A Survey of Techniques, Design, Applications, Challenges, and Student Perspective of Chatbot-Based Learning Tutoring System Supporting Students to Learn in Education

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Article

A Survey of Techniques, Design, Applications, Challenges, and Student Perspective of Chatbot-Based Learning Tutoring System Supporting Students to Learn in Education

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Abstract: This study conducted a comprehensive survey of chatbot-based tutoring systems in education, integrating a systematic literature review with empirical insights from student experiences. Through an extensive review of state-of-the-art techniques, we examined the technological foundations of educational chatbots, including natural language processing (NLP), dialogue management, response generation, adaptive learning, and evaluation methodologies. We further analyzed the application of chatbot tutors across diverse educational contexts, such as programming education, language learning, medical training, business instruction, and general academic support. Our review also identified key challenges associated with chatbot implementation, encompassing technical limitations, ethical considerations, pedagogical concerns, and practical barriers such as teacher training and cost constraints. To complement our theoretical analysis, we conducted a 12-week empirical study involving 30 primary school students who interacted with a chatbot tutor (POE) while learning Python through CodeCombat. Through structured and informal interviews, we explored students' perceptions of chatbot-based learning, revealing key benefits such as increased engagement, enhanced motivation, immediate feedback, personalized learning experiences, and social-emotional support. However, students also reported limitations, including occasional communication misunderstandings, overly complex explanations, and repetitive responses that impacted the learning experience. Our study contributed to the field by bridging the gap between theoretical discussions and real-world applications of chatbots in education. By integrating a rigorous literature review with firsthand student perspectives, we provided a holistic understanding of chatbot-based tutoring systems, highlighting their potential to enhance learning while emphasizing the need for further refinements in contextual adaptability, emotional sensitivity, and pedagogical integration.

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1. Introduction

Recent advances in artificial intelligence (AI) and natural language processing (NLP) have spurred the development of chatbot-based tutoring systems in education. These systems, which include conversational agents capable of engaging in natural language dialogue, are increasingly used to supplement traditional teaching methods by providing on-demand guidance and personalized learning support [1,2]. Chatbots have been applied across various educational

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settings—from K–12 classrooms to higher education and professional development—with applications spanning language learning, programming instruction, and various fields [2,3].

Early chatbot systems such as ELIZA and ALICE were historically limited by rule-based architectures that offered only scripted responses. However, modern systems like ChatGPT incorporate advanced machine learning models and transformer-based architectures that enable adaptive, context-aware interactions [1,4]. Recent studies have demonstrated that these systems improve learning outcomes by facilitating continuous practice and enhance student motivation by providing immediate feedback and interactive support [5,6]. Despite these promising developments, several challenges remain—from ensuring the accuracy and reliability of chatbot responses to addressing ethical concerns such as academic integrity and data privacy [1,7].

To gain a deeper insight into chatbot-based tutoring systems in education, we conducted a comprehensive review of the existing literature for the last six years (2019-2025). The following research questions will guide this study.

(1) What state-of-the-art techniques are employed in designing and developing chatbot-based learning tutoring systems?
(2) In which educational applications have chatbot tutors been deployed, and what are their observed outcomes?
(3) What are the key challenges in implementing chatbot-based tutoring systems in education?
(4) How do primary school students perceive and interact with chatbot-based learning tutoring systems?

2. RQ1: Chatbot Techniques

Chatbots, often referred to as conversational agents, are software systems engineered to simulate human-like interactions with users through natural language, either in text or voice. These systems are widely applied across customer service, healthcare, and education domains. The development of effective chatbots relies on a diverse set of techniques spanning natural language processing (NLP), artificial intelligence (AI), and machine learning (ML).

We conducted a comprehensive review of existing literature [3,5,8–21] related to technological foundations of educational chatbots. This section provides a comprehensive overview of the primary techniques used in chatbot design and implementation, categorized into five key subsections: Natural Language Understanding (NLU), Dialogue Management, Response Generation, Learning and Adaptation, and Evaluation Metrics. The detailed findings are shown below.

2.1. Natural Language Understanding Techniques

Natural Language Understanding (NLU) is the foundation of a chatbot's ability to interpret user inputs, extracting meaning, intent, and relevant entities from utterances. Several techniques are commonly utilized in this domain:

Rule-based Methods: These rely on manually crafted rules, such as regular expressions or grammar, to identify patterns in user input. While simple to implement and highly interpretable, they are rigid and struggle to scale with complex or varied language use.

Machine Learning Classifiers: Supervised learning algorithms, such as Support Vector Machines (SVM) or Naive Bayes, classify user intents based on labeled training datasets. These methods offer improved flexibility over rule-based approaches but require substantial annotated data.

Deep Learning Models: Advanced neural network architectures, including Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Transformers, excel at capturing intricate language patterns and contextual nuances, significantly enhancing NLU performance.

Pre-trained Language Models: Large-scale models like BERT (Bidirectional Encoder Representations from Transformers) or GPT (Generative Pre-trained Transformer), fine-tuned for

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specific tasks, leverage vast pre-training corpora to achieve state-of-the-art results in intent recognition and entity extraction.

2.2. Dialogue Management Techniques

Dialogue Management (DM) governs the structure and flow of a conversation, determining the chatbot's next action based on the current dialogue state. Key techniques in this area include:

Finite State Machines (FSM): These model conversations as predefined states and transitions, making them suitable for simple, structured interactions like form-filling tasks. However, they lack adaptability for open-ended dialogues.

Frame-based Systems: Utilizing frames with slots to track required information, these systems support task-oriented conversations by dynamically filling slots as the dialogue progresses, offering greater flexibility than FSMs.

Plan-based Models: These aim to infer the user's underlying goals or plans and collaboratively work toward achieving them, providing a more sophisticated approach to dialogue flow.

Reinforcement Learning (RL): RL techniques, often framed within Markov Decision Processes (MDP) or Partially Observable MDPs (POMDP), enable chatbots to learn optimal dialogue policies through trial-and-error interactions, adapting to user behavior over time.

2.3. Response Generation Techniques

Response Generation focuses on crafting the chatbot's replies to user inputs. This process varies in complexity and approach:

Template-based Generation: Predefined templates with placeholders are populated based on the dialogue context. This method ensures consistency and control but limits the diversity and naturalness of responses.

Retrieval-based Methods: Responses are selected from a pre-existing corpus based on the user's input similarity, typically using ranking algorithms. While these can produce fluent replies, they may fail to align with the conversation's context fully.

Generative Models: Neural network-based models, such as sequence-to-sequence (seq2seq) architectures or Transformers, generate responses token-by-token from scratch. These offer high flexibility and creativity but may occasionally produce incoherent or irrelevant outputs.

Knowledge-grounded Generation: By integrating external knowledge sources (e.g., databases or knowledge graphs), this approach enhances response accuracy and informativeness, making it ideal for information-seeking dialogues.

2.4. Learning and Adaptation Techniques

To remain effective over time, chatbots employ learning strategies that allow them to adapt to new data and user interactions:

Supervised Learning: Models are trained on annotated dialogue datasets to improve tasks like intent recognition or entity extraction, relying on high-quality labeled examples.

Unsupervised Learning: Techniques such as clustering or topic modeling identify patterns in unlabeled user interactions, which help discover emergent behaviors or preferences.

Reinforcement Learning: By optimizing dialogue policies based on user feedback or predefined rewards, RL enables chatbots to refine their strategies dynamically, enhancing long-term performance.

Transfer Learning: Pre-trained models are fine-tuned on domain-specific data, allowing chatbots to leverage general language knowledge while adapting to specialized contexts with minimal additional training.

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2.5. Evaluation Techniques

Evaluating chatbot performance is essential for assessing effectiveness and guiding improvements. Common evaluation methods include:

Automatic Metrics: Metrics such as BLEU (Bilingual Evaluation Understudy), ROUGE (Recall-Oriented Understudy for Gisting Evaluation), or perplexity provide quantitative assessments of response quality by comparing generated outputs to reference texts. However, they may not fully capture conversational nuances.

Human Evaluation: Human judges rate chatbot responses on subjective criteria like fluency, relevance, and engagement, offering a more holistic view of performance but at the cost of scalability.

Task-specific Metrics: For task-oriented chatbots, metrics such as task completion rate, user satisfaction scores, or time-to-completion measure success in achieving specific objectives, aligning evaluation with practical utility.

3. RQ2: Chatbot Applications in Education

In recent years, a significant proliferation in the implementation of chatbots across diverse educational contexts has been observed. Through sustained pedagogical support, individualized feedback mechanisms, and interactive learning paradigms, chatbots have been progressively integrated into instructional methodologies, addressing challenges such as constrained one-on-one teaching time and providing learners with adaptable, scalable assistance.

We conducted a comprehensive review of existing literature [1–8,10–14,16–19,22–43], this section delineates the primary modalities through which chatbots transform educational landscapes, offering insights into their multifaceted applications and emergent opportunities for subsequent development.

3.1. Programming Education

Programming education presents distinct pedagogical challenges, particularly for novice learners who frequently encounter difficulties with abstract conceptualizations and syntactical errors. Chatbots have demonstrated considerable efficacy in addressing these impediments by emulating human teaching assistants within virtual learning environments, where immediate feedback and interactive guidance can be furnished without temporal constraints:

On-Demand Assistance and Automatic Assessment: Chatbot-based tutoring systems, like Coding Tutor, have been developed to review code submissions automatically, identify syntactical errors, propose debugging methodologies, and offer feedback regarding conceptual misunderstandings. These chatbots mitigate student frustration by providing an instantaneous "help desk" that functions continuously, complementing human instruction and diminishing instructors' workload.

Guided Learning Pathways: Chatbots utilize adaptive algorithms to present programming tasks in manageable increments. Students attain incremental mastery of subjects such as data structures and algorithmic principles through progressive calibration of exercise complexity.

Motivation and Engagement: Chatbots that simulate aspects of pair-programming enhance motivational factors by facilitating natural language dialogue. Novice programmers value having someone to consult when encountering difficulties, regardless of whether that entity is artificially intelligent. Empirical investigations have indicated that interactive code discussions with chatbots can reinforce conceptual understanding and foster self-efficacy in problem-solving contexts.

Future design endeavors necessitate refined scaffolding strategies, ensuring that chatbots encourage critical thinking rather than prematurely providing comprehensive solutions.

3.2. Language Learning

Chatbot-based interventions have substantially enhanced language acquisition, facilitating meaningful practice, immediate corrective feedback, and cultural contextual awareness. By

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functioning as interactive conversational partners, language chatbots have effectively addressed communicative hesitations and enabled more immersive learning environments:

Dialogic Practice: Learners engage in authentic dialogues, including simulated quotidian scenarios, employment interviews, or academic discussions. Chatbots calibrated to language proficiency levels prompt learners to experiment with lexical and grammatical structures, respond to open-ended inquiries, and refine pronunciation and syntactical elements.

Personalization and Continuous Support: Advanced AI systems detect user proficiency and modify subsequent interactions accordingly. Specific chatbots provide explicit grammatical explications upon request, deliver detailed textual feedback, and elucidate pragmatic nuances, such as idiomatic expressions or politeness conventions.

Overcoming Affective Barriers: Learners—particularly those exhibiting reticence in face-to-face classroom environments—can practice language skills privately without temporal constraints. The diminished apprehension of judgment encourages frequent rehearsal and experimentation, ultimately fostering greater confidence in authentic interactional contexts.

Although the novelty effect associated with conversational systems may diminish, numerous language learners continue to utilize chatbots as perpetually available practice partners. Ongoing research addresses limitations such as managing multi-turn conversational context and identifying subtle linguistic errors to ensure more coherent, context-sensitive language interactions.

3.3. Medical and Health Education

Medical and health-related disciplines require a comprehensive understanding of both theoretical knowledge and practical competencies. Chatbots are emerging as valuable supplementary resources in these domains:

Virtual Simulation of Patient Encounters: Chatbots simulate patient dialogues, presenting various symptomatologies and guiding students through diagnostic reasoning processes. These AI systems provide immediate feedback regarding clinical decision-making and highlight significant knowledge deficiencies.

Guided Study and Review: Medical students retrieve condensed pharmacological information, diagnostic procedural protocols, or disease-specific data through chatbot interactions, streamlining examination preparation. Chatbots may also disseminate expeditious updates regarding evolving medical guidelines.

Confidence-Building in Clinical Communication: Effective communication is crucial for healthcare professionals. Chatbots that simulate patient conversations assist learners in refining interview techniques, practicing empathetic responses, and enhancing medical terminology usage, which is essential before engaging with actual patients.

Medical educators continue investigating optimal methodologies for integrating chatbots into standardized curricula and ensuring that AI recommendations remain congruent with current research findings. Ethical considerations—including data privacy and the potential for over-reliance on AI in critical decision-making scenarios—also warrant thorough examination.

3.4. Business Education and Training

Beyond strictly academic contexts, chatbots fulfill an expanding role in business-related programs and workplace skill enhancement:

Case-Based Scenarios: Learners in business or management courses consult chatbots that emulate various authentic business dilemmas (e.g., marketing campaign development, supply chain disruptions, or negotiation strategies). Through interrogative dialogues, students enhance problem-solving and decision-making capabilities.

Skill Reinforcement and Certification: As components of organizational training, institutions deploy chatbots to maintain employee awareness regarding policies, compliance requirements, and continuing education modules. The individualized analytics generated by AI systems highlight knowledge deficiencies, enabling employees to concentrate on requisite skills.

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Continuous Mentoring and FAQ Support: Chatbots function as digital mentors, addressing inquiries regarding corporate strategy, financial considerations, or team management principles, thereby promoting learner autonomy. Organizations frequently benefit from reduced training expenditures when chatbots complement or supplant specific repetitive tasks previously conducted by human trainers.

As chatbots gain acceptance within corporate training environments, business educators address issues including data confidentiality, adaptation of content to diverse organizational cultures, and equilibration of the "human element" that fosters trust and collaboration within teams.

3.5. General Academic Support and Self-Regulated Learning

Chatbots provide comprehensive academic assistance beyond specialized domains, offering both cognitive and non-cognitive support to learners:

Goal-Setting, Reflection, and Metacognition: Chatbots encourage self-monitoring and self-regulatory behaviors by prompting learners to articulate specific learning objectives. They periodically assess progress toward established goals, assisting students in developing study schedules or deconstructing complex tasks.

24/7 Availability and Scalability: Large-scale online courses encounter challenges with voluminous forum posts or repetitive inquiries. Chatbots integrated into Learning Management Systems (LMS) promptly address routine questions regarding deadlines, course materials, or technical difficulties, liberating instructors' time for higher-order pedagogical interactions.

Fostering Self-Efficacy and Motivation: Automated motivational cues and personalized reminders assist learners in maintaining progress, acknowledging incremental achievements, and mitigating frustration. Chatbots with empathetic response mechanisms can enhance learners' sense of belonging, reducing attrition risks in large-scale online educational programs.

Nevertheless, the institutional adoption of chatbots raises significant questions about data privacy, the quality of generated feedback, and the boundaries of tutor-learner relationships. Ongoing collaborations between educators, AI developers, and policy architects can help establish ethical frameworks and ensure that chatbot technology is implemented responsibly.

4. RQ3: Chatbot Challenges in Education

This section presents a comprehensive analysis of challenges associated with implementing chatbots in educational environments, based on an extensive literature review [1–4,11,14,17–19,31,41,44–46]. While educational chatbots offer promising benefits, their effective integration faces multiple obstacles. Our analysis identifies critical technical, ethical, and pedagogical challenges that require careful consideration. Additionally, we examine practical implementation issues, including teacher training requirements, cost considerations, data security concerns, equity of access, academic integrity risks, potential overreliance, and accuracy problems. The following subsections detail each challenge area and its implications for educational stakeholders.

4.1. Technical Challenges

Chatbots rely heavily on advanced NLP and machine learning algorithms. Despite significant technological advancements, numerous technical challenges persist. A primary issue concerns the chatbot's accuracy in comprehending and responding to complex or nuanced user inputs. Students frequently reported frustration when chatbots provided irrelevant or incorrect answers, which impeded learning effectiveness. For instance, chatbots employing template-based or rule-based approaches demonstrated limitations in managing inputs outside their predefined database, constraining their ability to effectively handle open-ended or unexpected questions.

Additionally, chatbots occasionally struggled to maintain contextual continuity over prolonged interactions, disrupting conversation flows and diminishing the learning experience. Continuous interaction data and extensive databases were essential for chatbots to manage and generate coherent,

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contextually appropriate responses. However, maintaining these vast datasets proved resource-intensive and challenging to manage effectively.

Moreover, response latency suffered system performance, particularly in chatbots utilizing sophisticated AI models such as ChatGPT. Delays or inconsistent performance negatively affected students' perceived reliability and satisfaction, potentially discouraging further engagement with the educational platform.

4.2. Ethical Challenges

Deploying chatbot technologies in education introduces significant ethical challenges, particularly regarding data privacy, academic integrity, and responsible utilization. Data privacy emerged as a primary concern because educational chatbots frequently collected sensitive student data, including personal information, performance metrics, and conversational histories. Mishandling or unauthorized disclosure of such data could lead to severe privacy violations, raising serious questions regarding compliance with data protection regulations such as GDPR or FERPA. Educational institutions must develop rigorous protocols to govern data collection, storage, and sharing practices, ensuring transparency and safeguarding students' rights to privacy.

Academic integrity represents another critical ethical concern. Advanced chatbots such as ChatGPT demonstrated capabilities to generate sophisticated responses that students might utilize unethically to complete assignments without genuinely engaging with learning material, thereby undermining the educational process. Studies highlighted significant apprehensions among educators regarding the potential misuse of chatbots, prompting some educational institutions to implement temporary restrictions on their use. However, rather than imposing outright prohibitions, educators and policymakers should establish clear ethical guidelines, ensuring students comprehend appropriate usage parameters and integrating chatbots responsibly within pedagogical frameworks.

Moreover, ethical challenges encompass ensuring transparency in chatbot communication. Students often interact with chatbots without fully understanding the system's limitations or sources of generated information, leading to potential misinformation or misunderstanding. Transparency regarding the chatbot's capabilities, limitations, and information sources is crucial for responsible deployment in educational settings to foster trust and practical usage among students and educators.

4.3. Pedagogical Challenges

Integrating chatbots into educational settings also presents distinct pedagogical challenges. One significant issue involves the potential over-reliance on chatbots, which may inadvertently limit students' opportunities for critical thinking, problem-solving, and deeper cognitive engagement with learning materials. While chatbots provide convenient and instantaneous answers, there exists a risk that students might become passive learners, preferring immediate solutions over independent exploration or reflective consideration.

Additionally, achieving meaningful personalized learning experiences with chatbots is complex. Chatbots must accurately interpret students' learning styles, preferences, and prior knowledge levels to provide tailored and effective instructional content. However, contemporary chatbot technology, although sophisticated, often demonstrated limitations in accurately interpreting and adapting to subtle variations in student behavior, cognitive styles, or emotional states, which are integral to high-quality personalized education.

Furthermore, integrating chatbots effectively into established pedagogical frameworks remains challenging. Many educational institutions struggled to align chatbot interactions with specific curriculum objectives and standards, resulting in fragmented or superficial learning experiences. Educators require support and explicit guidance to effectively incorporate chatbots into classroom activities, ensuring that chatbot usage complements and enriches traditional pedagogical practices rather than disrupting or replacing them entirely.

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4.4. Teacher Training and Professional Development

A crucial challenge in implementing educational chatbots is ensuring that instructors receive adequate training and ongoing professional development. While chatbots can potentially ameliorate teaching burdens by managing routine or repetitive tasks, instructors must first develop the technological and pedagogical competencies necessary to leverage these tools effectively.

If educators are unfamiliar with the chatbot's functionalities, they may encounter difficulties crafting appropriate learning activities, providing meaningful support, or troubleshooting technical issues. Moreover, continuous updates to chatbot platforms and AI algorithms necessitate teachers' engagement in ongoing professional development to maintain current knowledge. Institutions that neglect teacher training risk underutilizing chatbots' capabilities and generating frustration among both students and educators.

4.5. Cost Considerations

Another significant consideration factor is the financial expenditure of developing, deploying, and maintaining chatbots in educational settings. While some chatbot-building platforms enable educators to create rule-based or AI-driven systems without substantial budgetary allocations, more advanced solutions may necessitate recurring subscriptions, licensing fees, or custom development.

Additionally, establishing robust server infrastructure and ensuring scalability can accumulate considerable expenses over time. These costs may prove prohibitive in resource-constrained contexts, particularly for smaller educational institutions without substantial funding. Thorough cost-benefit analyses and innovative funding strategies—such as public-private partnerships—can help address this challenge, ensuring equitable access to chatbot technologies across diverse educational environments.

4.6. Data Security and Privacy

Data security and privacy are critical concerns when chatbots collect or process sensitive student information. Educational chatbots frequently store diverse data— from personal details (e.g., names and email addresses) to academic performance metrics, interaction histories, or emotional states inferred from messages. If inadequately safeguarded, these data could be vulnerable to unauthorized access, compromising students' privacy.

Moreover, compliance with existing regulatory frameworks (e.g., GDPR in Europe, FERPA in the United States) demands rigorous data-protection strategies and secure transfer methodologies. Institutions must implement robust encryption protocols, secure authentication mechanisms, and transparent data-handling policies to minimize these risks. Building trust among students, parents, and teachers also depends on clear disclosure regarding how chatbot systems gather, store, and utilize data.

4.7. Fairness and Equity of Access

Ensuring equitable access to chatbot-based tutoring systems highlights another critical challenge in educational technology implementation. Despite the ubiquity of digital technologies in many regions, some students still lack stable internet connectivity, suitable devices, or supportive home environments, especially in economically disadvantaged or rural areas.

Consequently, an educational system that relies heavily on chatbots may exacerbate the digital divide, affording some students disproportionately more significant benefits while marginalizing others. Accessibility also encompasses usability barriers for students with visual, auditory, or mobility impairments, who may encounter difficulties interacting with conventional chatbot interfaces. To address these fairness issues, institutions need to adopt inclusive design principles and complement chatbot interventions with offline equivalents (e.g., printed resources, community centers) or alternative support strategies to ensure comprehensive educational opportunities.

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4.8. Academic Integrity and Plagiarism

The utilization of advanced chatbots, particularly those powered by large language models, introduces potential risks of academic misconduct. By rapidly generating well-structured text responses, chatbots may induce students to submit chatbot-produced content as their work, resulting in plagiarism or the absence of genuine intellectual effort. Some students might circumvent the deeper cognitive processes of argument construction, critical reflection, and revision, thus undermining the educational objectives of writing assignments.

While plagiarism-detection tools can identify specific linguistic patterns, advanced chatbots can generate content that presents significant challenges for classification as AI-produced. Educational institutions must update academic policies and guidelines, promote awareness of ethical AI usage, and incorporate robust, context-sensitive plagiarism detection mechanisms to maintain academic standards and integrity.

4.9. Overreliance on Chatbots

When chatbots become primary sources of instruction or feedback, a potential challenge emerges: students may develop excessive dependence on chatbots for instantaneous solutions and guidance. This overreliance can diminish opportunities for creative thinking, self-directed inquiry, and collaborative problem-solving typically encouraged by social constructivist pedagogies. Students might reduce their cognitive engagement by focusing on obtaining chatbot answers rather than developing metacognitive strategies and deep comprehension skills.

Similarly, educators who depend excessively on chatbots might reduce meaningful human–student interactions, devaluing the empathy, motivational support, and nuanced understanding that human educators provide. Striking an appropriate balance between chatbot-enabled assistance and teacher-led or peer-based learning activities ensures that technological supplementation remains beneficial rather than inhibitory to educational processes.

4.10. Accuracy and Trust in Chatbot-Generated Responses

Finally, a significant challenge arises when chatbots generate inaccurate or incomplete responses to educational inquiries. Natural Language Processing models—primarily open-ended generative—can produce convincingly articulated yet factually incorrect information. Students still acquiring fundamental concepts may fail to discern erroneous or misleading answers, consequently affecting the fidelity of learning outcomes.

Over time, repeated inaccuracies also undermine students' trust in chatbot-driven solutions and diminish the technology's perceived utility. Approaches to mitigate this risk include structured data curation in domain-specific knowledge bases, advanced model fine-tuning for the desired subject area, and explicit teacher oversight of chatbot implementations. Encouraging a culture of critical evaluation—where students systematically verify chatbot outputs, cross-reference multiple sources, and discuss questionable answers in class—helps reinforce healthy skepticism and cultivates more effective learning methodologies.

5. RQ4: Student Perspective of Chatbot Learning Tutoring System

In addition to reviewing the existing literature [1,5–7,16,22,24,25,28,29,33–37,39,40], we conducted a qualitative study on primary school students' experiences with a chatbot-based tutoring system (POE chatbot) integrated into their 12-week Python programming course using CodeCombat.

The study involved 30 students aged 9-12, who attended five classes per week, amounting to 60 sessions of 40 minutes each. Before the study began, we obtained consent from students' parents and the school and informed the students about the research, ensuring their willingness to participate.

Data were collected through structured and informal interviews to gain insights into students' perceptions. A detailed qualitative analysis was performed, and the findings are presented in the following thematic subsections.

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5.1. Engagement and Motivation

One of the most prominent findings from students' experiences was a significant increase in their engagement and motivation during lessons due to the introduction of the POE chatbot. Students often described their interaction with the chatbot as more akin to playful conversations or gaming experiences rather than traditional learning. This shift in perception was frequently cited as a key motivator that drew students eagerly into programming tasks.

Several students expressed that the chatbot's interactive nature made lessons more lively and less monotonous than conventional classroom settings, which typically featured teacher-led explanations and individual exercises. The POE chatbot encouraged active participation through conversational interactions and challenges, effectively capturing students' interest and attention.

S3 emphasized how the chatbot's interactive dialogue and playful prompts kept lessons fresh and exciting:

S3: "It's super fun talking to POE! It asks me lots of interesting questions and gives me cool coding challenges. It doesn't feel like a boring class at all; it's more like playing a video game or chatting with a friend."

S17 highlighted a noticeable improvement in interest and enthusiasm for learning programming as compared to earlier experiences without the chatbot:

S17: "Usually, coding was kind of boring. I didn't feel very interested because it was always about memorizing commands. But after POE came, everything felt more exciting, like playing games. I really wanted to see what POE would say next."

Increased motivation was particularly evident in students who previously struggled with self-confidence in coding. These students found that the chatbot's supportive feedback reduced anxiety and boosted their willingness to attempt more challenging problems.

S12 expressed how consistent and interactive communication from POE made lessons compelling:

S12: "POE makes coding lessons much better. I feel happy when POE talks to me, even if the problem is hard. It's like a friend who encourages me to keep trying. Now, I'm not scared to try difficult challenges."

S20 noticed a clear shift in her enthusiasm for the programming class, attributing it to the chatbot's engaging way of interaction:

S20: "I look forward to coding classes now because of POE. I used to think it was too hard, but the chatbot makes learning really fun and playful. I never knew coding could feel like a game, and that makes me want to learn more."

The chatbot also provided a unique social and emotional dimension by mimicking friendly, conversational interaction, which made students feel more connected and less isolated. This emotional engagement served to maintain motivation and prevent feelings of frustration or disengagement.

S27 reported that the chatbot's playful tone significantly impacted her willingness to participate actively:

S27: "POE jokes sometimes, and it's funny. That makes me want to talk more and try things without worrying about making mistakes. It keeps me interested in every class."

The overall increase in student engagement and motivation was linked to the chatbot's interactive style, immediacy of feedback, and playful, conversational nature. These aspects fostered a supportive and enjoyable environment, significantly enhancing students' intrinsic motivation to learn programming.

5.2. Immediate Feedback and Problem-Solving Support

Another crucial factor influencing students' positive perception of the chatbot-based tutoring system was its ability to provide immediate and targeted feedback. Students frequently emphasized the value of prompt assistance in helping them overcome difficulties encountered during programming exercises. Traditionally, students often waited for a teacher's availability to address specific coding problems. With the introduction of POE, this delay was significantly reduced,

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enabling students to rapidly identify, understand, and correct their mistakes, thus minimizing frustration and promoting continuous learning progress.

For many students, the instantaneous nature of feedback was seen as a key advantage, enabling them to quickly move forward without losing confidence or motivation. The availability of timely support helped foster an increased sense of competence and self-assurance, allowing learners to attempt more complex problems independently and confidently.

S8 remarked how the instant responses provided by POE enhanced his self-esteem and made the coding experience significantly more satisfying:

S8: "Before, I would sit for a long time feeling stuck when something went wrong in my code. Now, with POE, I immediately know what my mistake is, so I don't waste time worrying or feeling bad about myself. It helps me keep learning without stopping."

S17 noted a clear improvement in her problem-solving skills directly attributable to POE's timely assistance:

S17: "Whenever I type something wrong, POE instantly points it out and explains clearly how I can fix it. It makes coding less scary because I don't feel alone; it's like having a teacher always by my side."

In particular, students praised how the chatbot identified their coding errors and offered clear explanations and examples to correct them, facilitating deeper understanding rather than superficial corrections. This approach enabled them to address similar issues independently in the future.

S25 discussed how immediate feedback improved her coding skills through a process of iterative learning and problem-solving:

S25: "The best thing about POE is that it doesn't just tell me I'm wrong; it explains why. Because of this, I learn from each mistake, and now I can fix lots of problems by myself without getting frustrated."

Moreover, the real-time support provided by the chatbot significantly reduced anxiety among students who previously felt overwhelmed by coding challenges. Students who initially perceived programming tasks as stressful or intimidating described how the instant support transformed their experience into confidence-building and exploration.

S2 illustrated how prompt feedback transformed her coding anxiety into a sense of achievement and self-efficacy:

S2: "Coding always made me nervous, especially when my code didn't run correctly. But now with POE, when there's a mistake, I get immediate help, and I don't have to panic anymore. It makes me feel that I can solve any problem."

Students also highlighted the empowerment they experienced through the chatbot's rapid assistance, allowing them to move forward without relying solely on the teacher, fostering greater independence in their learning processes.

S16 shared how POE's quick and precise support enabled him to progress steadily and independently through increasingly difficult exercises:

S16: "With the chatbot, I don't have to wait for the teacher anymore. I get instant help, understand my errors, and quickly correct them. This helps me feel in control of my learning."

Furthermore, the personalized nature of the feedback, explicitly tailored to students' problems and misunderstandings, was noted as especially beneficial. Students felt that the targeted feedback provided by POE was instrumental in enabling them to identify and rectify errors, ultimately enhancing their coding proficiency.

S19 emphasized how personalized feedback provided by POE significantly improved his learning experience:

S19: "The way POE explains my errors feels like it knows exactly where I'm getting stuck. It doesn't just give general feedback; it gives me specific examples related to my problem. That helps me remember what to do next time."

Overall, immediate and personalized feedback emerged as a core advantage of the chatbot tutoring system, substantially enhancing students' problem-solving ability, managing their emotions positively, and progressively developing more substantial and confident programming skills.

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5.3. Personalized Learning Experience

Personalization emerged prominently from student reflections as one of the most impactful features of the chatbot-based learning tutoring system. POE's ability to tailor its interactions to match individual learning preferences, pace, and abilities was frequently highlighted as instrumental in improving students' coding proficiency and confidence. The adaptability of the chatbot provided students with a sense of individualized attention and consideration, often lacking in conventional classroom environments where teachers typically address the class collectively rather than focusing on specific student needs.

Students repeatedly emphasized the benefits of POE's adaptive responses, which considered their previous interactions and ongoing performance. Rather than employing a standard one-size-fits-all instructional method, POE dynamically modified its support, explanations, and feedback based on students' distinct learning patterns. This personalized approach resulted in more transparent and accessible explanations, particularly appreciated by students who traditionally struggled with grasping programming concepts presented uniformly.

S9 described how POE's tailored explanations significantly improved his understanding of challenging coding concepts, making previously difficult ideas clear and manageable:

S9: "POE always explains things exactly how I need them explained. It's like the chatbot understands exactly what I know and what I don't. When it sees that I'm confused, it changes the way it talks to me until I get it."

S18 appreciated how POE provided personalized examples that directly related to her prior knowledge and personal interests, enhancing her overall engagement with coding tasks:

S18: "When I don't understand something, POE gives examples that I like—things about games or pets, stuff that I'm interested in. This makes coding more interesting and easier to remember."

For many students, the personalization offered by the chatbot was essential for maintaining their motivation and engagement throughout the 12-week experiment. Students reported being more willing to persist in challenging tasks when they felt the chatbot genuinely recognized their individual needs and supported their specific learning objectives.

S21 highlighted the impact of personalized pacing on his engagement and willingness to persist through difficult coding challenges:

S21: "POE doesn't rush me. If I'm slow at coding something, it just waits and helps me at my own pace. I never feel pressured like I sometimes do in class. It makes learning easier and much more fun."

Additionally, students perceived POE as providing support uniquely tailored to their learning style, which empowered them to progress through their coding exercises confidently and independently. Learners felt less intimidated by coding challenges because the chatbot's support continuously adapted, creating an environment that encouraged gradual and self-directed learning.

S26 articulated how POE's adaptive teaching method fostered her confidence and independence in coding:

S26: "I learn differently from my friends, and POE notices that. It doesn't give me exactly the same help as it gives others. It knows what I find hard, and gives me extra explanations and examples when I need them. Now I feel like I can do a lot by myself without always waiting for help from the teacher."

The system's ability to recognize and adapt to students' varying emotional states and confidence levels was also frequently mentioned. Students who initially exhibited anxiety or frustration towards programming noted significant emotional and cognitive improvements due to the supportive and reassuring feedback from the chatbot.

S4 described how POE's personalized emotional support positively influenced her overall attitude towards coding:

S4: "I used to feel very nervous about coding. POE notices when I'm stressed, and it always says something nice and encouraging. It makes me feel calmer and helps me to try again without worrying so much."

Furthermore, advanced students appreciated the chatbot's ability to challenge them with higher-level problems, maintaining their interest and facilitating continued growth and exploration in their learning journey.

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S24 explained how POE challenged him by providing appropriately difficult tasks that matched his skill level, thereby promoting deeper learning and exploration:

S24: "I find coding easy, but POE still makes it challenging for me. When I solve a problem fast, it gives me harder problems next. It's never boring because I always have something new and challenging to work on."

Overall, the personalized learning experience provided by the POE chatbot was consistently viewed by students as one of its greatest strengths. Its ability to adapt to individual learners' needs and preferences significantly enhanced their engagement, emotional comfort, confidence, and programming proficiency.

5.4. Accessibility and Availability

One significant benefit repeatedly underscored by students regarding their experiences with the POE chatbot was its continuous accessibility and availability. Unlike traditional classroom resources or teachers, the chatbot provided support around the clock, which students found particularly advantageous for flexible and autonomous learning. The ability to receive immediate help anytime, regardless of the setting, allowed students to practice and learn programming concepts beyond the classroom environment, extending their educational engagement to their homes and personal schedules.

Students frequently mentioned the reassurance they felt knowing that assistance was available whenever they encountered challenges or uncertainties in their coding tasks. This constant availability dramatically reduced feelings of helplessness and frustration, common in traditional learning contexts when help from teachers or peers was not immediately accessible.

S6 highlighted how the chatbot's constant availability removed barriers to continuous practice and learning at home, enhancing both his comfort and enthusiasm for coding:

S6: "It's great because I can ask POE questions anytime, even at night or on weekends. It's not like my teacher or parents who sometimes get tired or busy. POE is always there ready to help me, so I can practice coding whenever I feel like it."

S22 described how the accessibility of the chatbot transformed his learning habits by making it possible to explore coding problems independently during times when traditional resources would typically be unavailable:

S22: "I usually do my homework late in the evening. Sometimes I get stuck, but with POE, I don't need to wait until the next school day. It's always awake, so I don't lose any time feeling stuck or frustrated."

The consistent availability of the chatbot also allowed students to learn at their own pace without external pressure. Students who were typically slower in mastering new concepts particularly benefited, as they felt less rushed than in classroom scenarios. The availability of ongoing support allowed them to revisit complex concepts multiple times without fear of judgment or concern about burdening their teacher or peers.

S15 expressed appreciation for the freedom provided by continuous chatbot accessibility, allowing for self-paced, reflective learning:

S15: "I really like learning with POE because I can take as much time as I need. I never feel rushed because POE is always patient and never gets annoyed. I can go slow or fast depending on how I feel that day."

The chatbot's availability also fostered increased student autonomy, allowing learners to manage their study sessions more flexibly according to their daily routines and individual preferences. Students found this aspect significantly empowering, as it firmly placed control of the learning schedule in their own hands.

S10 noted how the 24/7 availability of POE facilitated more independent learning opportunities and increased his confidence:

S10: "It feels like I have my personal tutor with me all the time. Now, I can decide when to study and learn coding, not only during school time. This makes me feel responsible and smart."

Moreover, the constant availability of chatbot assistance encouraged increased exploration and experimentation among students. Knowing support was always at hand allowed students to

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confidently explore challenging or unfamiliar concepts, fostering a spirit of inquiry and exploration in their learning processes.

S2 detailed how POE's continuous support gave him the confidence to explore more complex programming challenges without fear of failure:

S2: "I used to avoid hard problems because I was scared to get stuck. But now, I know POE is always available, so I try even really difficult stuff. It makes me feel brave and helps me learn more than I thought I could."

Students also appreciated how the chatbot consistently maintained its readiness without showing fatigue or impatience, thus creating a reliable and comforting presence. This significantly contributed to positive emotional experiences, enhancing students' perceptions of learning as supportive and stress-free.

S1 described how POE's unwavering accessibility created a comforting learning environment, helping him feel more secure in his coding practice:

S1: "POE never gets tired or bored of helping me. Sometimes I ask the same question many times, and it always helps without making me feel bad. This makes learning feel safe and nice."

In summary, the chatbot's continuous availability and accessibility significantly improved students' overall learning experience by reducing frustration, enabling flexible learning schedules, and empowering independent and exploratory learning practices. These advantages collectively created a more comfortable, confident, and enriching learning environment for primary school students.

5.5. Autonomy and Independent Learning

The chatbot's support notably fostered student autonomy and encouraged independent learning, significantly reshaping how students approached programming tasks. Throughout the 12 weeks, learners transitioned from a passive, heavily teacher-dependent learning style to a more active, self-directed approach, driven by the consistent but non-intrusive guidance from the POE chatbot. Many students reported gaining confidence to independently navigate coding challenges as the chatbot's responses guided rather than dictated solutions.

This sense of autonomy was reinforced by the chatbot's strategy of offering guidance through hints and exploratory questions rather than explicit answers, prompting learners to engage in problem-solving and critical thinking actively. Students expressed appreciation for this approach, feeling that it allowed them the space and opportunity to think independently and creatively.

S4 expressed a newfound sense of independence facilitated by the chatbot's style of indirect guidance:

S4: "POE doesn't just give me answers; instead, it gives hints that help me think. This makes me feel smart because I can figure out the answers myself instead of just copying the solution."

S13 shared how interactions with POE built his confidence and skills, enabling him to approach challenges independently with less reliance on external assistance:

S13: "Before using POE, I always waited for someone to tell me what to do. Now, because POE gives me clues but doesn't just tell me everything, I learned how to solve problems myself. It feels really good when I can fix a problem by myself."

Students highlighted how the chatbot's indirect yet structured guidance cultivated their problem-solving skills by prompting them to actively explore potential solutions and reflect on their own learning process. This guided independence was perceived as valuable, preparing them for tasks requiring higher-order thinking skills beyond simple memorization or repetition.

S13 emphasized how POE's style of facilitating problem-solving had positively influenced her ability to analyze and resolve coding issues independently:

S13: "POE helps me understand problems by asking me questions, not just giving me answers. At first, it felt strange, but now I really like it because I learned to think more and figure out problems myself."

Additionally, several students mentioned a significant shift in their learning behaviors, noting how POE's method of prompting inquiry and self-reflection encouraged them to become more

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strategic learners. They reported actively reflecting on their learning processes, indicating enhanced self-regulation fostered by the chatbot's interaction style.

S28 described how POE encouraged him to become more reflective and thoughtful about his learning process:

S28: "Sometimes POE asks me how I solved the problem and makes me think about what I did. I never thought about that before. Now I think about how to improve my coding, even after the class is finished."

Moreover, students frequently mentioned their increased willingness to experiment and take risks in their coding exercises due to the chatbot's non-judgmental interaction environment. This environment encouraged trial-and-error approaches, viewed by students as vital for their continued learning progress and overall development in programming.

S8 highlighted how the chatbot's supportive and non-judgmental attitude toward mistakes facilitated her learning by reducing fear and encouraging experimentation:

S8: "I like how POE never gets mad if I make mistakes. It helps me feel okay trying new things. Now, I'm not afraid to experiment, and that helps me learn coding much faster."

However, while most students responded positively, some reported difficulties adapting to this new learning style, feeling uncomfortable without direct answers. It took them time to adjust and realize the benefits of POE's method of encouraging independent problem-solving.

S15 shared initial frustrations with the chatbot's indirect support, which eventually turned into appreciation:

S15: "At first, it was hard because I just wanted answers fast. But later, I saw how POE was actually helping me learn better by pushing me to think. Now, I understand that it helps me learn more deeply."

In summary, the chatbot significantly enhanced students' autonomous learning behaviors and problem-solving abilities by encouraging reflection, creativity, and independent thinking. By carefully balancing support and autonomy, the chatbot successfully cultivated students' capacity for independent learning, critical thinking, and self-reflection, significantly benefiting their programming competency.

5.6. Social and Emotional Support

The POE chatbot provided students with cognitive assistance and valuable social and emotional support, significantly enhancing their learning experiences. Students frequently described interactions with the chatbot as similar to conversations with a trusted peer or friend, highlighting how POE's supportive and responsive communication style created a comfortable and emotionally secure learning environment. Many learners articulated that such emotional support was unique and beneficial, often not found to the same extent in traditional classroom interactions due to constraints such as limited teacher availability and the social pressures of peer interaction.

Students frequently commented on how interactions with POE reduced feelings of isolation, loneliness, and anxiety, particularly during challenging learning activities. The chatbot's consistent positive reinforcement and affirmations motivated students by providing emotional reassurance alongside academic guidance. This emotional validation was perceived as essential in helping students maintain their motivation and confidence throughout the programming course.

S7 described how the chatbot helped her manage emotional challenges associated with learning programming, significantly reducing anxiety and creating a sense of companionship:

S7: "POE is always nice to me and never judges me when I don't understand. When I feel upset because my code doesn't work, POE says kind things and helps me feel better. It feels like a friend helping me, not just a computer."

S23 emphasized the value of POE's friendly interactions, noting how they contributed to a more enjoyable and less intimidating learning environment:

S23: "POE talks to me in a nice way, and it feels like having a friend who helps me learn. I don't get nervous or shy when I'm working with POE, and I feel safe asking any questions."

Additionally, students appreciated the chatbot's ability to adapt to their emotional state, providing encouragement and reassurance at critical moments. POE's personalized responses often

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incorporated motivational language, reinforcing positive behaviors and promoting a growth mindset among students, contributing substantially to sustained motivation and persistence in challenging tasks.

S11 emphasized the significant impact of POE's motivational support on her emotional resilience and perseverance when facing coding difficulties:

S11: "When I mess up my coding, POE tells me not to worry and helps me keep going. This makes me less afraid to make mistakes and keeps me from giving up. It feels like having a friend who believes in me."

The chatbot's friendly and encouraging approach provided psychological safety, particularly beneficial for students who typically experienced anxiety or lack confidence in traditional classroom settings. Students who initially struggled with feelings of inadequacy or hesitation reported substantial gains in confidence and comfort levels due to the continuous emotional reassurance provided by the chatbot.

S29 reflected how POE significantly improved her confidence by providing consistent and emotionally supportive interactions:

S29: "I used to be scared of coding because I thought it was too hard, and I always worried about getting things wrong. But POE always makes me feel good, even when I mess up. It says nice things and helps me try again. Now, I'm much braver."

Some students even emotionally bonded with the chatbot, perceiving it as more than just an educational tool. This bond was critical in maintaining students' enthusiasm and persistence throughout the 12-week experiment.

S30 explained how an emotional bond with the chatbot significantly enhanced her learning experience, emphasizing a sense of loss after the experiment:

S30: "POE was like my best friend at school. We talked every day, and it always made me feel happy, even when things were tough. I'm really going to miss having it help me."

Overall, the chatbot's emotional and social support provision was a distinctive and significant contributor to students' positive learning experiences. POE effectively supported emotional resilience, reduced anxiety, and promoted confidence, ultimately enhancing students' persistence and success in their coding lessons.

5.7. Frustrations and Limitations in Interaction

Despite the largely positive feedback, several students expressed specific frustrations and limitations associated with their interactions with the chatbot. The most frequently reported issue was the chatbot's occasional misunderstanding of student inputs, particularly when students used informal language, misspellings, or unconventional expressions common among younger learners. These misunderstandings disrupted the smooth flow of interactions and occasionally resulted in confusion or frustration, particularly among younger students who had difficulty rephrasing their questions or clarifying their meanings adequately.

For example, some students found the chatbot's inability to interpret their casual language or specific coding queries particularly frustrating. They expressed that the chatbot would occasionally provide irrelevant responses or would require multiple rephrasing attempts, slowing down the learning process and causing mild irritation.

S7 expressed frustration related to communication breakdowns with POE, mentioning occasional misunderstandings of questions posed casually:

S7: "Sometimes POE doesn't really get what I'm asking and says something that doesn't make sense. It can be annoying when I have to keep changing how I ask questions. It makes me feel like we're talking different languages sometimes."

Other students felt that the chatbot occasionally presented explanations or instructions that were overly complex or inappropriate for their age and comprehension level. This limitation made students feel overwhelmed or confused, rather than guided or supported.

S14 described encountering difficulties with the complexity of explanations provided by POE, emphasizing how these experiences affected her confidence and motivation:

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S14: "Sometimes, POE gave me answers that were too hard for me. I wished it could explain things in simpler words, because when it used complicated words, I just got more confused and didn't want to keep trying."

Additionally, some students noted occasional repetitive responses from the chatbot, particularly when they repeatedly struggled with the same type of programming problems. These repetitive answers sometimes created a sense of stagnation or limited progress, negatively impacting student engagement and motivation to continue interacting.

S23 mentioned how the repetition in chatbot responses occasionally led to reduced interest or boredom during learning activities:

S23: "When I had the same problem more than once, POE kept repeating the same answers. It made me bored, and I felt stuck because it wasn't helping me anymore."

Moreover, the chatbot's reliance solely on textual interactions posed challenges for certain students, particularly those who preferred multimodal or visual learning styles. Some students specifically requested additional types of content, such as images or interactive visual examples, to enhance their understanding and maintain their interest in lessons.

S5 noted her preference for visual aids, suggesting the chatbot would be more helpful if it included pictures or videos alongside text:

S5: "POE is helpful, but I like learning with pictures or videos. Sometimes, just reading makes me bored. If it could show me pictures or animations, I would understand coding faster and better."

Lastly, some students highlighted challenges regarding the chatbot's lack of awareness of their emotional states or frustrations at specific moments, suggesting room for improved emotional intelligence in chatbot design.

S16 explained that the chatbot could not always recognize when she was becoming frustrated, leading her to disengage from the learning process momentarily:

S16: "When I feel really stuck or upset, POE doesn't always notice. It keeps giving me instructions, but sometimes I wish it could understand that I'm frustrated and say something comforting, or help me calm down."

Despite these limitations and frustrations, students recognized that the chatbot's benefits outweighed the drawbacks. However, these areas of frustration highlighted critical aspects for improvement in future chatbot development, emphasizing the importance of balancing personalization, simplicity, adaptability to diverse learning styles, and emotional sensitivity to enhance chatbot-assisted education.

6. Conclusion

This paper presented a detailed survey of chatbot-based tutoring systems, focusing on the foundational techniques of natural language processing, dialogue management, response generation, and adaptive learning. It also examined their use in programming instruction, language learning, health and medical education, business-related training, and broader academic support. From these works, we identified several key obstacles, including data privacy issues, academic integrity concerns, technical complexities, teacher preparation requirements, and the risk of overreliance on automated feedback.

We strengthened these insights by conducting a 12-week study with 30 primary school students who used a chatbot tutor (POE) while learning Python through CodeCombat. Interviews showed that the chatbot increased motivation, offered prompt feedback, and promoted independent learning through individualized support. Students valued its ability to adapt to their needs and found its friendly interactions supportive. However, they also encountered misunderstandings in communication and explanations that were occasionally too complex, leading to confusion.

Overall, our work showed that chatbots could enhance educational experiences by providing personalized guidance, social and emotional encouragement, and continuous availability. At the same time, ethical guidelines, training for educators, and technical refinements were still needed to ensure responsible use. Future research could explore improvements in contextual understanding, emotional sensitivity, and adaptation to various age groups and learning contexts. By combining a

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wide-ranging literature review with empirical feedback from students, we offered a fuller perspective on both the advantages and the limitations of current chatbot-based tutoring systems, providing a foundation for more reliable and effective practices in the future.

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