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A Systematic Review of AI Chatbots in Education Using NLP and LLMs

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ABSTRACT

AI chatbots have emerged as an important part of the contemporary education structure, assisting students in academics and administration, as well as increasing their access to information. Due to the rule-based nature of early chatbots, their flexibility and comprehension capacity were limited. However, due to advances in Natural Language Processing (NLP), Deep Learning (DL), and Large Language Models (LLM), increasingly sophisticated chatbot systems that understand contexts and can interact with users have been introduced. This paper provides a comprehensive analysis of twelve notable research articles that highlight the use of AI chatbots in education. The selected research articles are analyzed in terms of chatbot architecture, technology, data sources, and evaluation criteria under the framework of systematic literature review. The results demonstrate a shift from rule-based machine learning techniques to RAG model, deep learning, and semantic embeddings. These novel methodologies imply higher quality and accuracy of responses. However, there are numerous including hallucinations in generative models, lack of evaluation metrics, scalability, and trust in data sources. This research highlights the present research trends, limitations of existing methodologies, and future directions of research in developing trustworthy, scalable, and intelligent AI chatbot applications in education settings.

Keywords: AI chatbots; conversational AI; educational technology; natural language processing; deep learning; retrieval-augmented generation

INTRODUCTION

Voice bots using advanced intelligent software allowed humans to communicate using natural speech. In earlier times, these assistants were limited in capabilities since they operated under certain instructions based on specific keywords and phrases – this resulted in problems with comprehension and handling difficult situations. Nowadays, these machines can comprehend meaning, identify user's needs, track the conversational process, especially in educational issues, due to significant progress in language technologies, pattern recognition, and neural networks.

A number of different scientific studies confirmed the efficiency of the rule-based and NLP-based chatbots in handling standard academic requests like enrolment, examinations, and course information. Despite the fact that these technologies significantly decreased the work load and reaction time, they failed in adapting to new conditions and unidentified inputs [1,2]. The analysis of the evolution of NLP-based chatbots revealed certain difficulties in conversational adaptability and scaling issues [3].

In order to tackle these problems, there emerged a tendency to implement deep learning algorithms in the creation of chatbots. It has been proven that neural networks including LSTM, BiLSTM, CNN, and Seq2Seq significantly exceed traditional machine learning techniques in regard to accuracy and semantics representation based on several comparative tests [4]. The use of sentence embedding models allowing to provide an enhanced semantic similarity match between user input and existing knowledge base is becoming common practice in the recent scientific researches on building chatbots [5].

In the current time, chatbots become smarter owing to big language models. However, these intelligent systems often reply in a very confident manner though giving incorrect answers. In order to solve this problem, certain

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strategies involve obtaining the factual data from credible sources prior to providing any response. This strategy brings about the increase in precision and topic adherence in conversation [6,7].

Moreover, researches on retrieval-based and web-based chatbots that could retrieve data from university websites and documents have also been conducted. Such a feature makes chatbots more accessible, as there is no need for manual navigation or static FAQ pages anymore [8,9]. Chatbots that enable speech interaction become even more accessible and convenient for users from various backgrounds [10].

Besides, multimodal chatbots that provide users with the ability to use text, speech, and image interaction are also beneficial in enhancing students' accessibility and engagement while learning [11]. Systematic reviews of the application of artificial intelligence-based chatbots in education were conducted and found consistent benefits and drawbacks, including the need for evaluation criteria and ethical considerations [12].

Despite progress, challenges persist - costs remain excessively high, certain languages are not considered, testing criteria do not exist, one method creates fictitious information. It is because of such difficulties that this study examines a dozen important AI-based chatbot developments, analyzing their operation, form, applications, identifying trends in research and suggesting future directions for robust, scalable, intelligent chatbots within educational institutions.

Background Study

Hidden inside each chatbot are basic concepts, working together without much attention. These parts support the studies looked at here, yet rarely get mentioned directly. What matters grows clear only by exploring how things actually function, not just their results. Even when outcomes feel surprising, earlier work still plays a role behind the scenes. Truth is, patterns take center stage, not guesses. The true story is in how systems adapt their behavior, incrementally, with enough time.

Artificial Intelligence Chatbots

Chatbots aren't real people but act like them when chatting. Some speak out loud while others type back replies. When it comes to classrooms, these bots hand out study details whenever a student asks. Questions about lessons? Just ask one of these helpers instead. Getting support on school tasks becomes easier since they're always ready to respond. Chatbots let users grab needed details without hassle, according to certain research. Schools find them useful since replies repeat without tiring - no human required each time [1,2,11]. Tasks humans avoid? Machines handle those smoothly. Help arrives fast when bots step in.

Rule-Based and Early NLP-Based Chatbots

The initial designs of chatbots were based on rule-based systems, scripted responses, and pattern recognition. Rule-based systems are useful for structured and predictable queries but are not flexible or context-aware. Research papers on college enquiry chatbots demonstrate the usefulness of rule-based systems and simple NLP-based solutions but also point out the limitations of these solutions in dealing with complex or novel user inputs [1,2]. Research papers with a review focus also point out the scalability and flexibility limitations of these solutions [3].

Machine Learning and Deep Learning Approaches

To get around the limitations of systems that are based on rules people started using machine learning techniques to figure out what someone means and to choose the response. The old way of doing machine learning was more flexible. It still needed people to create special features. Then came the new way of doing machine learning, which includes things like LSTM, BiLSTM, CNN and sequence-to-sequence architectures. This allowed chatbots to learn what things mean directly from the data. When people compare the ways of doing things and try them out they always find that chatbots that use deep learning are better, at understanding what people mean are more stable and can understand the context of a conversation. This is what the studies [3,4] say about machine learning and chatbots and deep learning and chatbots.

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Semantic Embeddings and Sentence Representation

Modern chatbot models have started to make use of sentence embedding models to identify semantic similarities between user queries and existing knowledge. Embedding models enable chatbots to search for appropriate responses to user queries even if they are posed in different forms. Research studies using semantic embeddings, like SBERT-based retrieval models, have shown enhanced relevance of responses and the ability to process paraphrased academic queries effectively [5].

Large Language Models (LLMs)

Large Language Models make it possible for chatbots to produce fluent and contextually informed responses. This is supported by a number of studies that have been reviewed, and they show the effectiveness of LLMs in improving the quality of conversations. But these models have the tendency to hallucinate, which can result in linguistically correct but factually incorrect responses, which can be a challenge in learning environments [6,10].

Retrieval-Augmented Generation (RAG)

Retrieval-Augmented Generation is the integration of information retrieval and language generation to improve the reliability of chatbots. In RAG-based models, the relevant documents are fetched from reliable knowledge sources and are used as context for the language model while generating responses. The reviewed studies show that RAG-based academic chatbots have been able to decrease hallucinations and increase factual accuracy and trust [6, 7].

Web-Based and Document-Centric Chatbots

Some of the chatbot systems are designed to dynamically retrieve information from college websites or documents uploaded by users. The system allows users to communicate with the official web content and documents in a conversational manner, thus minimizing the need to browse manually. Web-based and document-oriented chatbots have proven that by using official content, they offer improved accessibility and accuracy of the information provided [8,9].

Multimodal and Voice-Enabled Chatbots

Talking to machines goes beyond typing. There is sound, and there is even imagery. This technology breaks down barriers, allowing more users to participate, particularly in educational settings. When multiple communication modalities combine, burdens lessen, obstacles become smaller. Studies prove this: combining various communication modalities promotes inclusion while reducing strain on personnel during regular operations. When chat systems speak and answer through speech, more individuals are included in the discussion, particularly those encountering barriers. Evidence confirms: combining visual, auditory, and textual communication deepens engagement among learners and improves usability of technology [9,11].

METHODOLOGY

This study employs an analysis of previous literature using a systematic approach that aims at arriving at clear conclusions. The method can be easily replicated since it is designed in such a way that every step taken is clearly defined. In evaluating all sources, no bias towards a particular result was observed.

Research Design

The research method is qualitative in its essence and systematic in its execution. The research is based on established principles of systematic literature reviews. The aim of the research is to determine, assess, and compare the relevant literature on the development of AI chatbots, including techniques, architectures, applications, and issues in the educational setting. The review is more focused on comparing methodologies than on experimental validation.

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Data Sources and Search Strategy

Looking into key research spots turned up useful papers - places like IEEE Xplore, SpringerLink, and others played a part. One by one, each source added pieces to the picture, pulling findings from ScienceDirect or the ACM library. Even Google Scholar helped connect dots across different areas. What showed up came from digging deep, using every channel just enough.

One query used terms like AI chatbot mixed with conversational AI. Another tied educational chatbot to NLP chatbot through shared traits. Sometimes deep learning chatbot appeared alongside LLM-based chatbot by design. Retrieval-augmented generation entered when context demanded depth. Each phrase linked distinct but overlapping ideas. Keyword blends emerged depending on user focus. Patterns shifted without fixed rules.
Only peer-reviewed articles, conference papers, and highly relevant preprints were considered.

Study Selection Criteria

Before picking any study, clear rules were laid out to check if it fit the purpose, stayed trustworthy, matched the goals. That way, only suitable ones moved forward through a steady filter - keeping choices fairer, more focused. Each step followed those early guidelines without drifting off track.

Inclusion Criteria

Focus on AI Chatbot Design, Development, or Evaluation

Not every paper made the cut - just those laying out clear work on AI chatbots. Whether building, testing, or analyzing such systems, they had to center on them directly.

Some papers touched on chatbots but didn't dive deep; those got left behind. Designs, code structures, how things moved through a system - all fair game if it was the main focus. If mention of a chatbot slipped by without real discussion, it played no role here.

Educational or Academic Application Domain

Chatbots in schools and universities shape the core of this review. Thus, articles dealing with the use of chatbots in a university setting qualify for inclusion in this study – e.g., those where the bot is used for responding to questions about admissions, getting course information, providing tutoring services, or scheduling classes.

Use of AI and NLP Techniques

One of the requirements for some of the selected studies is the use of certain methodologies, such as NLP or deep learning. It is not only about writing some simple code, but also about technologies used to find chatbots that were smarter than others. They did not pay much attention to old-school menus. They needed bots with adaptable approaches.

Technologies, such as LLMs and retrieval techniques, were among the most popular in those papers. As a result, only adaptive chatbots could be included in this review. Machine learning was quite popular, and sometimes it was combined with semantic techniques.

Clear Methodology and System Description

Only those studies that provided adequate technical details were included in the analysis. This encompasses system architecture, data processing methodology, algorithms used, as well as the implementation process. This is critical for comparisons as well as reproducibility of results.

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Exclusion Criteria

Non-English Publications

Non-English academic writings were excluded just because their comprehension would require translation, which may distort the interpretation of the content. Limiting sources to English-language studies ensured consistency of the interpretations made.

Non-Research Content

Those articles that included opinion pieces, tutorial writings, blogs, posters, and papers which are intended only for presentation were excluded as they lack any form of methodology and experimentation and/or peer-review process.

Irrelevant Research Scope

Researches dealing with other aspects of studies such as artificial intelligence, web-based development, and automation without the inclusion of chatbot functionalities were considered out-of-scope.

Insufficient Technical or Methodological Detail

The lack of some important information prevented the assessment of some research papers. If the procedure description was not clear enough – for example, when the evaluation procedures were described ambiguously or when the system architecture was not provided – such a paper could not be considered.

Data Analysis Procedure

For the assessment of the selected studies, a qualitative comparative analysis technique was adopted, since the intention behind this research paper was not to conduct any kind of statistical meta-analysis but rather to contrast different methodologies, designs, and findings. Each of the selected twelve papers was assessed and contrasted against each other using predetermined analysis criteria.
In the first place, the studies were divided into groups based on the nature of the chatbot design and the underlying principle used.

Depending on the technologies that have been deployed in the research studies, the chatbots can be classified as follows:

(i) rule-based and basic natural language processing chatbots,
(ii) deep learning chatbots,
(iii) semantic embeddings retrieval system chatbots,
(iv) Retrieval Augmented Generation chatbots, and
(v) multimodal and voice-enabled chatbots.

The subsequent phase involved a detailed analysis of every study focusing on the primary methods and approaches used, including the text cleaning process, deep learning, word embedding model, large language models, query generation processes, as well as the communication style used by the participant in the study. The sources of information were important, whether it is FAQ databases, university websites, existing text files, or archives and records departments.

Evaluation of the method and approach used to analyze results was the next step. In case where data was available, factors such as accuracy, meaning clarity, usability, accessibility, and participants' feedback were taken into account. Due to variations in measures of success in every project, judgment was based on trends rather than data.

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When analyzed retrospectively, all strengths and weaknesses were considered in detail. Common problems emerged time after time, such as bots misunderstanding context, making assumptions, lacking metrics for evaluating their efficiency, being unable to scale up, and posing ethical issues. As combined, the research conclusions of all twelve sources indicate both gaps that have yet to be filled and trends to watch out for regarding educational chatbots.

Breaking down all results in order helps to maintain consistency across studies, providing an excellent framework for discovering novel aspects of AI-powered tutoring bots and identifying possible areas for further exploration.

RESULTS AND DISCUSSION

The findings and analysis are provided below in relation to the systematic study conducted on AI chatbot creation in an educational context. The findings are categorized in accordance with approaches, methodologies, emphasis, and difficulties associated with the chatbots' usage.

Methods and frameworks utilized

Among the discussed papers, natural language processing is one of the fundamental aspects that helps to perform tokenization, identify intents, and generate responses. In addition, deep learning models like artificial neural networks are utilized for identifying intents and predicting sequences.
A number of other papers use techniques for embedding sentences to achieve better matching of the query-response pairs. Such techniques proved to be more powerful compared to search algorithms based on keywords due to the capability of detecting semantic similarity between the query and stored knowledge. The best models integrate Large Language Models and knowledge from the outside using the RAG framework.

Performance Metrics and Evaluation Methods

Every research does not test their findings equally. Some focus on the quantitative approach by assessing how accurate the models identify the intent and reply. Others do away with statistical testing and instead show how it works through actual cases, visuals, or even feedback from users.
There are no universally accepted methods of evaluation, although some try to verify whether the responses are correct, reasonable, contextual, effective, and comprehensive. Chatbots that deal with visuals and speech seem to attract more users, particularly those with varying engagement patterns. However, the lack of standard methods to evaluate these chatbots makes it difficult to compare findings across studies.

Challenges Identified

Now and again, there are some recurring challenges. In the case of rule-based and straightforward natural language chatbots, managing scaling is quite a challenge since context is easily lost. Additionally, deep learning systems require lots of information alongside substantial computing capabilities. Despite being great at dialogue and discussion, these large language models might fabricate data at times and pose serious issues for students within classroom settings.
Other issues include the fact that many scientific studies fail to use consistent methodologies to evaluate the effectiveness of chatbots, thereby hampering an accurate assessment of their performance. Issues regarding ethics arise, specifically concerning privacy concerns, accountability, and reliability of chatbot technology as they handle sensitive scholarly information.

DISCUSSION AND RESEARCH IMPLICATIONS

One change can be seen very clearly by studying changes in studies about chatbots used in education – more attention paid to the usage of hybrid models, combining neural networks with retrieval-based generation and

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searching methods. It means that researchers do not focus only on one type of research; they combine various methodologies to make sure that responses will be consistent but true.

However, technological progress is not enough for successful development; to develop the area, it is necessary to create new measurement criteria, improve transparency and use of educational chatbots, and learn about long-term impacts on teaching process and school administration. Summarizing the dozen articles discussed above, one can understand key aspects to consider when developing an educational chatbot.

Challenges and Limitation

From the literature above, some of the challenges that exist in the development and implementation of chatbots using AI technology can be identified. One such challenge is the ability of many chatbots to maintain the context of the conversation in case there are several rounds of conversation. In particular, this challenge is evident in cases where the questions posed by the user are not clear or straightforward. Even though the usage of LLMs has greatly helped to improve the flow of conversation, the issue of hallucination still exists with respect to the accuracy of the answers.
Not all researches reveal this fact, but there still seems to be some space for improvement when speaking about knowledge regarding chatbots in terms of learning. There is still an issue of using data sets specific to certain subjects, which need constant updates to keep up with the current situation. The fact is that despite their great performance, the best models now are rather demanding in terms of computing resources, which makes it challenging to implement them on a large scale due to budgeting issues. There is a language issue as well; currently, not all chatbots operate several languages successfully. Also, there was no focus on the issues of transparency, ethicality, etc. of the used datasets.

CONCLUSION

This review examined few studies concerning the development and application of AI chatbots in an educational setting. All the articles demonstrated the progression of the chatbot architecture, from rule-based approaches to more advanced models, which included the ability to understand natural language and learn through machine learning and deep learning technologies. Moreover, some chatbots became equipped with sophisticated mechanisms of semantic knowledge and used large language models and retrieval-augmented generation to produce answers.

As for the initial version of AI chatbots, they proved to be quite efficient in providing standard information about schools' curriculum since all the responses were limited to predetermined patterns. However, they could not provide answers when students asked unique questions, because of the inflexible framework and lack of continuity. As for current advancements, all modern chatbots utilize deep learning technologies and sophisticated mechanisms to provide more context-relevant information. Therefore, responses become more accurate and do not resemble robotic replies. Large language models also contribute to making dialogue flows more consistent. However, such models tend to generate information without a source, which is unacceptable for classroom discussions.

What stands out is the fact that such chatbots and their document-based design help minimize false information while increasing trust. The other important point here relates to the fact that visual or voice-enabled chatbots facilitate accessibility for many users who are likely to engage with the system easier because of their design.
Despite all these successes, a number of issues still require solutions such as the lack of standardized performance testing, difficulties associated with scaling, concerns about privacy, and insufficient research regarding the long-term consequences. It should be noted that the further development and efficient implementation of such technologies within the academic environment will not be possible without resolving all the above-mentioned issues.

One single look at this literature review demonstrates what is currently known about the use of chatbots within the learning process by schools – strengths, weaknesses, opportunities. In its turn, it can help future developers

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make certain decisions regarding further improvements and adjustments in order to design highly scalable, rational, and robust systems.

Future works

Despite many successful accomplishments made in the field of application of AI chatbots to the educational sphere, there are some promising directions which should be considered in further studies based on the examined literature. First of all, it is crucial to develop unified metrics. Due to the variety of the approaches applied by different researchers, the process of comparison seems to be rather difficult because of inconsistent results. In order to make a clear understanding of chatbot performance, the issue of unifying common datasets and evaluating their correctness, simplicity, and learning capacities should be considered first of all.

Among other issues, the capacity of the models to follow conversation is particularly significant. It is necessary to note that the models currently being used are characterized by the capability of managing background information effectively, although such an aspect is hardly developed in deep learning and embedding-based models. Despite that, chatbots still demonstrate inability to engage in a series of questions or to understand the context of the conversation within a relatively long period of time.

Hallucinations in LLM-powered chatbots constitute a critical issue. Although the use of the RAG model helps resolve the issue in question. Using hybrid models based on both symbolic reasoning and neural networks would be an efficient way to solve the issue in question.

A number of improvements have been observed in the realm of developing chatbots for educational purposes using AI. However, as it was shown in the above analyses, some important aspects of researching such tools remain uncovered. For example, one of the most crucial issues related to research in this area refers to the establishment of standardized evaluation criteria. Nowadays, most studies apply a set of established evaluation criteria. Therefore, this area of research remains highly relevant and important to consider.

Another exciting area of study that can yield interesting results is the area of context awareness and memory for extended conversations. While advances in deep learning and embeddings have made significant improvements in semantic understanding, chatbots cannot yet engage in multiple-round conversations and be aware of context throughout such extended conversations. This combination can help significantly enhance the user experience. Finally, the hallucination problems of large language model-based chatbots have resolved by retrieval-augmented generation models ensuring that outputs are generated from verified sources, there still remains a need for more research on making chatbot outputs more faithful, explainable, and trustworthy.

Comparison Table

Reference	ChatBot Type	Technique	Data Source	Interaction Type	Strength	Limitation
1	Rule based/ NLP	AI ML, Pattern Matching	Predefined FAQ	Text	Provides fast response for structured queries	No contextual understanding
2	ML Based	NLP & Neural Network	Structured dataset	Text	Improved intent classification	Limited multi-turn reasoning
3	Review Paper	NLP Techniques	Multiple studies	N/A	Comprehensive overview of NLP chatbots	No Implementation
4	Survey Paper	ML vs DL models	Multiple studies	N/A	Strong comparison of	No experimental validation

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					chatbot techniques	
5	Semantic chatbot	SBERT + TFIDF	Student queries dataset	Text	High semantic similarity matching	Limited generative capability
6	RAG chatbot	LLM & Retrieval	Institutional data	Text	High factual accuracy	Computational cost
7	RAG chatbot	LLM & Vector DB	Website data	Text	Context-aware responses	Depends on data freshness
8	ML chatbot	NLP & Neural Network (BoW)	Website content	Text & voice	Easy integration with websites	Limited semantic understanding
9	Retrieval chatbot	Web scraping & Embeddings	Website & Documents	Text & voice	Dynamic data retrieval	Sensitive to website changes
10	Technical study	NLP & Transformers	Multiple dataset	Text/ voice	High conversational accuracy	Complex implementation
11	Multimodal chatbot	NLP & ML	Institutional data	Text, voice & image	High accessibility & usability	Limited deep reasoning
12	Systematic review	Literature analysis	Multiple studies	N/A	Identifies trends & research gaps	No implementation

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