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Transforming K-12 education: A systematic review of AI integration

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Abstract

The application of Artificial Intelligence (AI) has developed in different sectors including teaching and learning where students and teachers can learn AI and augment it in K-12 education settings. The objective of this systematic review is to provide a wide perspective and the understanding the use of the AI for students and teachers in K-12 education setting, by analysing AI technology applications, implementation methods, and its impact. The systematic review searched the databases, and the PRISMA flowchart was applied to search and screen the studies. Articles were screened at the title, abstract and full-text level then coded and analysed. Major findings indicates that AI powered chatbots improve learning outcomes and emphasize the collaboration among teachers, parents, and students to work together for AI integration. This paper also recommends leveraging AI tools like the Interactive Mobile Application for Nurturing (IMAN) Vocab and Intervention in classroom to improve academic performance and critical thinking skills. Despite the advancements, still there are some challenges to overcome such as digital divide, ethical considerations and professional development foe teachers. The study evaluates these challenges alongside advantages such as personalized learning to provide teachers, policymakers, and researchers with transformative pathways. We concludes that AI complements education methods and underscore the need for strategic cooperation and ongoing research efforts to maximize AI benefits while addressing its limitations effectively.

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AI integration
K-12 education
Parent roles
Teacher's professional development.

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1. Introduction

The integration of artificial intelligence (AI) brings about a significant and transformative change in education, affecting the way teaching is conducted and the way students learn at all levels, ranging from primary to secondary schools (Bates, Cobo, Mariño, & Wheeler, 2020; Liua, Salehb, & Huang, 2021; Zanetti, Iseppi, & Cassese, 2019). The applications of AI in education (AIEd), are gaining significant recognition as a developing area of educational technology, especially in formal K-12 education (Chen, Chen, & Lin, 2020; Grassini, 2023; Pedro, Subosa, Rivas, & Valverde, 2019). There is growing emphasis on educating K-12 students how to effectively use AI and develop their problem-solving skills through creative thinking (Murphy, 2019; Zimmerman, 2018). Zhou, Van Brummelen, and Lin (2020) emphasized that AI can contribute to K-12 education by compelling schools to include technology in order to improve teaching and learning outcomes. The emergence of AI presents novel abilities and educational prospects, compelling students and teachers to reconsider conventional instruction (Luckin & Holmes, 2016). It is crucial to educate learners and instructors on AI, including its importance, limitations, and potential societal impacts, as emphasized by experts (Luckin, Cukurova, Kent, & Du Boulay, 2022).

The use of artificial intelligence for educational purposes bring up a real promise of the ability to meet different requirements of students and create an individualized educational experience for them. Adaptive learning pathways are made available through educational technologies and platforms that are powered by artificial intelligence. These pathways allow teachers to personalize training to the specific requirements and preferences of each individual student (Srinivasa, Kurni, & Saritha, 2022). Intelligent Tutoring System (ITS) may utilize different algorithms with in-built artificial intelligence to offer individualized support and feedback for students which in turn may induce students to participate in independent learning and self-development (Aleven, Mclaren, Sewall, & Koedinger, 2009).

This study will review the capability of artificial intelligence technologies to change education decision-making processes through the scientific analysis of large volumes of student data, with an aim to understand learning patterns and trends (Ahmad et al., 2024). Facilitation of the educational process by the AI-based information technologies eventually gives educators an insight concerning students' learning process. It makes possible for them to adjust teaching strategies and interventions so that their students can learn more easily (Bienkowski, Feng, & Means, 2012).

The existence of a digital divide highlights the unequal distribution of technology and digital resources among students of varying economic origins, which worsens existing disparities (Isotani, Bittencourt, Challco, Dermeval, & Mello, 2023; Livingstone & Helsper, 2007; Lythreatis, Singh, & El-Kassar, 2022). Issues surrounding data privacy, security, and algorithmic bias provide ethical challenges when deploying AI-powered educational systems (Abbas, 2023; Ali, 2023).

In addition, for AI to be successfully integrated into education, it is essential to provide teachers with thorough training and continuous professional development. This will ensure that educators have the necessary knowledge and abilities to properly use AI technologies (Abulibdeh, Zaidan, & Abulibdeh, 2024; Pedro et al., 2019). To ensure the ethical utilization of AI in education, it is crucial to thoroughly contemplate values such as transparency, impartiality, and responsibility in order to prevent unforeseen repercussions and foster equal opportunities for educational access.

This paper examines the progression of AI applications in K–12 education from the 1980s, specifically focusing on the transition from Computer-Assisted Instruction (CAI) to Intelligent Computer-Assisted Instruction (ICAI) (Bottino & Molfino, 1985). A recent study explores different AI technologies, including Machine Learning (ML) algorithms, Natural Language Processing (NLP), and data analytics, to analyse their use in personalized learning, adaptive assessment, intelligent tutoring systems, and educational mobile applications. The paper critically evaluates the contributions and achievements made by researchers in the field of AI in education from 1985 to 2024. The objective of the study is to classify various research areas and do a thorough examination of suggestions and findings derived from the existing literature on artificial intelligence in education. The study aims to comprehend the course of AI technology in education and its consequences by assessing scholars' work during the last thirty years. This lead the formulation of the important research questions revolves around;

(1) RQ1: What are the current AI applications in K–12 education?
(2) RQ2: How effective are these AI applications in improving learning outcomes? And
(3) RQ3: What are the challenges and limitations of AI integration in K-12 education?

The objective is to identify gaps current knowledge and explore how AI applications can improve learning outcomes while addressing challenges and limitations. The study utilize a methodical approach to examine the impact of Artificial Intelligence on K-12 education and offers recommendations for future research directions and policy considerations. The study aims to provide practical suggestions on how AI can transform revolutionize teaching and learning experience in K-12 education. It highlights the significance of assessing carefully the advantages and disadvantages of AI in educational environments.

2. Methodology

The study employed a systematic review methodology to fulfil its primary objective. A systematic review

aims to investigate specific research inquiries by employing a methodical and reproducible search approach, along with predetermined criteria for inclusion and excluding publications to be included in the study Gough, Oliver, and Thomas (2017). The overall procedure for selecting and rejecting articles for this study was conducted using the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group*, 2009). The process of including search articles has been conducted according to specific predetermined criteria. In accordance with the PRISMA methodology, the primary findings of the chosen publications were systematically organized and extracted in order to synthesize and present a response to the specific research questions of the study.

2.1. Database Search Strategy

The electronic databases were utilized to conduct literature searches. The study examined the primary electronic database, Scopus. It is currently one of the largest curated abstract and citation collection of research literature in the world. Researchers generally use it for its extensive and comprehensive content (Burnham, 2006). The articles included in this review study are restricted to the specific time frame spanning from 1985 to January 2024. During the initial phase, a total of 618 articles were identified.

2.2. Search Strategy

To give preference to a particular source of literature the Scopus database was chosen because of its high coverage of the scholarly publications in several disciplines. The search was carried out in the period 1985 - 2024 applying the Boolean/phrase retrieval system using the following strings; ("Artificial Intelligence" OR "AI" OR "Machine Learning" OR "deep learning") AND ("K12 Education" OR "Primary Education" OR "Secondary Education" OR "K12 Learning" OR "teaching and learning"). The selection of the keywords was done to make sure how it is related to the planned theme and that will cover a wider perspective of the research articles on the subject. On January 24th 2024, the literature was obtained from the Scopus database. When the search was limited to English language publications from 1985 to 2024 in the topic of artificial intelligence, the database produced a total of 618 articles. When articles are extracted to the EndNote software from Scopus database, the references were limited to 609 papers that were available and other 9 studies were retracted. Excel was used to import all of the included data for further analysis.

2.3. Inclusion and Exclusion Criteria

The eligibility for inclusion and exclusion criteria of the articles was observed critically to make sure we get the best articles for the analysis. The review contains only those articles that have met rigorous standards. Studies were included if they satisfied the following criteria: (a) the studies considered for the review have to be published in respected scholarly journals to guarantee the research's legitimacy and rigor. (a) Only English articles were included to ensure comprehension and accessibility for the review's intended audience. (c) Articles were required to particularly discuss the integration of artificial intelligence in K-12 educational environments in order to fit with the research topic of the review. (d) The studies that were chosen needed to present either concrete data or theoretical perspectives on how AI is being used in educational techniques. This requirement was to ensure that the articles made a significant contribution to our understanding of AI application in education. After going through this procedure, the 16 studies that fulfilled the selection criteria were included into account for the ultimate analysis.

In the final process, the evaluation of the papers' quality was conducted by considering the (a) research design, which focuses on the assessment of the strength of the studies' research design, which encompassed the clarity of research objectives, methodology, and data analysis techniques. (b) Sample size, to evaluate studies based on the sufficiency of their sample sizes to guarantee that the study findings were statistically significant and accurately represented the target population. (c) Data collection procedures, as the studies' reliability and validity of research outputs were evaluated by considering the suitability and rigor of the data collection procedures used. (d) Validity of findings, taking into account aspects of each study including bias, confounding variables, and how the findings can be applied to a broader context in order to determine the credibility and reliability of the research results. After carefully considering the specific criteria for including and excluding articles, as well as the process for evaluating their quality and relevance, a total of 16 studies (Appendix A) that addressed both study issues were selected for data coding and analysis.

2.4. Screening and Selection Process

On 24 January 2024, Scopus database was searched and 618 items were found in very first search. Following the duplicate elimination, the titles and abstracts of all the remaining publications underwent a review to discover their salience in regards to the study all articles that passed the initial inclusion criteria attempt to read in full, which is evaluated to determine their suitability for this review. The top 16 articles were included in study. Database search strategy was performed to identify common themes, trends and patterns that reflect how AI is used in education as shown below in Figure 1 (Haddaway, Page, Pritchard, & McGuinness, 2022).

2.5. Data Coding and Analysis

We performed data analysis by consciously collecting necessary details from read journals, for instance, aims of research, methods applied, key findings, and implications. Information obtained from the data coding and analysis process to obtain significant insights and findings on the applications of AI in K-12 education. The data extraction technique involved methodically gathering relevant information from the included studies, covering study aims, methodologies, important findings, and consequences. This phase ensured that all relevant information from each methodology was collected for subsequent analysis. A coding strategy was developed to classify and systematize the retrieved data. The coding scheme had predetermined categories or themes relating to AI applications in K-12 education, including types of technology, learning outcomes, research methods, and ethical concerns. Every section was methodically assigned codes based on the predetermined coding strategy. Appropriate codes were allocated to certain sections of the papers according to the selected themes or categories. The coding methodology facilitated the methodical arrangement and examination of the data across numerous research. A variety of data analysis techniques were used to analyse and combine the coded data. This encompassed the utilization of qualitative research techniques, such as theme analysis, to distinguish and establish patterns, trends, and associations within the data. Quantitative analysis approaches have been employed to evaluate numerical data or to measure the frequency of particular themes or categories. A comparative analysis was performed to compare and differentiate the outcomes from other inquiries. This procedure entailed perceptive similarities and differences in the outcomes, methodology, and conclusions of the incorporated papers in order to derive comprehensive insights and findings. Thematic analysis was employed to discern repetitive themes or patterns within the coded data. Through a methodical analysis of the themes that arose from the data, we acquired a more profound comprehension of the primary concerns and patterns associated with AI applications in K-12 education. The results from separate investigations were combined and analysed to offer a thorough overview of the current state of AI in education. The review sought to provide a comprehensive assessment of the effectiveness, difficulties, and consequences of AI technology in K-12 educational environments by combining the findings of several studies.

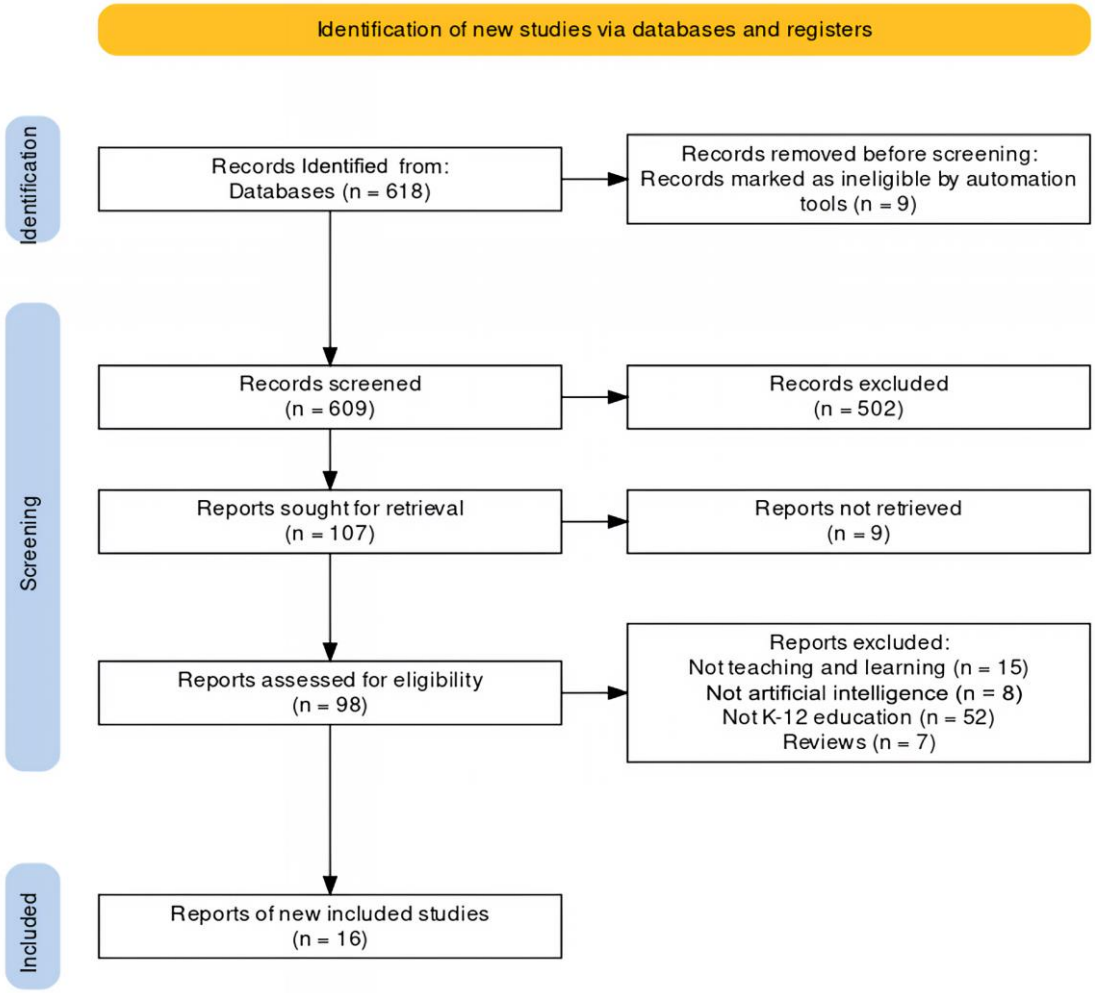

Figure 1. PRISMA 2020 diagram of selection and screening process.

3. Analysis

The chosen papers were systematically organized according to their publishing years, ranging from 1985 to 2024. Most of the publications (13 out of 16) were published in the last five years (2022–2023), suggesting a major increase in research on incorporating AI into K–12 education. This trend highlights an increasing curiosity in investigating the most effective methods for incorporating AI into educational environments in order to improve learning results. The allocation of these publications among different publishing categories, as depicted in Figure 2, demonstrates the growing scholarly focus on the incorporation of AI in school instruction. In addition, after conducting a thorough study of the articles, researchers have discovered three significant aspects that shed light on the manner in which AI can be integrated into K-12 education settings. (1) The efficacy of AI technology in enhancing learning outcomes, (2) The correlation between the application of AI and its influence on learning outcomes, and (3) The effect of teacher professional development in motivating the use of AI. The allocation of articles among these impact elements provides valuable observations into the developing terrain of AI incorporation in education, emphasizing significant areas of concentration and possible obstacles.

3.1. Descriptive Analysis

The analysed data from a systematic literature review is highly illuminating on how deep the AI penetration has gone by and affects elementary, middle, and high school education as well as going beyond. The first research question that we are seeking to address is, "What are the current applications of artificial intelligence in K-12 education?" A detailed summary is given down below that focus on the first research question.

3.2. Trend Over Time: Year and Number of Studies

On the bar chart (Figure 2), from 1985 until this day it illustrate how many studies that focus on AI application in K-12 education settings were published over each year. Over the past few decades, there have been significant increases in the total amount of articles published. From 1985 – 2024, there is about 34 years gap passed without any study paper being published. AI-related publications about K-12 learning have been continuously increasing since 2019, with an especially remarkable increase in 2023 that reached eight articles published, which shows the growing importance and concentration on the applications of artificial intelligence in education for elementary, middle and high school levels.

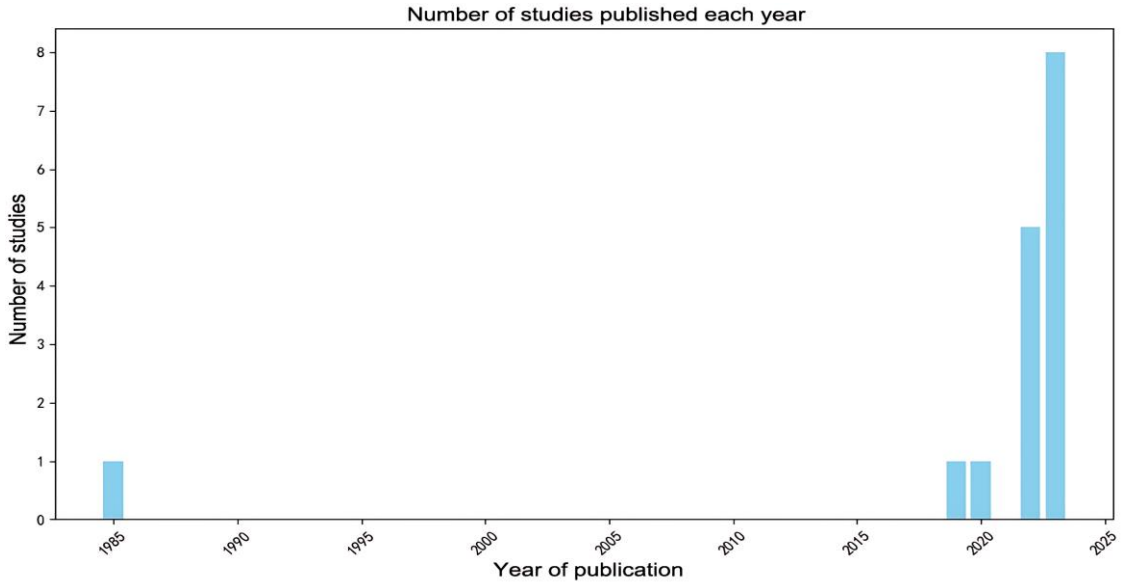

Figure 2. Publications trend from 1985 to 2024.

4. Findings and Discussions

The education system in schools is transitioning from traditional teaching methods to smart education in order to improve students' learning experiences (Chen et al., 2020). The incorporation of information technology into the classroom has provided teachers with significant convenience for this digital transformation (Earle, 2002; Xue & Wang, 2022). Artificial intelligence is increasingly becoming a prominent information technology that is being utilized across all professions and educational levels (Jaiswal & Arun, 2021). In the near future, it is quite improbable to envision a student's life without the utilization of AI. All 16 examined articles concluded that AI has a significant and broad potential impact on the school education system. The swift integration of AI advancements in educational institutions is expected to provide extensive advantages alongside notable problems (Abulibdeh et al., 2024). In order to ensure the successful integration

of AI in K-12 school settings, certain elements must be taken into account. The determinants that facilitate seamless integration are derived from the reports and conclusions of 16 papers and are detailed below.

4.1. Classification of the Impact of the AI Application in K-12 Education System

To tackle the question, "How efficient are these AI applications in K–12 learning outcomes?" This study offers meticulous database sorting to ensure that the chosen articles stand for cases of improving learning outcomes after AI applications. The overview, the detailed analysis, and the comprehensive approach covered the bulk of the research, and Table 1 is showing the results of classifications.

4.2. Effective AI Technology in Improving Learning Outcomes

This literature review offers a study of the efficacy of AI applications in the field of education, utilizing a classification analysis of a carefully chosen set of research publications. The document identifies prospective areas for enhancement and proposes avenues for future investigation within this domain. The evaluation additionally assesses the efficacy of AI applications in augmenting educational achievements, utilizing a comparative examination of four investigations pertaining to AI chatbot learning methodologies. These studies provide useful insights on the potential of AI in education and potential areas for improvement, based on their specific objectives, methodologies, outcomes, and limitations. Conducting a thorough literature review to recognize the main themes, effectiveness, and aspect areas of improvement concerning AI chatbot and procedure implementation in the education sector. The representation of the literature classifications concentrated on objectives, methodologies, results and constraints across the four selected papers and concluded that the two papers demonstrate similarities. Whereas paper 1, "Educational Design Principles of Using AI Chatbot That Supports Self-Regulated Learning in Education: Goal Seeking, Feedback, and Personalization" (Chang, Lin, Hajian, & Wang, 2023) and in paper 2 there is "A framework and exemplars for ethical and responsible use of AI Chatbot technology to support teaching and learning" (Chauncey & Patricia McKenna, 2023). Common objectives: 1) in both cases, the authors point out self-regulated learning popularization after AI chatbot application. 2) Integration with Pedagogical Principles: The role of AI chatbot combination with the pedagogical principles is stressed out. 3) Adaptation to Education: AI tools like ChatGPT signify for a transferable move in education approaches. The other common variables in these articles were the methodologies: 1) Educational Frameworks: In the first paper, the Self-Regulated Learning theory of Zimmerman (2018) is applied, while in the second paper, a concept of moral AI chatbot utilization is conceptualized. 2) Personalized approach employs the fundamental concepts such as goal setting, self-assessment, and feedback like any other program. In addition, there were similarities in the articles' results: 1) while emphasizing the significance of AI-assisted pedagogy, Paper 1 outlines three pedagogical principles for chatbot integration. 2) In the Paper 2, a conceptual framework and exemplars are presented, with an emphasis on cognitive innovation and ethical design. Moreover, the last common variable was the articles' constraints: 1) Information quality is a prevalent concern due to the potential for misinformation, bias, and lack of accuracy in content generated by artificial intelligence. 2) Ethical Considerations: This paper addresses the potential risks and ethical ambiguities associated with the responsible utilization of AI chatbots.

Table 1. Distribution of literature with AI effective pathways.

Authors	Variables	Findings
1. Chang et al. (2023) 2. Chauncey and Patricia McKenna (2023)	Effective AI technology in improving learning outcomes	AI chatbots, have shown to be helpful in improving learning experiences
3. Madhavi, Sivapurapu, Koppula, Rani, and Sreehari (2023) 4. Haslinah Mohd Nasir, Brahin, Sani, Mispan, and Abd Wahab (2023) 5. Dixon-Román, Nichols, and Nyame-Mensah (2020) 6. Xiongwei Lin et al. (2022) 7. Lu and Fan (2023) 8. Samar Mouti and Samer Rihawi (2023)	Relationship between AI application and roles on learning outcomes	Successful implementation of AI technology in education relies on the cooperation of instructors, parents, and students in various subject areas.
9. Arja Kangasharju, Liisa Ilomäki, Minna Lakkala, and Auli Toom (2022) 10. Chauncey and Patricia McKenna (2023) 11. Lin et al. (2022)	The impact of teacher professional development on motivating AI application	By recognizing and overcoming AI adoption challenges, educators may use AI technology to improve teaching methods, student learning, and educational environments.

The analysis offers a detailed summary of the use of AI chatbots in education, as outlined in specific research papers. The articles provide insights on the effectiveness of AI applications in improving educational experiences and identify areas for more investigation and enhancement.

Artificial intelligence chatbots, particularly ones specifically developed for educational purposes, have demonstrated a notable capacity to augment self-regulated learning in students. This is achieved through the facilitation of goal setting, self-assessment, feedback, and personalization, all of which are fundamental components of self-regulated learning. In order to enhance learning results, educators must modify their instructional approaches to incorporate AI tools such as ChatGPT, thereby effectively integrating pedagogical principles with AI technology. The effective incorporation of AI chatbots in educational settings relies on the devotion to pedagogical principles that enhance student learning, hence highlighting the capacity of AI to enhance conventional instructional approaches.

There are concerns regarding the correctness and precision of content produced by AI algorithms, particularly the possibility of spreading false information. This emphasizes the importance of guaranteeing the dependability of AI-generated content. Furthermore, more research is needed to examine the ethical utilization and structure of AI chatbots in the field of education. Various obstacles, including cognitive flexibility, critical thinking, and ethical uncertainties, underscore the importance of embracing a responsible approach towards AI in the field of education.

4.3. Relationship between AI Application and Roles on Learning Outcomes

AI applications in education have many benefits, but teachers, parents, and students must recognize their changing roles. Literature and data from observations help educators and policymakers use AI while evaluating the effects on all learning ecosystem stakeholders. AI technology in education has changed the roles of instructors, parents, and students, affecting learning results and academic subjects. The data shows that these duties subtly affect instruction in certain subjects. AI-driven systems like IMAN Vocab App and Google Translate (Madhavi et al., 2023; Haslinah Mohd Nasir et al., 2023) have improved vocabulary and language learning, although their performance varies by subject. AI solutions like Essay Helper give students formative writing feedback and assessment, affecting learning results (Dixon-Román et al., 2020). AI can improve the efficacy and efficiency of intelligent tutoring systems and pedagogical agents across subjects. Teachers teach pupils how to use these technologies, while parents provide feedback and install suitable apps. Parents' AI opinions may influence students' profession choices and AI's value, thereby influencing education integration (Wang, Wang, Jiang, Li, & Yang, 2023). Thus, kids gain tailored learning, engagement, and language skills. In Science Technology Engineering and Mathematics (STEM) education (Xiongwei Lin et al., 2022) especially machine learning and robotics, teachers, parents, and students shape learning outcomes. Teachers manage ML projects, help students solve problems, and teach AI concepts (Lu & Fan, 2023). Parents encourage students' AI interests and provide instructional input. This cooperation helps students understand AI and robotics for data-focused employment and promotes interdisciplinary learning. AI voice and sign language recognition systems help disabled pupils in special education (Samar Mouti & Samer Rihawi, 2023). Teachers, parents, and students analyse, give comments, and track progress to create an inclusive learning environment. AI can help teachers personalize lessons, predict learning outcomes, and support students, ensuring fair access to education and academic achievement for everyone. Teachers, parents, and students from different subjects must work together to utilize AI technology in education.

Successful implementation of AI technology in education relies on the cooperation of instructors, parents, and students in various subject areas. Stakeholders may utilize the revolutionary potential of AI to improve learning outcomes, promote engagement, and meet the varied requirements of learners in the digital era by recognizing and accepting their roles. It is crucial to address ethical concerns, protect privacy, and encourage appropriate usage of AI tools in educational environments to maximize their advantages and minimize any drawbacks.

4.4. The Impact of Teacher Professional Development on Motivating AI Application

The results indicate that the promotion of artificial intelligence in educational environments has multiple challenges and complexities, which are influenced by a range of factors that impact the attitudes, behaviours, and choices of individuals involved. One of the primary obstacles that has been found pertains to the restricted extent of involvement, underscoring the imperative for a more all-encompassing strategy to promote the utilization of artificial intelligence tools inside educational communities. The significance of broadening the scope beyond AI-based technologies to include a broader range of strategies that facilitate the incorporation of AI in educational practices is emphasised in the study conducted by Xiongwei Lin et al. (2022). This implies that adopting a comprehensive approach to professional development is crucial in order to inspire instructors to proficiently employ AI technology within the educational setting. Furthermore, the incorporation of artificial intelligence in the field of education is heavily influenced by ethical considerations. Chauncey andPatricia McKenna (2023) emphasize the ethical considerations pertaining to the suitable and ethical application of AI chatbot technology in educational settings. It is emphasised that the incorporation of AI technology to facilitate teaching and learning necessitates the consideration of cognitive load, self-regulation, and other ethical factors. This highlights the necessity for educators to undergo training that encompasses not

just the technical facets of AI, but also the ethical ramifications and deliberations associated with its integration. By implementing comprehensive professional development programs, educators can enhance their ability to effectively navigate the complicated process of incorporating AI into their instructional methodologies. The case studies conducted by Ding, Shi, Yang, and Choi (2024) reveal how the level of structure in instructional case issues might impact teachers' problem-solving approaches and the growth of AI literacy. Moreover, the results indicate that promoting the use of AI in educational settings necessitates a comprehensive strategy that takes into account the varied requirements and viewpoints of stakeholders. By comprehending and resolving the obstacles to the use of AI, educators can effectively utilize the complete capabilities of AI technologies to augment instructional methodologies, boost student learning experiences, and cultivate a more inventive and engaging educational environment. United Nations Educational, Scientific and Cultural Organization (UNESCO) performed a thorough survey (Miao & Shiohira, 2022) and put forward various recommendations for enhancing the skills of current teaching personnel through training and support. In addition, cooperation with non-governmental entities has resulted in the implementation of alternate approaches for teacher education. The Massachusetts Institute of Technology (MIT) daily curriculum included teachers from three districts in the USA. These teachers received training that consisted of general seminars and 30 hours of implementation practice. The training took place at summer camps organized by non-governmental organization (NGO) partners.

4.5. The Effectiveness of AI Applications in K–12 Education based on Various Metrics

The analysis of data has been conducted to assess the effectiveness of AI applications in K-12 education. The analysis specifically focuses on important metrics such as (a) academic performance, (b) engagement levels, (c) problem-solving ability, and (d) critical thinking skills (Doleck, Bazelais, Lemay, Saxena, & Basnet, 2017). The collected review articles' results offer useful insights into the impact of AI on student learning, allowing educators to assess the effectiveness of AI interventions in enhancing educational outcomes.

The data extraction and analysis method on AI applications in K-12 education focused mainly on metrics such as academic accomplishment, engagement levels, problem-solving capacities, and critical thinking abilities. These measures were developed from datasets taken from relevant articles. The process entailed identifying and retrieving relevant data on the influence of AI on educational results, the responsibilities of students, teachers, and parents, from the studied information on student engagement and academic advancement. Moreover, the process of identifying and categorizing various AI applications, such as App A (Google Translate), App B (Natural Language Processing - NLP), App C (IMAN Vocab App), and App D (Generative Pre-trained Transformer - GPT), was carried out by extracting the names from the datasets of review articles (Table 2).

The results concerning these four criteria employed to assess the efficacy of AI applications in K-12 education unveil noteworthy observations. An examination of bar charts in Figure 3 reveals that all four AI applications (App A, App B, App C, and App D) have resulted in gains in academic achievement. App C has shown the most significant influence, closely followed by App B. A line graph illustrates a consistent rise in engagement levels from January to April, with a significant surge between February and March (Figure 3). This indicates a continuous and noticeable growth in student interest and participation, which can be attributed to the use of AI applications. Furthermore, a scatter plot illustrating the relationship between problem-solving skills and the number of hours spent using AI shows a positive association, suggesting that increased AI usage may improve problem-solving capabilities. Furthermore, a box plot illustrating the spread of critical thinking scores among several AI interventions showcases Intervention D as notably successful, exhibiting the greatest median score and consistent efficacy in enhancing critical thinking skills.

Table 2. Articles with the most AI Application used.

App	AI application names	Author/Year	Article titles
	- The research paper does not provide information on AI technology brands.	Jia, Sun, Ma, and Looi (2022)	Developing a weather prediction project-based machine learning course in facilitating AI learning among high school students
A	- Google translate is a significant AI technology brand.	Dixon-Román et al. (2020)	The racializing forces of/In AI educational technologies
	- Natural language processing (NLP) is crucial in advancing computer-assisted language learning.		
B	- IMAN Vocab App utilizes AI technology for interactive vocabulary learning.	Arja Kangasharju et al. (2022)	Lower secondary students' poetry writing with the AI-based Poetry Machine.
	- The app integrates deep learning image classification for vocabulary		

App	AI application names	Author/Year	Article titles
	enhancement.		
	- CNN model used for image recognition in the educational mobile app.		
C	- AI technologies: Natural language processing, machine learning.	Sperling, Linnéa Stenliden, Jörgen Nissen, and Fredrik Heintz (2022)	Still w(AI)ting for the automation of teaching: An exploration of machine learning in Swedish primary education using actor-network theory
	- Brand: Not specified in the provided contexts.		
	- Subject: Language education, specifically English as a second language.		
D	- Generative pre-trained transformer (GPT) architecture is a popular AI technology brand.	Jia et al. (2022)	Developing an AI-based learning System for L2 learners' authentic and ubiquitous learning in English language

The review articles propose a wide array of AI applications, including mobile apps that employ deep learning, tools for improving English-speaking abilities, and tools for conducting assessments for individuals with special needs. The dataset obtained from the review articles offers contextual information regarding the various AI systems under study. However, it lacks specific quantitative data, which is essential for analysing learning results, student engagement, and academic growth indicators. Therefore, it is advisable for educators to incorporate App C and Intervention D into the curriculum, since they have shown good outcomes in improving academic performance and critical thinking skills. Additionally, it is recommended to monitor and increase the number of hours AI is used in order to potentially improve problem-solving abilities, as suggested by the positive association observed in the scatter plot. Furthermore, study recommends to analyse the patterns of user involvement over a period of time and determine the elements that contribute to the highest levels of engagement observed between February and March. This information may then be used to replicate these characteristics in future time periods.

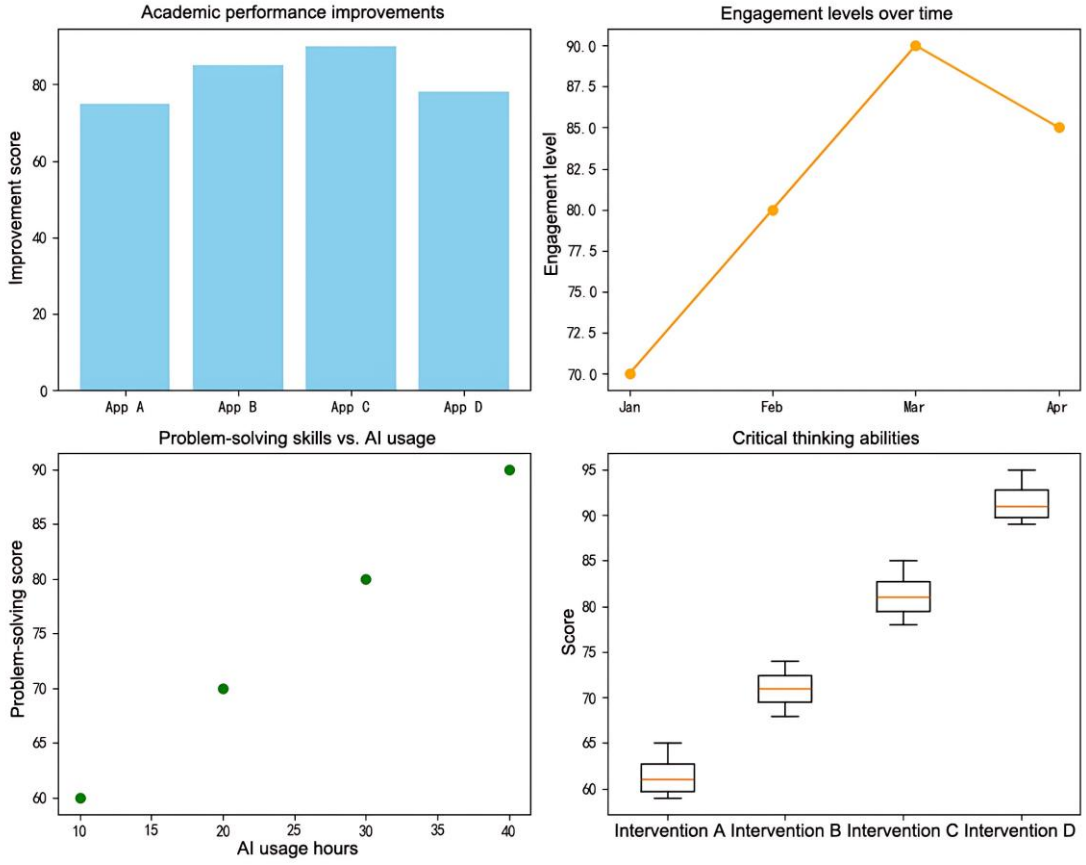

Figure 3. Effectiveness of artificial intelligence (AI) applications in K-12 education.

Note: App A: Google translate, App B: Natural language processing (NLP), App C: IMAN Vocab App, and App D: Generative Pre-trained transformer (GPT).

In order to provide additional evidence and support for these findings and suggestions, future studies should prioritize the analysis of AI effectiveness explicitly in relation to these measures. This involves analysing the effects of AI on educational results, the responsibilities of students, instructors, and parents, as well as other measures of involvement. This will enable a more thorough evaluation of the specific roles and implications of AI in K-12 education.

5. Conclusion

This systematic research provides valuable insights on the effective application of AI in K–12 education, emphasizing its capacity for transforming educational practices. By conducting a thorough analysis of the literature, we have found significant improvements and transformative pathways in which AI has improved learning outcomes. The integration of AI technologies like ChatGPT is recognised as a crucial catalyst for change, as it enables the provision of tailored learning experiences for each student and the optimization of teaching methods. This integration enables the harmonization of pedagogical principles with AI technology, demonstrating AI's capacity to augment conventional teaching techniques by providing customized education to address individuals' distinct requirements and preferences, hence enhancing learning results and fostering greater engagement. AI chatbots built for education have shown notable improvements in self-regulated learning. They achieve this by promoting goal setting, self-assessment, feedback, and customization, which are important aspects of self-regulated learning.

The review finds that artificial intelligence enables instructors to make well-informed decisions by monitoring student performance, detecting areas of learning shortfall, and applying specific interventions. Through the utilization of AI analytics, educators can acquire crucial information regarding the progress of students, enabling them to adapt teaching methodologies in order to maximize learning outcomes. The incorporation of artificial intelligence into primary and secondary education has the potential to improve learning outcomes in various subjects and fields. This is supported by the success of AI-driven programs in enhancing vocabulary acquisition, writing skills, and problem-solving abilities, ultimately leading to academic success.

Furthermore, the changing responsibilities of educators, parents, and students in the AI-enabled learning environment recognised as crucial for achieving the advantages of AI technology. Efficient cooperation among individuals or groups with an interest or involvement in a particular matter is essential for establishing a favourable atmosphere for the incorporation of artificial intelligence in the field of education. Moreover, the importance of teacher professional development in facilitating the effective utilization of AI technologies is emphasised, emphasizing the requirement for comprehensive training to tackle ethical issues, minimize potential risks, and proficiently employ AI tools to improve teaching methods and enhance student academic performance.

The study also uncovers the diverse effects of AI on student learning outcomes in different subjects and fields, with a tendency to utilize AI for customized learning experiences, such as providing feedback on writing assignments and employing machine learning-based teaching tools in mathematics education. While the specific socioeconomic backgrounds are not clearly specified, the incorporation of AI in various educational environments indicates an effort to cater to a wide range of student requirements, including those pertaining to special education. The study highlights the capacity of AI to transform K-12 education by providing engaging, personalized, and effective learning opportunities for children in the digital world.

5.1. Limitations and Future Research Directions

This systematic review offers unique insights into the integration of AI in K–12 education. However, it is important to realize certain limitations that could affect the interpretation and generalizability of the findings. A notable constraint exists within the extent of the literature review. The review is conducted using a compilation of articles and studies that were available up until the publishing date. It is important to note that this may not include the latest breakthroughs in AI technologies and their applications in education. Due to the swift advancement of AI, it is possible that recent studies and advances have not been taken into account, potentially restricting the comprehensiveness of the analysis. Furthermore, it is important to consider the possibility of publication bias in the review, as it is based exclusively on published articles and studies. By excluding unpublished research, grey literature, or studies in languages other than English, there is a risk of introducing bias into the conclusions. This is because valuable ideas from these sources may have been disregarded.

Furthermore, the drawback of the selected studies is in their quality. The range in study quality, together with possible limitations in methodology, sample sizes, or data analysis approaches, may affect the overall dependability and accuracy of the conclusions derived from the review. Moreover, the conclusions of this analysis may not have broad applicability across all educational environments and circumstances due to variables such as regional disparities, resource accessibility, and cultural issues. The application and success of AI technology in K–12 education can be influenced by various contextual factors in distinct situations. Finally, the data extraction and analysis procedure may add bias due to the subjective interpretations and categorizations made by academics on the impact of AI applications on educational achievements. The

presence of subjectivity in the evaluation may influence the conclusions drawn, hence requiring careful interpretation.

Considering future study approaches, it is evident that there is a requirement for additional inquiry to tackle developing challenges and explore novel possibilities for utilizing AI technology in educational environments. Comprehensive understanding of the influence of AI on students from various economic strata will be facilitated by detailed data on socioeconomic backgrounds. Conducting longitudinal research to monitor the lasting impact of AI on learning outcomes and skill development would yield more profound understanding of the effectiveness of AI in education. Furthermore, it is imperative for future studies to focus on narrowing the existing gap in scholarly works by investigating the potential impact of upcoming artificial intelligence technologies on teaching methods. To fully harness the promise of AI in K-12 education, it is crucial to comprehend how new AI tools can be seamlessly included into teaching and learning processes. This understanding should take into account the responsibilities of students, instructors, and parents, as well as the specific requirements of various student populations. Hence, it is crucial for future research efforts to give priority to resolving these deficiencies in order to enhance our comprehension of the incorporation of AI in educational settings and its influence on students' academic achievements.

Although AI has the potential to significantly transform K-12 education, further study should focus on addressing emerging issues and exploring new possibilities, particularly with how developing AI technologies affect teaching methods. Considering the ethical consequences is crucial to guarantee the reliability and precision of study results, thereby enhancing our comprehension of how AI might be integrated into educational settings and its effects on student learning outcomes.

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Appendix A

Table 3. Detail of selected articles with the conclusion pathways.

Authors and years	Customized learning	Data-Informed education	Enhanced learning results	Role redefinition	Teachers' professional development
Dixon-Román et al. (2020)	- AI technologies like Essay Helper offer personalized formative feedback on writing. - Learning analytics platforms aim to optimize student learning experiences. - AI technologies can address educational inequities through personalized learning experiences.	- AI technologies in education analyze student performance and inform instructional decisions. - Learning analytics platforms like Essay Helper use machine learning for feedback.	- AI platforms provide immediate formative feedback on student writing. - Learning analytics optimize and reconfigure educational environments using AI technologies. - Algorithms shape students and educational practices in learning analytics platforms. - Machine learning algorithms grade writing with reliable equivalence to humans.	- Teachers use Essay Helper for formative feedback and instructional decision-making. - Parents may have limited involvement in the platform's use. - Students interact with the platform to compose essays and receive feedback.	- Essay Helper automates writing instruction aligned with state standards. - Platform shifted focus from peer collaboration to automated assessment.
Sing, Teo, Huang, Chiu, and Xing wei (2022)	- AI curriculum design should consider readiness, social good, and optimism. - AI curriculum should highlight how AI knowledge can benefit students. - AI curriculum should focus on core concepts and social good. - Efforts are being made to educate students about AI globally.	- AI literacy predicts students' behavioral intention. - AI readiness, social good, and optimism moderate path-to-path relationships.	- Factors like readiness, social good, and optimism enhance learning intentions. - Psychological model based on Theory of Planned Behavior (TPB) and Technology Acceptance Model (TAM) aids AI curriculum design.	- Teachers foster students' understanding and positive attitude towards AI. - Parents influence students' perception of social good and readiness for AI. - Students' behavioral intention to learn AI is influenced by teachers, parents, and peers.	- Teachers should foster students' understanding and positive attitude towards AI. - Training programs should offer diverse challenges for students. - Empower students to formulate challenges based on personal concerns. - AI textbooks should focus on practical applications relevant to

Authors and years	Customized learning	Data-Informed education	Enhanced learning results	Role redefinition	Teachers' professional development
					daily life.
Nasir, Brahin, Ariffin, Mispan, and Wahab (2023)	- Mobile apps offer customized learning through interactive teaching methods. - Customized learning enhances vocabulary acquisition and student motivation. - Customized learning integrates technology with student-teacher interaction.	- Educational mobile app enhances vocabulary through deep learning image classification. - Vocabulary learning at a young age is crucial for language development. - Technology-based language learning influences early education sector.	- IMAN Vocab App achieved over 90% accuracy in image classification. - Mobile learning aids in applying new vocabulary to real-life contexts.	- Teachers provide feedback for app improvement based on classroom testing. - Parents can give feedback on the app through the Google Play Store. - Students interact with the app independently to complete tasks.	- Teachers' feedback gathered to improve application for kindergarten requirements. - Application refinement done based on teacher feedback for better improvement. - Testing conducted in real kindergarten environment with teacher feedback.
Mouti and S. Rihawi (2023)	- Cognitive, Affective, Social, and Contextual (CASC) model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- The research focuses on special needs students in the United Arab Emirates (UAE). - Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Madhavi, Sivapurapu, Koppula, Esther Rani, and Sreehari (2023)	- CASC model customizes courses and activities for Special	- The research focuses on special needs students in the UAE.	- CASC model enhances learning outcomes for special	- Teachers: Implement CASC model, adjust teaching methods	- CASC model enhances teaching strategies for special

Authors and years	Customized learning	Data-Informed education	Enhanced learning results	Role redefinition	Teachers' professional development
	Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Lu and Fan (2023)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Kangasharju, Ilomäki, Lakkala, and Toom (2022)	- CASC model customizes courses and activities for Special Needs Students.	- The research focuses on special needs students in the UAE. - Classroom assessment	- CASC model enhances learning outcomes for special needs students.	- Teachers: Implement CASC model, adjust teaching methods based on feedback.	- CASC model enhances teaching strategies for special needs students.

Authors and years	Customized learning	Data-Informed education	Enhanced learning results	Role redefinition	Teachers' professional development
	- Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- AI tools support teachers in overcoming language barriers with deaf students.
Lin et al. (2022)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Lee, Tan, and Teo (2023)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for	- CASC model enhances learning outcomes for special needs students. - Real-time feedback	- Teachers: Implement CASC model, adjust teaching methods based on feedback.	- CASC model enhances teaching strategies for special needs students. - AI tools support

Authors and years	Customized learning	Data-Informed education	Enhanced learning results	Role redefinition	Teachers' professional development
	outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	teachers in overcoming language barriers with deaf students.
Jia, D. Sun, Ma, and Looi (2022)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Ferreira, Lemgruber, and Cabrera (2023)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for teaching evaluations.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming

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	student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	language barriers with deaf students.
Sperling, Stenliden, Nissen, and Heintz (2022)	- CASC model customizes courses and activities for Special Needs Students. - Predicts learning outcomes based on student responses for effective teaching. - Monitors gestures to reduce failure rate and identify at-risk students.	- The research focuses on special needs students in the UAE. - Classroom assessment model uses AI tools for teaching evaluations. - CASC model converts speech to sign language and vice versa. - The model captures facial and hand movements using Python library. - Instructors customize teaching methods based on student feedback.	- CASC model enhances learning outcomes for special needs students. - Real-time feedback improves instructional strategies and student success. - Indirect assessment through CASC provides systematic and effective learning feedback. - CASC model predicts and monitors special needs students' learning outcomes.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- CASC model enhances teaching strategies for special needs students. - AI tools support teachers in overcoming language barriers with deaf students.
Luckin and Cukurova (2019)	- Educational AI can support individualized learning experiences. - Learning Sciences research informs AI algorithms for personalized	- Data analysis in EdTech and AI design is crucial. - Big data revolutionizing education with rapid growth in data	- AI systems like OLI learning course have shown positive impacts. - Learning technologies like CENTURY Tech use cognitive science and neuroscience	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students,	- Educators need to understand AI for effective teaching. - AI developers must grasp the educator's perspective for educational

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	scaffolding.	collection.	findings.	engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	applications.
Chang, Lin, Hajian, and Wang (2023)	- AI chatbots offer personalized feedback and resources tailored to learners' needs. - Educational chatbots integrate pedagogical principles like goal setting and prompting. - Goal setting in education motivates students and guides self-regulated learning.	- Incorporating AI chatbots for goal setting, feedback, and personalization in education. - Lack of studies on effective integration of AI tools in classrooms.	- Personalized chatbot interactions improve metacognitive skills and learning outcomes. - Reverse prompts guide self-assessment and reflection, enhancing learning strategies. - Goal setting with chatbots fosters motivation and active learning involvement. - Just-in-time feedback and self-assessment repair knowledge gaps for better learning.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- Educational chatbots can supplement teacher instruction by providing personalized feedback. - Chatbots can prompt reflection on student learning progress. - Incorporating AI chatbots can support self-regulated learning in education. - AI chatbots can assist in promoting students' self-regulation in higher education.
Chauncey and McKenna (2023)	- AI chatbots support cognitive flexibility and self-regulation in education. - Prompts guide students in understanding, researching, and writing with AI chatbots. - Excessive cognitive load can overwhelm	- ChatGPT can assist in understanding datasets and selecting statistical methods. - ChatGPT should not be used to make decisions about students.	- AI chatbots enhance learning by providing personalized feedback and guidance. - Responsible use of AI chatbots fosters student engagement and cognitive flexibility. - Cognitive flexibility theory supports problem-solving with	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model,	- AI chatbots can enhance teachers' professional development in educational settings. - AI supports critical thinking, cognitive flexibility, and self-regulation in teaching. - AI literacy integration in K-12 education enhances

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	students in AI-rich learning environments. - AI enhances teaching practices and accelerates progress towards sustainable development goals. - ChatGPT responses motivate deep exploration and innovative instructional practices.		multiple perspectives.	provide feedback for effective learning.	learning experiences.
Bottino and Molfino (1985)	- Intelligent Computer-Assisted Instruction (ICAI) systems offer personalized learning experiences tailored to individual students. - AI techniques in ICAI systems allow for theoretical modeling of teaching. - ICAI programs engage students actively, adapting to their interests and misunderstandings.	- ICAI systems use AI techniques for teaching and learning processes. - AI techniques in ICAI programs focus on student knowledge representation.	- ICAI systems improve learning by engaging students actively in educational environments. - ICAI programs model student skills and address misunderstandings effectively. - ICAI systems use AI techniques to stimulate and control student learning.	- Teachers: Implement CASC model, adjust teaching methods based on feedback. - Parents: Support special needs students, engage in their learning progress. - Students: Benefit from CASC model, provide feedback for effective learning.	- ICAI systems focus on modeling teaching and learning processes. - AI techniques separate subject matter from teaching methods in ICAI.