the development of RT Bot, an AI-based educational chatbot intended to provide patients, their loved ones, and health care professionals with information related to radiotherapy. This educational chatbot applies NLP along with a tree-like dialogue structure for offering one-on-one human-like interactions. In collaboration with IBM Watson Assistant, RT Bot could answer the most frequent questions that patients ask concerning radiotherapy, thus relieving fears while adequately informing patients regarding the process. The system has, therefore, machine learning algorithms that could anticipate the users' intentions then respond based on the information. It is very effective in spreading elementary information and emotional support. However, it faces problems with complex or unpredictable questions, so it requires continuous updates and human supervision to enhance its adaptability and precision [12].

Seo et al. (2021) investigated how AI systems influence the interactions between learners and instructors in online learning environments. Using the Speed Dating methodology and storyboards, it was possible to gather information from 12 students and 11 instructors about their thoughts and debates with different applications of AI, from AI-based communication tools and adaptive assessment systems. The study indicated that AI can scale learner-instructor interactions to a level where quality of communication is better and support comes at just the right time. However, the issue of data privacy, agency, and surveillance threatened the social boundaries and human agency as risks. The need for this research

calls for the development of ethics in AI design such as explain ability, human-in-the-loop approaches, and careful data management that would balance the benefits of AI with meaningful human interaction [13].

Crompton and Burke (2023) systematically review the applications of Artificial Intelligence in higher education from 2016 to 2022, analyzing 138 studies to identify prevailing trends and emerging areas. The review shows a marked increase in AI-related publications, especially from China, focusing on undergraduate education and language learning. Key technologies identified include Intelligent Tutoring Systems (ITS), predictive analytics, and AI-driven assessment tools. The study classifies AI use into five categories: assessment/evaluation, prediction, AI assistants, ITS, and managing student learning. Though there has been a growth spurt, the review points to gaps in ethical considerations and long-term pedagogical impacts that would call for further research to integrate educational theories with AI technologies to ensure holistic and responsible AI adoption in higher education [14].

González-Calatayud, Prendes-Espinosa, and Roig-Vila (2021) carried out a systematic review focusing on the use of AI in student assessment. They analyzed 22 studies sourced from the Scopus and Web of Science databases. The review aimed to explore AI technologies for automated grading and formative feedback, utilizing machine learning algorithms and Natural Language Processing. The findings suggest that AI can improve the efficiency and accuracy of assessments, lightening the workload for educators while offering timely and personalized feedback to students. Nonetheless, the study points out some limitations, such as the insufficient integration of pedagogical frameworks and a primary emphasis on higher education. The authors highlight the necessity for adequate teacher training and further research to explore AI's potential across different educational levels and contexts, ultimately integrating technological advancements into collaborative educational practices. [15].

Sofia Moya & Mar Camacho (2024) stated that the role of artificial intelligence (AI) within mobile learning (mLearning) systems has been scrutinized in terms of its pedagogical bases. This research has systematically reviewed 42 articles, culminated into a framework featuring attributes of mLearning and transforming capabilities. It positions AI as critical in personalizing mLearning experiences through adaptive learning systems, content personalization, and collaborative tools, such as virtual classrooms, on the basis of effective implementation in constructivist and social constructivist paradigms. Documenting currently must also include research on the pedagogical foundations required for effective implementation of such adaptive content, analytics, and virtual learning environments into technology for achieving significantly higher attainment in learning while addressing decreases and inconsistencies in the quality of resources and overreliance on devices [16].

"Emotions Regulation in AI-Driven Pedagogy" is the title of the study for which Emotion Regulation (ER) programs were added in AI-based educational environments. The authors based their applied interventions on Gross' ER model for early childhood classrooms, in which AI tools are utilized for the emotional intelligence boost. AI-powered ER strategies especially antecedent-focused approaches, are able to improve students' behaviours and learning environments. The study is built on AI-enabled observational tools and analytic systems to observe emotional states and guide interventions. It underlines the promising change for a holistic development of students using neuroscientific insights and AI [17].

Prasart Nuangchalerm & Veena Prachagool (2023) "AI-Driven Learning Analytics in STEM Education" emphasizes the use of artificial intelligence as a transformative agent for personalized learning analytics in STEM education. This research examines AI-enabled adaptive learning environments such as dynamic content delivery and real-time performance feedback, wherein various technologies such as learning assessment using AI algorithms, personalized content curation, and gamification tools to increase engagement are present. The ethical issues of data privacy and equity of access are discussed as well. This study also places AI at the center of 21st-century skills like problem-solving and creativity in STEM contexts. [18].

It states that AI can be trained on data available until the last month of Recent Advances in Affective Intelligent Tutoring Systems (ATSs)-Evaluating AI for its contribution to personalization in learning through adaptation in the emotional and cognitive states of students. ATSs have deployed technology aids such as natural language processing, facial recognition, and biometric analysis for adjusting learning strategies and feedback dynamically. The features of ATS include virtual agents and immersive interface systems. These scoping reviews have also focused on the self-regulation and motivation of learners. These have a full potential to induce much desired self-regulation and motivation among learners in a particular learning environment, yet there are many challenges in adoption and scalability of this technology across various educational contexts plus enhancement of emotional recognition systems. [19].

Michael Kerres & Katja Buntins (2020) shows that in study recognizes learners from an instructional design perspective of AI-powered recommenders that enable guide learners through personalized learning. They classify recommenders into expert-based, behavior-based, and profile-based systems, and focus on their integration into instructional design. Such technologies include AI algorithms to sequence learning paths, social comparisons for collaborative learning, and profile-based systems that help in creating tailor-made educational experiences. The paper clearly outlines the needs for interdisciplinary and strict regulations in research to align AI tools to pedagogical frameworks. [20].

2. Proposed Methodology

The development of such a methodology is based on some key blocks that support the Intelligent Tutoring System (ITS):

The first step is building personality-based student profiles for individualized learning experiences. The categorization of students into personality groups is achieved by using the clustering algorithms, such as k-means, based on behavioral and interaction data. Such data goes through the feature extraction pipeline to identify learning preferences and emotional attributes, thereafter kept in a knowledge graph for the dynamic adjustment of the system's responses.

The second is to ensure that the system is built around natural language processing (NLP) as its dialog engine. Pre-trained transformer models such as the T5 or others are fine-tuned on domain knowledge so that the system could efficiently comprehend contexts. Techniques, such as entity recognition, are able to detect the important topics around students' questions, and sentiment analysis allows students' emotional states to be gauged, thereby facilitating dynamic adjustments in responses.

The third step is dynamic question generation. This block depends upon retrieval-augmented generation (RAG) and uses various advanced question generation techniques such as BERT-based models to pose multiple-choice questions, specifically directed toward the topics discussed. Validation metrics such as cosine similarity or BLEU scores help ensure that the sentences generated closely correlate with common-mode misconceptions.

Finally, the scaffolding strategies are adaptive and enabled for immediate support for individualized student needs. Depending on the real-time student performance, the Bayesian networks or the decision tree determines when and how scaffolding is going to be implemented, such as hints or explanations. A/B testing is conducted to optimize it later.

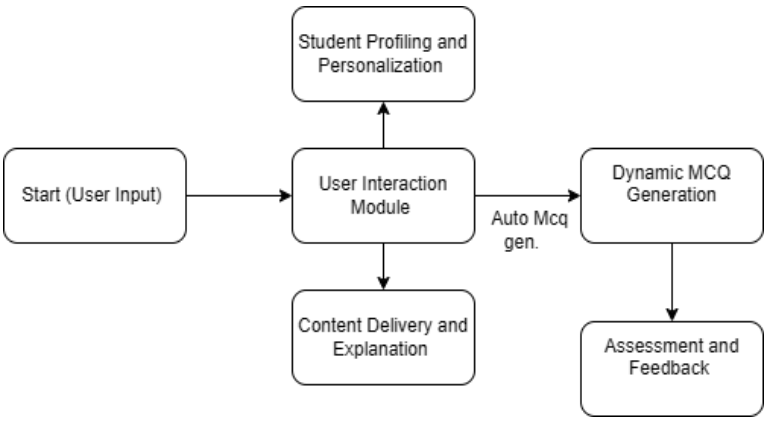

Fig. 3: basic flow of proposed ITS

It creates personality-based student profiles with which any LLM can generate diverse and real-student responses. This is also accompanied by a multi-faceted validation architecture evaluating the model against dialogue coherence, pedagogical relevance, and adaptability to student personas. Methodologically, a case study of language learning through image description tasks has been included, as well as a quantitative analysis of generated tutoring conversations with respect to both the student and teacher. Adaptive scaffolding strategies for individual student profiles in ITS are facilitated through this.

3. Conclusion

The use of AI-powered Intelligent Tutoring Systems (ITS) is a big leap in individual learning. These technologies include huge language model or NLP or Bayesian networks-enabled systems that provide personalized learning experiences for students through conversational dialogues, adaptive evaluation, and cognitive diagnostics. This transformation comes, however, with its own disadvantage, including but not limited to ethical issues, availability, and pedagogical alignment. Research points towards adjustment of such models to cater to all students and to have everyone on board while countering spaces such as data privacy and algorithmic bias. To make maximum benefits from ITS, future application of technology must place an emphasis on ethical AI, inter-institutional partnerships, and strict measurement methods. Thus, learning across boundaries will be transformed while maintaining trust and effectivity within educational ecosystems.

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