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Advancing Equitable Education with Inclusive AI to Mitigate Bias and Enhance Teacher Literacy

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Review Article

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Abstract

Background/purpose. The integration of artificial intelligence (AI) in education has the potential to address inequalities and enhance teaching and learning outcomes. However, challenges such as AI biases, limited teacher literacy, and resource constraints hinder equitable implementation, especially in contexts like South Africa. This study investigates strategies for inclusive AI adoption, focusing on localized solutions, co-design practices, and ethical frameworks tailored to the region's unique needs, including linguistic diversity and cultural inclusivity.

Materials/methods. Using a literature review methodology spanning studies from 2000 to 2024, this research examines global and local initiatives to identify effective practices for AI integration in education. The study emphasizes the importance of localized datasets, culturally responsive AI tools, continuous professional development, and collaborative learning communities.

Results. The study proposes a phased implementation model that includes fairness-aware algorithms, diverse datasets, and sustainable infrastructure investments. It highlights the need to adapt global frameworks to local contexts and foster stakeholder collaboration. These strategies aim to address barriers and provide policymakers and educators with practical recommendations for equitable AI adoption.

Conclusion. The findings highlight the importance of localized and culturally responsive approaches to AI integration in education. By leveraging diverse datasets, co-design practices, and ethical frameworks, South Africa can create inclusive AI systems that address inequalities and improve learning outcomes. The study offers policymakers, educators, and stakeholders a practical roadmap to ensure context-sensitive and equitable AI implementation in education.

1. Introduction

Artificial intelligence (AI) increasingly influences education, offering tools and capabilities to enhance personalized learning, streamline adaptive tasks, and promote data-driven insights (Chaudhry & Kazim, 2022; Talan, 2021). Technologies like natural language processing (NLP), machine learning algorithms, and generative AI (genAI) enable tools that adapt instructional materials to suit students' unique needs and learning styles (Baker & Hawn, 2022; Baradziej, 2023). For instance, NLP facilitates language-based learning tools that can analyze student performance and suggest targeted interventions, while machine learning models enable the early identification of at-risk students based on patterns in large datasets. However, these technologies are not deterministic solutions; their effectiveness depends on thoughtful design, appropriate training data, and ethical implementation (De Back et al., 2023; Shiohira, 2021), offering significant potential to transform educational practices when thoughtfully designed and implemented.

Despite AI's transformative potential, its integration into education faces challenges such as data privacy concerns, algorithmic bias, and ethical dilemmas (Nguyen et al., 2023; Pedro et al., 2019). AI-driven assessment tools may disadvantage students from underrepresented demographics if trained on biased data, while language processing systems often struggle with underrepresented dialects and accents, marginalizing certain groups (Buolamwini & Gebru, 2018). Furthermore, predictive analytics used to identify at-risk students may unintentionally reinforce stereotypes due to biases in historical data, potentially exacerbating existing educational disparities (Kizilcec & Lee, 2022; Williams et al., 2018).

While existing research has explored AI's transformative potential in education, there remains a gap in understanding how to mitigate biases in AI systems and promote responsible AI literacy among educators and students. Addressing these concerns is particularly crucial in regions with historical inequalities, such as South Africa, where AI can either bridge or widen the digital divide (Francis & Webster, 2019; Holstein & Doroudi, 2022). Ethical AI integration must focus on ensuring fairness, transparency, and inclusivity to create equitable learning environments for all students.

This study aims to address the gap in AI bias mitigation strategies and the promotion of AI literacy among educators. The research will provide practical insights to ensure that AI technologies align with educational equity goals by exploring inclusive AI integration approaches. The study seeks to answer the following research questions:

1. How can AI integration in education be designed to mitigate algorithmic bias and promote inclusivity?

2. What strategies can be employed to enhance AI literacy among educators and students to ensure responsible use of AI in education?

This study contributes to the broader discussion on responsible AI adoption by offering practical guidelines for policymakers, educators, and developers. The findings will help ensure AI tools are designed and implemented in ways that promote fairness, inclusivity, and transparency, ultimately empowering educators and students to engage with AI responsibly. The next section transitions to the research methodology, outlining the literature review protocols that underpin the study. Following this, the literature review section explores strategies for empowering educators, discussing bias mitigation in AI integration, and examining methods to enhance teacher literacy in AI technology. Finally, the discussion synthesizes key insights from the literature review, culminating in a conclusive analysis presented in the conclusion section.

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2. Methodology

This study employed a literature review approach to synthesize existing research on inclusive AI integration, bias mitigation, and teacher literacy in educational contexts. The review focused on identifying key themes, research gaps, and practical insights from peer-reviewed journal articles, policy reports, and government documents published between 2000 and 2024. By prioritizing evidence-based sources, the study aimed to develop a framework for addressing factors influencing AI integration, strategies for mitigating bias, and enhancing teacher literacy in AI, with consideration of diverse perspectives on AI's role in education. While other qualitative methods, such as interviews or case studies, could have provided complementary insights, this review focused on synthesizing published research to establish a solid foundation for future studies.

2.1. Search Strategy and Selection Criteria

The literature search utilized EBSCOhost for education-focused journals, Google Scholar for broader coverage, and Scopus for peer-reviewed, interdisciplinary insights. This approach ensured a comprehensive review of inclusive AI, bias mitigation, and teacher literacy in education. Keywords included "AI in education," "Inclusive AI," "Bias mitigation," "Teacher AI literacy," and "AI ethical challenges," capturing diverse perspectives on AI integration while addressing equity and inclusivity. The combination of databases and targeted search terms facilitated a well-rounded exploration of relevant themes.

Inclusion Criteria

Studies were included in the review if they met the following criteria:

- Studies published between 2000 and 2024 to ensure coverage of foundational and recent developments.
- Studies focused on inclusive AI integration, bias mitigation in AI systems, or teacher literacy in AI within educational contexts.
- Studies offering insights into AI's role in improving educational practices, teacher empowerment, or addressing AI-related challenges.
- Studies written in English to ensure accessibility for the review process

Exclusion Criteria

Studies were excluded based on the following criteria:

- Studies outside the scope of AI in education, such as general technology integration or unrelated fields.
- Studies not providing clear, evidence-based conclusions regarding bias mitigation or teacher literacy in AI.
- Studies with non-peer-reviewed sources
- Studies lacking a direct focus on educational equity or AI's role in addressing disparities in educational outcomes.

2.2. Data Extraction and Analysis

The selected articles were reviewed to extract key data relevant to the study's thematic focus, including empowering educators, bias mitigation strategies, inclusive AI design, and teacher training programs. Studies were organized into thematic areas: Empowering Educators (strategies to enhance AI literacy and educator capacities), Bias Mitigation (approaches to reduce algorithmic biases), Inclusive AI Design (principles for creating culturally responsive AI tools), and Teacher Literacy

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Programs (frameworks to equip educators with AI-related skills). Practical recommendations for policymakers, educators, and AI developers were also included.

2.3. Quality Appraisal

To ensure rigor and reliability, studies in this literature review were evaluated based on methodological soundness, relevance, contribution, and clarity. Priority was given to studies addressing inclusive AI integration, bias mitigation, and teacher literacy. Contribution was assessed through pragmatic insights, research gaps, or innovative perspectives, highlighting practical recommendations. Clarity was determined by how well findings were structured, evidence-supported, and aligned with research questions. This appraisal ensured high-quality, relevant studies, forming a strong foundation for synthesizing literature and guiding AI integration in education.

3. Literature Review

Promoting AI literacy among educators and students is essential for advancing digital literacy and ethical awareness, enabling critical engagement with AI technologies technologies (Luckin et al., 2022). Integrating AI literacy and ethical frameworks into education allows institutions to leverage AI for equity, diversity, and data ethics, creating a more inclusive learning environment. By equipping educators with the necessary skills and promoting inclusive practices, stakeholders can bridge the digital divide and promote equitable learning opportunities (Roshanaei, 2024).

To achieve these goals, ethical frameworks such as deontological ethics provide essential guidance for AI integration in education (Jedličková, 2024; McGraw, 2024). These frameworks support bias mitigation through diverse datasets, promote transparency in AI systems, and align AI tools with human-centred pedagogies. Given the historical inequalities in regions like South Africa, it is crucial to implement AI strategies that prioritize inclusion and accessibility (Francis & Webster, 2019; Holstein & Doroudi, 2022).

3.1. Deontological Ethics

Deontological ethics emphasize the moral duty to uphold fairness and equity, advocating for AI systems that treat all users impartially and without discrimination, regardless of factors like language, gender, or socioeconomic background (Jedličková, 2024). This principle supports the development of AI tools that prioritize inclusivity, such as creating localized datasets that reflect South Africa's diverse languages and cultural contexts. By embedding fairness into the design phase, deontological ethics ensure the creation of systems that foster equitable access and representation (McGraw, 2024).

3.2. Consequentialist Ethics

Consequentialist ethics focus on the outcomes of AI use, advocating for tools that maximize benefits while minimizing harm. This perspective emphasizes the need to assess the real-world impact of AI systems, ensuring that they provide equitable access and enhance learning opportunities for all students (McGraw, 2024; Woodgate & Ajmeri, 2022). For example, personalized learning tools should be designed to improve educational outcomes for underrepresented groups, rather than reinforcing existing inequalities. Consequently, the benefits of AI systems, such as improved resource allocation, must outweigh potential harm, including the risk of algorithmic biases that could deepen inequalities.

These ethical frameworks are particularly relevant for South Africa, where linguistic and cultural diversity require adaptable AI tools. Their integration strengthens bias mitigation strategies, including the development of transparent and accountable AI policies rooted in deontological duties and consequentialist outcomes (Jedličková, 2024; McGraw, 2024). By addressing biases and reinforcing responsible AI integration, this study offers actionable insights for policymakers, educators, and stakeholders working to create equitable and inclusive learning environments.

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4. Results

This section explores how inclusive AI integration techniques can empower educators to address bias and improve teacher literacy in educational settings, with a focus on South Africa. Emerging trends and insights were analyzed using primary data sources, such as reports, research articles, and government policies covering the period from 2000 to 2024. The discussion will cover implications for practice, policy, and future research, highlighting areas that need more investigation and possible interventions to promote the inclusive integration of AI in education.

4.1. Strategies for empowering educators

Empowering educators with AI integration requires robust professional development programs that focus on AI literacy, bias awareness, and the integration of AI into teaching practices. These programs, available across several platforms, aim to improve educators' confidence and skills in using AI technologies (Pedro et al., 2019). Additionally, collaborative learning communities, supported by workshops, conferences, and online forums, offer continuous support for educators. However, AI integration presents significant challenges, including ethical concerns such as algorithmic bias and inequity, which can result in unfair outcomes like biased grading, misidentification of at-risk students, and the reinforcement of educational disparities (Ni et al., 2023). Moreover, data privacy and security issues arise due to the extensive collection of student data needed for AI systems, raising concerns about potential breaches and misuse, which could undermine trust in educational systems (Al-Zyoud, 2020; Ni et al., 2023).

Recognizing and addressing these complexities is important for ensuring responsible AI use in education. By providing educators with tools to address ethical concerns, institutions can support the ethical integration of AI technologies, ultimately enhancing teaching and learning outcomes (Lameras & Arnab, 2022; Saxena et al., 2023). Curriculum integration is key to empowering educators, enabling them to seamlessly incorporate AI principles and ethics into their teaching. This can be achieved by embedding AI-related content across disciplines and grade levels, as well as using AI tools in lesson plans. Hands-on learning activities, such as seminars and hackathons, further build educators' confidence and competence in using AI (Oluyemisi, 2023). Additionally, conducting research to evaluate the impact of AI on student learning outcomes is essential. Sharing these insights within the educational community can strengthen AI integration efforts and contribute to the broader knowledge base.

For AI integration to be successful, strong leadership and well-defined policies are essential. Establishing a culture that values AI initiatives, enacting policies to promote responsible AI use, and ensuring adequate funding and resources are critical steps in achieving effective AI adoption. Moreover, recognizing and celebrating educators' successes in leveraging AI for teaching and learning can sustain momentum and further support AI integration (Kim et al., 2022). In sum, these strategies are crucial for empowering educators, addressing ethical concerns, and ensuring that AI is used responsibly to improve educational outcomes.

4.1.1. Codesign approaches and successful initiatives in education

Co-design is a collaborative process that involves key stakeholders such as educators, students, and administrators in the development of inclusive and effective AI tools for education. This approach emphasizes shared decision-making, iterative feedback, and alignment with the needs of end-users, ensuring that AI tools are culturally responsive and adaptable (Holstein et al., 2019; Walsh et al., 2014). The co-design process typically includes structured phases, such as needs assessment, ideation, prototyping, and evaluation, with regular feedback loops to maintain relevance and effectiveness (Bhimdiwala et al., 2022). Through engagement in needs assessments, workshops, and

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user-centered design sessions, educators are empowered to contribute creatively and collaboratively, ensuring the tools are well-aligned with their needs and pedagogical goals.

Moreover, this participatory approach enhances skills development in AI, pedagogy, and data literacy among educators, ultimately improving teaching practices and advancing inclusive education. It requires cultural sensitivity, clear communication, and the recognition of educators' contributions to build trust and maintain active participation throughout the process (Holstein et al., 2019). Several examples of co-design in educational settings demonstrate their effectiveness in improving educational outcomes and ensuring inclusivity. Table 1 presents a summary of these successful initiatives, illustrating the vital role of collaboration in integrating AI and technology into education.

Table 1. Successful codesign initiatives

Initiative	Region	Stakeholders Involved	Objective	Key Features	Outcomes
Scratch	Global	Educators, Students, MIT Media Lab	Promote creativity in coding for students	Block-based programming, visual interface	Enhances cognitive, emotional, and behavioural engagement; boosts academic achievement in primary schools (Belessova et al., 2024).
Amathuba	South Africa	UCT, South African communities, Educators	Improve digital learning infrastructure	Collaboration tools, personalised dashboards, digital learning platform, multimedia support	Improves education accessibility and learner engagement (Manashe, 2022).
Kolibri	Global/South Africa	Learning equality, Educators, Students	Provide offline educational resources	Open-source platform, low-connectivity, educational resources, offline access	Enhances learning in marginalized communities (Kabugo, 2020).
Siyavula & Shuttleworth Foundation	South Africa	Siyavula, Shuttleworth foundation, Educators	Provide educational resources	Open educational resources, personalized learning, tailored instructional content	Enhances classroom engagement and supports professional development (Lambert, 2019).
Bridge International Academies (BIA)	South Africa, Global	Government, Community organizations, Educators	Enhance learning in underserved communities through AI integration	AI-powered personalized learning, student progress monitoring	Improves educational access in township schools (Riep, 2019).
UmojaHack Africa	Sub-Saharan Africa	Zindi Africa, Data scientists, Educators, Learners	Solve societal challenges using AI and data science	AI, machine learning, societal challenge projects	Tackles critical societal challenges and promotes AI-driven positive change (Butcher et al., 2021).

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FundZa Literacy Trust	South Africa	Educators, Writers, Tech Innovators	Promote literacy and reading through digital storytelling	Digital storytelling, e-books, mobile tech	Promotes literacy through accessible and engaging content (Mahao, 2019)
ICT4RED	South Africa	Teachers, School community, ICT experts	Integrate technology into rural education	Technology-based interventions, educator training	Enhances learning outcomes in rural schools (Botha & Herselman, 2013).

These initiatives demonstrate the potential of co-design in creating inclusive and culturally sensitive educational tools. While global programs like Scratch and Microsoft Education's AI efforts provide valuable insights, South African initiatives address the region's unique challenges. For example, Scratch, integrated into South African after-school programs, teaches coding through an interactive block-based interface, enhancing creativity, critical thinking, and problem-solving skills. This has significantly improved students' digital literacy and problem-solving abilities (Cárdenas-Cobo et al., 2021; Malan & Leitner, 2007). Similarly, the Amathuba platform bridges the digital divide in rural South Africa by offering AI-driven personalized learning, offline compatibility, and automated assessments (Manashe, 2022).

Equally, the Kolibri platform offers offline, open-source resources to overcome learning obstacles in underserved areas, leveraging AI to tailor content to student achievement and focus on areas where they struggle. After its implementation, schools in Limpopo, South Africa, saw a 30% increase in reading scores, highlighting its effectiveness in targeted interventions for struggling readers (Kabugo, 2020). Similarly, Bridge International Academies in South Africa uses AI to enhance teaching in township schools. By analyzing student performance, its AI-powered tools provide adaptive exams and custom lesson plans. A Gauteng pilot project showed a 20% increase in math exam scores over one academic year (Riep, 2019).

The FundZa Literacy Trust in South Africa promotes literacy using mobile technology and digital storytelling, offering culturally relevant content, especially in indigenous languages, to underserved communities (Mahao, 2019). Additionally, Zindi Africa's UmojaHack Africa engages students and professionals in developing AI solutions for local challenges like education access (Butcher et al., 2021). The ICT4RED initiative provides rural educators with AI and digital teaching tools, tailoring content to local needs while supporting professional development. In the Eastern Cape, it has increased teacher confidence and improved learning environments, showing the long-term benefits of AI integration in underserved communities (Botha & Herselman, 2013; Mabila et al., 2017).

Together, these examples highlight the value of inclusive, collaborative, and culturally sensitive approaches to AI in education. By focusing on co-design, partnerships, and ongoing engagement, they show how technology can promote educational equity and enhance learning outcomes in underserved communities.

4.1.2. Effectiveness and outcomes of codesign strategies

Globally, co-design strategies have proven effective in tailoring educational technologies to meet the needs of educators and learners. By involving stakeholders, these strategies ensure tools are relevant, intuitive, and user-friendly, increasing adoption and usage. Co-design also integrates diverse cultural perspectives, making technologies more inclusive. As a result, co-designed educational tools improve student engagement and learning outcomes. By incorporating pedagogical principles and educator feedback, these tools enhance teaching practices and academic performance. Furthermore, co-design fosters collaboration among educators, developers, and researchers, promoting knowledge exchange and community building (Cviko et al., 2015; Kelter et al., 2021; Wu et al., 2021).

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Locally, codesign strategies have been successful at addressing educators' unique challenges, such as linguistic diversity and limited resources. By engaging local stakeholders, solutions are customized to meet these specific needs, effectively overcoming contextual hurdles. Moreover, codesign initiatives instill a sense of ownership among educators and communities, promoting local sustainability (Külvik et al., 2021; Matthews et al., 2024). Moreso, locally developed solutions are culturally relevant and aligned with African schools, ensuring lasting impact. These initiatives empower educators by enhancing their tech skills and decision-making roles, thereby boosting confidence and facilitating the integration of AI tools into teaching practices (Sanusi et al., 2022).

In South Africa, codesigned interventions have positively impacted teaching and learning outcomes, particularly in areas such as literacy. Platforms like Kolibiri and Amathuba have successfully improved literacy among young learners, promoting greater equity and accessibility in education. These platforms are inclusive and contextually relevant, addressing the diverse needs of South African students (Kabugo, 2020; Manashe, 2022). In conclusion, codesign strategies have proven to be relevant, inclusive, and sustainable educational interventions. Engaging stakeholders in this process empowers them to shape the future of education, with a strong emphasis on bias mitigation and teacher literacy in AI integration. The next section will examine biases in AI systems used in education, exploring their impact and strategies for mitigating these biases.

4.2. Bias mitigation in AI integration

Bias in AI systems used within educational settings can significantly impact teaching, learning, and overall educational outcomes. Specifically, algorithmic bias may favor or disadvantage certain groups, such as when predictive models for student performance are used. Similarly, data bias arises from skewed or unfair training data, which perpetuates existing inequalities (Baker & Hawn, 2022; Ferrara, 2024). Furthermore, socioeconomic bias exacerbates disparities by disadvantaging low-income students, ultimately widening the achievement gap. In addition, gender bias can negatively affect student confidence and reinforce gender-based educational disparities. Similarly, cultural bias often reflects dominant social norms, favouring certain languages while excluding minority languages, which undermines the educational experience for diverse learners (Gupta et al., 2022; Siddique et al., 2024). Table 2 summarizes these key bias categories in AI systems, providing examples and real-world implications within educational contexts, further highlighting the need for bias mitigation strategies.

Table 2. Key bias categories in AI systems

Bias Category	Description	Examples	Real-World Implications
Algorithmic Bias	Biases in AI algorithms due to design or implementation choices that create unfair outcomes.	Predictive models for student performance, grading systems	Disadvantages specific groups, such as underperforming students or those from marginalized backgrounds (Baker & Hawn, 2022).
Data Bias	Biases resulting from unrepresentative or skewed training data.	Biased datasets favouring specific demographics or schools.	Perpetuates inequalities and reinforces existing stereotypes (Ferrara, 2024).
Socioeconomic Bias	Biases based on socioeconomic factors, often disadvantaging low-income students.	AI tools that offer limited resources for lower-income schools.	Widening the achievement gap and limiting access to quality education for low-income students (Ferrara, 2024).
Gender Bias	Biases based on gender, affecting representation and opportunities.	Algorithms favouring male students for STEM-related activities.	Reinforces gender stereotypes, discouraging underrepresented genders in certain academic or career paths (Lainjo, 2023).

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Cultural Bias	Biases that reflect dominant cultural norms often marginalize minority groups.	AI tools prioritizing certain languages or cultural contexts.	Exclusion of minority languages or cultures leads to disengagement and alienation (Gupta et al., 2022).

Given these challenges, designing inclusive AI systems for education is paramount. Bias mitigation requires multi-pronged strategies, including data diversification, bias detection, and the integration of inclusive design principles. These measures aim to promote equitable learning opportunities by ensuring that AI systems are free from discriminatory biases and promote inclusive education for all students (Mohamed, 2023; Tang & Zhu, 2024). However, in diverse and resource-constrained contexts like South Africa, these issues are particularly pronounced. For example, natural language processing tools often lack adequate support for indigenous African languages, such as isiZulu, Xhosa, or Sesotho, creating barriers for learners in these language groups (Mabokela et al., 2023). To address these biases, context-specific strategies are necessary, such as the development of localized datasets. AI systems must be trained on datasets that reflect South Africa's linguistic and cultural diversity (Chitapi, 2018). In addition, collaboration with local linguistic experts and educators is crucial to curating comprehensive datasets that include underrepresented languages and dialects, ensuring that AI tools can cater to a broad spectrum of learners (Zhong et al., 2024).

4.2.1. Impact of biases on educational outcomes

Biases in AI systems significantly impact educational outcomes, influencing students' learning experiences, performance, and attainment. These biases perpetuate existing inequalities by favoring certain groups, widening the achievement gap, and leading to unequal resource distribution among schools (Baker, 2021; Chinta et al., 2024). Moreover, biased systems reinforce stereotypes about students' abilities and career paths, limiting aspirations and perpetuating gender stereotypes (Lainjo, 2023). They also influence teachers' perceptions, resulting in differential treatment based on perceived abilities, race, or socioeconomic status, which affects students' self-esteem, motivation, and academic performance.

Additionally, the limited diversity and representation of AI systems pose significant challenges to educational equity and inclusion, as these systems may fail to address the needs and experiences of diverse student populations, ultimately leading to disengagement and alienation (Ferrara, 2024; Roshanaei, 2024). Bias in training data further marginalizes certain groups, limiting their access to educational opportunities and resources. This exclusion perpetuates disparities in academic achievement, as biased algorithms drive inequitable assessment practices that penalize underrepresented students. Furthermore, biased placement or tracking systems reinforce segregation, hindering advancement opportunities based on factors such as race or socioeconomic status (Pagano et al., 2023; Pedro et al., 2019).

4.2.2. Strategies for effective bias mitigation in AI tools for educators

To ensure fair and equitable outcomes in education, addressing biases in AI tools requires deliberate strategies. These include collecting diverse datasets that appropriately represent a range of demographic groups, implementing bias detection and monitoring mechanisms, and designing fairness-aware algorithms. Human-in-the-loop approaches enhance fairness by allowing educators to validate outputs and intervene when biases are detected, while ensuring explainability and transparency in AI systems builds trust among users (Chen et al., 2023; Pagano et al., 2023). Table 3 outlines the challenges educators face when integrating AI systems, along with corresponding mitigation strategies. By addressing these challenges and implementing the suggested strategies, educators can effectively leverage AI tools to foster equitable and inclusive learning environments that meet the diverse needs of all students.

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Table 3. Challenges and mitigating strategies faced by educators

Challenge	Description	Mitigation Strategy
Bias in AI systems	Algorithmic and data biases perpetuate inequities in learning outcomes.	Use bias detection tools, fairness-aware algorithms, and diverse datasets (Chen et al., 2023; Siddique et al., 2024).
Infrastructure gaps	Limited access to internet, devices, and electricity, particularly in rural areas.	Invest in infrastructure, deploy solar-powered devices, and develop offline-compatible tools (e.g., Kolibri) (Ferrara, 2024; Holmes et al., 2022).
Lack of teacher literacy	Educators lack AI skills and confidence to integrate AI tools effectively.	Implement comprehensive professional development programs and teacher literacy initiatives (e.g., AIMS training program) (Herrmann & Pfeiffer, 2023; Minkkinen et al., 2022).
Data privacy concerns	Risks of breaches and misuse of sensitive student data.	Enforce data protection policies and use transparent AI systems (Bhimdiwala et al., 2022; Holmes et al., 2022).
Resistance to change	Institutional reluctance to adopt new technologies.	Promote leadership-driven initiatives and showcase success stories to build trust and buy-in (Kamat & Nasnodkar, 2019; Rejmaniak, 2021).
Lack of data diversity	Training datasets may lack representation of diverse student populations.	Collect diverse datasets and apply oversampling and data augmentation techniques (Chen et al., 2023; Pagano et al., 2023).
Limited transparency in AI decisions	AI tools may operate as "black boxes," making their decisions unclear to users.	Ensure explainability and transparency through interpretable models and detailed decision-making processes (Bhimdiwala et al., 2022; Herrmann & Pfeiffer, 2023; Minkkinen et al., 2022).
Inadequate stakeholder engagement	Lack of collaboration with diverse stakeholders during AI tool development.	Foster participatory design through workshops, focus groups, and community involvement (Bhimdiwala et al., 2022; Holmes et al., 2022).
Resource constraints in low-Income Schools	AI tools may be more accessible in wealthier areas, creating an equity gap.	Develop scalable, affordable AI tools for schools in low-income areas (Ferrara, 2024; Minkkinen et al., 2022; Riep, 2019).
Teacher unfamiliarity with AI	Educators may lack the necessary skills to effectively use AI tools.	Provide continuous professional development programs on AI literacy and bias awareness (Herrmann & Pfeiffer, 2023).

AI has the potential to transform education, but challenges such as prediction errors, adaptation to diverse contexts, and biases must be addressed. First, prediction errors can arise from insufficient data or poorly tuned algorithms, which may lead to the misidentification of at-risk students. To mitigate this, developers can employ robust validation techniques, such as cross-validation, and test on localized datasets. Furthermore, incorporating feedback loops will allow for continuous refinement of algorithms over time (Baker & Hawn, 2022; Chinta et al., 2024; Tatineni & Allam, 2024). In addition, adapting AI tools to meet the needs of diverse educational environments, such as rural or multilingual classrooms, poses another challenge. This can be addressed through the localization of AI systems to accommodate linguistic and resource constraints. Moreover, involving educators in the co-design process and developing modular frameworks for customization can ensure that the tools are suitable for a variety of contexts. To foster trust in these systems, developers should also utilize interpretable techniques, such as decision trees, and offer training programs to help educators better understand AI outputs (Chaudhry & Kazim, 2022; Mathai, 2024).

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Furthermore, bias in AI systems, often arising from insufficient diversity in training data, is a significant issue that must be confronted. One-way developers can address this by curating datasets that reflect cultural, linguistic, and socioeconomic diversity. Techniques such as Generative Adversarial Networks (GANs) can be employed to balance underrepresented groups in the data (Nee et al., 2022; Sampath et al., 2021). In addition, fairness-aware algorithms and tools like AI Fairness 360 and Google's What-If Tool can be used to detect and reduce bias. Moreover, human-in-the-loop approaches, coupled with feedback loops, enable continuous adaptation. Finally, explainable AI (XAI) enhances transparency (Dwivedi et al., 2021; Kumar et al., 2024). A case in point is the Bridge International Academies initiative, which demonstrates how inclusive datasets and teacher feedback can lead to improved outcomes (Riep, 2019).

4.3. Improving teacher literacy in AI technology

Teacher literacy in AI is essential for promoting inclusive and equitable learning environments. Educators equipped with AI literacy can adopt innovative pedagogical methods, allowing them to personalize learning experiences more effectively, contributing to improved student outcomes (Baker, 2021; Chaudhry & Kazim, 2022). Moreover, by leveraging AI-driven data insights, teachers can make informed decisions that support personalized learning and identify at-risk students. In addition, AI-literate educators play a critical role in addressing biases in AI systems and promoting fairness in educational practices (Baker, 2021; Chen et al., 2020). As a result, these teachers not only enhance their own teaching abilities but also equip students with essential 21st-century skills, preparing them for careers in an AI-driven world. Through AI integration, educators promote equity, diversity, and success, ensuring that all learners benefit from personalized and inclusive opportunities (Chaudhry & Kazim, 2022; Chen et al., 2020).

Besides, teacher literacy in AI emphasizes lifelong learning and adaptability, equipping educators to guide students through an AI-influenced job market. Furthermore, with AI literacy, teachers can educate students on AI ethics, responsible decision-making, and privacy concerns, preparing them for the ethical complexities of an AI-driven world (Akgun & Greenhow, 2022). In addition to benefiting students, AI literacy cultivates professional development and collaboration among educators, creating opportunities for the exchange of best practices in AI integration (Baker & Hawn, 2022). Moreover, AI-literate teachers play a pivotal role in supporting technology adoption, promoting a culture of innovation within schools, and ensuring that AI is used responsibly to enhance educational outcomes (Akgun & Greenhow, 2022).

In South Africa, promoting teacher literacy in AI is particularly critical for successful integration into the diverse education system, especially in rural and underserved areas. One effective strategy is the implementation of context-specific training programs, such as ICT4RED, which provide models for AI literacy by equipping educators with the technological skills necessary for teaching in these environments (Mabila et al., 2017). These programs should focus not only on foundational AI concepts but also on their practical classroom applications, such as analyzing student performance data and creating personalized learning pathways. Also, blended learning models, which combine online modules with in-person support from district-level mentors, offer another key strategy to ensure accessibility and broad reach (Mendoza & Venables, 2023). These diverse initiatives have the potential to effectively boost teacher AI literacy, improve AI technology integration, and improve educational outcomes throughout South Africa.

4.3.1. Challenges faced by educators in adopting AI technology

Integrating AI technology into education presents significant challenges, especially in emerging economies like such as South Africa. Globally, there is a persistent digital gap, leaving some educators without access to essential technology infrastructure, devices, and internet connectivity needed for AI integration. This gap is even more pronounced in South Africa, where significant disparities exist

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between urban and rural areas and among socioeconomic groups. As a result, many schools in rural and underserved communities lack fundamental technological resources, hindering their efforts to adopt AI (Akgun & Greenhow, 2022; Mhlongo et al., 2023). Moreover, educators may lack technical skills and AI literacy essential for effective integration. This challenge is worsened in South Africa due to limited educational resources and scarce professional development opportunities. Consequently, educators face difficulties in acquiring the necessary skills and knowledge to utilize AI tools effectively (Mhlongo et al., 2023; Sharma et al., 2022).

Globally, implementing AI technologies can be financially demanding, and involve investments in hardware, software, training, and ongoing support. In South Africa, resource constraints such as limited budgets and infrastructure can make the adoption of AI technologies prohibitive, schools in disadvantaged communities may struggle to afford necessary equipment and training. (Alice & Ebuka, 2024; Mhlongo et al., 2023). Reliable internet connectivity is essential for accessing online AI tools and resources; however, many schools, particularly in rural areas, face significant infrastructure challenges. Issues such as unreliable electricity and limited internet access hinder efforts to adopt AI in education (Bosch et al., 2023; Botha & Herselman, 2013). Furthermore, the high cost of data presents an additional barrier, making online learning and AI integration even more challenging to implement effectively (Kamat & Nasnodkar, 2019; Mhlongo et al., 2023).

Resistance to change and ethical concerns, such as data privacy and bias, pose significant challenges to AI adoption globally (Dwivedi et al., 2021). Similarly, in South Africa, traditional teaching methods, institutional resistance, and cultural diversity further complicate integration (Kamat & Nasnodkar, 2019; Mhlongo et al., 2023). Specifically, resistance stems from mistrust of AI systems due to concerns about accuracy, fairness, and job displacement, as well as educators feeling overwhelmed by unfamiliar technologies (Cain, 2023; Nazaretsky et al., 2022). Moreover, educators frequently feel overwhelmed by unfamiliar technologies, which adds to the reluctance to adopt AI tools. Strategies such as using transparent tools like Google's What-If Tool and adhering to ethical guidelines that promote fairness and privacy are essential to address these challenges. Furthermore, empowering educators through training, peer learning communities, and professional development opportunities helps build trust while easing concerns about job displacement (Nazaretsky et al., 2022). For example, the ICT4RED program illustrates how involving educators in co-design and offering hands-on training promotes AI acceptance in rural schools. Therefore, by designing AI technologies that reflect South Africa's unique cultural and linguistic contexts, resistance can be reduced, ultimately ensuring that AI benefits all learners.

4.3.2. Approaches for promoting teacher literacy in AI technology

Promoting teacher literacy in AI technology is vital for equipping educators with the skills needed to integrate AI into teaching practices effectively. To achieve this, professional development programs should include AI literacy fundamentals, ethical considerations, and practical applications. These programs can be delivered through workshops, seminars, and online courses developed in collaboration with educational institutions, industry experts, and organizations to ensure educators gain comprehensive and up-to-date knowledge (Al-Zyoud, 2020). Hands-on training is particularly valuable as it provides practical experience with AI tools, fostering experimentation, peer collaboration, and confidence in applying these skills in the classrooms (Lee et al., 2022). Establishing collaborative learning communities, where educators can share knowledge, resources, and best practices, further supports these efforts (Pedro et al., 2019). Embedding AI literacy into both preservice and in-service teacher training programs is another strategy. Revising curricula to include modules on AI fundamentals, data literacy, and ethical considerations ensures educators acquire essential AI skills early in their careers, setting a strong foundation for future application (Baker, 2021; Lee et al., 2022).

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Additionally, partnerships with industry and research institutions play a pivotal role in advancing teacher literacy in AI. Collaborating with technology companies, universities, and AI research labs allows educators to participate in training sessions, internships, and mentorship programs, providing access to cutting-edge technologies and expertise. These partnerships keep educators informed about the latest advancements in AI and their potential applications in education (Pedro et al., 2019). To further support educators, curated resource libraries and toolkits should be developed, offering a range of AI-related materials such as lesson plans, case studies, and instructional guides. These resources demonstrate practical applications of AI, provide guidance on ethical considerations, and address biases, thereby equipping educators with the tools needed to navigate the complexities of AI integration (Akgun & Greenhow, 2022; Pedro et al., 2019). In conclusion, the successful implementation of these strategies depends on fostering a supportive culture of AI literacy at the institutional level. This requires leadership commitment to providing the necessary resources, time, and encouragement for professional development.

4.3.3. Examples of teacher literacy programs in AI integration

Several reputable institutions offer programs that blend hands-on experience, theoretical knowledge, and resources to enhance educators' AI literacy. A comparative analysis presented in Table 4 highlights the key features of selected global and local teacher training programs for AI integration.

Table 4. Teacher literacy programs in AI integration

Program Name	Region	Provider	Focus Areas	Delivery Mode	Key Outcomes	Notable Features	References
Microsoft AI school	Global	Microsoft Education	AI principles, machine learning, ethics, and educational applications	Self-paced online courses	Increased teacher familiarity with AI tools	Certification upon completion; practical experience with AI tools	(Pedro et al., 2019).
Generative AI for education professional development program	Global	Google	Incorporating Google AI tools like TensorFlow and Teachable Machine into classrooms, lesson plans, and activities	Digital courses, interactive workshops	Creation of AI-enhanced lesson plans	Resources include TensorFlow and Teachable Machine for innovative AI-based projects	(Al-Zyoud, 2020; Nyaaba & Zhai, 2024).
AI integration program	South Africa	South African National Department of Basic Education	AI in South African classrooms, data analysis, evaluation metrics, and personalized learning	Webinars, workshops, and curriculum resources	Enhanced AI use in teaching and assessment	Localized materials tailored to the South African educational landscape; focus on creativity and standards improvement	(Bosch et al., 2023; Greunen et al., 2021).
Teacher training program in STEM and AI	South Africa	African Institute for Mathematical Sciences (AIMS)	AI integration in STEM education, data science, and computational thinking	Blended (in-person and online)	Improved STEM teaching with AI tools	Comprehensive training for STEM educators; tailored modules for South African educators	(Giorgi, 2018; Mukagihana et al., 2024).

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These programs emphasize flexibility and practical engagement to meet educational needs. For instance, Microsoft AI School offers self-paced learning with certification, while Google's program combines tools with classroom-specific resources. Locally, South Africa's AI Integration Program and AIMS' initiatives tailor content to national curricula and STEM priorities, empowering educators to integrate AI, fostering creativity, enhancing teaching quality, and improving student outcomes. Effective AI integration requires educators to understand both technological concepts and pedagogical applications. Programs should provide practical experience with tools like IBM Watson and Google Classroom AI, while covering machine learning, data protection, and AI-driven assessments. Additionally, educators must be trained to critically assess AI outputs, customize learning pathways, and address ethical concerns such as bias and data privacy (Alalwany & Yonan, 2023; Pedro et al., 2019). To ensure accessibility, institutions should combine online and in-person instruction, supported by peer learning communities (Singh et al., 2021).

5. Discussion

This study highlights the transformative potential of AI in education, particularly in resource-constrained settings like South Africa. A key aspect of successful AI integration is the presence of clear policy frameworks, which have been widely recognized in previous research (Holstein et al., 2019; Luckin et al., 2022). While these studies emphasize the role of policies in guiding ethical AI adoption, our study extends this perspective by underscoring the need for context-specific policies that address unique challenges such as linguistic diversity and infrastructure disparities. Without tailored policies, the benefits of AI risk being inaccessible to marginalized communities. In addition to policy considerations, bias mitigation remains a critical concern in AI-driven education. Existing studies emphasize the importance of fairness-aware algorithms and diverse datasets to reduce bias (Pedro et al., 2019; Chen et al., 2023). However, our findings suggest that co-design practices which actively involve educators, learners, and community stakeholders, are equally essential. By integrating local perspectives into AI development, co-designed tools can be both technically sound and culturally relevant, ensuring fairer educational outcomes.

Another widely acknowledged challenge in AI adoption is infrastructure development (Mhlongo et al., 2023; Pedro et al., 2019). While prior research primarily highlights investments in digital tools, our study reveals that offline-compatible AI solutions and localized content are crucial in bridging the digital divide. Particularly in rural areas, limited internet access remains a significant barrier, necessitating AI solutions that function effectively in low-resource environments. Furthermore, the role of teacher AI literacy has been extensively discussed in existing literature (Lee et al., 2022; Saxena et al., 2023). While these studies advocate for AI training programs, our findings go further by demonstrating that hands-on learning experiences, such as hackathons and mentorship programs, play a pivotal role in boosting teachers' confidence in using AI tools. Practical exposure to AI fosters not only technical proficiency but also pedagogical innovation, enabling teachers to integrate AI effectively into their teaching practices

Beyond technical and pedagogical considerations, the ethical implications of AI in education must also be addressed. Previous studies have proposed ethical frameworks such as deontological and consequentialist ethics (Jedličková, 2024; McGraw, 2024). Our study builds on these frameworks by applying them specifically to the South African educational landscape, demonstrating their relevance in tackling systemic biases and ensuring equitable AI adoption. Ethical considerations must guide AI implementation to prevent deepening existing inequalities.

To ensure effective and inclusive AI integration, global frameworks must be adapted to address local challenges, such as infrastructure gaps, linguistic diversity, and socio-economic inequalities. While scalable solutions like Microsoft Education's AI tools are promising, they require customization to support indigenous languages and offline functionality. Locally driven initiatives, such as FundZa

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Literacy Trust and ICT4RED, further highlight the value of tailored interventions that prioritize cultural relevance, resource efficiency, and capacity-building (Botha & Herselman, 2013; Mahao, 2019; Pedro et al., 2019). Ultimately, bringing together educators, developers, and community stakeholders to co-create strategies informed by both successful local programs and global best practices will enhance AI's impact in education.

6. Conclusion

This study offers valuable insights into the inclusive integration of AI in education, with a particular emphasis on bias mitigation, teacher empowerment, and infrastructure development. Through an extensive literature review spanning 2000 to 2024, we synthesized successful AI initiatives and identified key factors essential for effective integration. The study underscores the importance of co-designing AI tools to ensure they are culturally relevant and equitable, especially in resource-limited contexts like South Africa. By highlighting successful initiatives and identifying existing gaps, this study provides a strategic roadmap for achieving equitable educational outcomes through responsible AI adoption.

Central to this study is the introduction of a phased implementation model for AI integration, offering a structured, incremental pathway with measurable milestones to guide stakeholders in adopting AI technologies in education. This model's feasibility and impact are demonstrated through case studies like Scratch, Kolibri, and UmojaHack Africa, each addressing disparities in technology access and educational resources, particularly in underserved regions. The phased approach equips educators with the necessary skills to effectively leverage AI tools, ensuring the adoption of inclusive practices that cater to diverse learner needs. This comprehensive framework sets the stage for responsible AI integration, with a focus on bridging gaps in technology access and promoting equitable learning experiences.

To ensure the sustainability and impact of AI integration, this study provides clear, practical policy recommendations with defined milestones and timelines. These steps offer institutions, particularly in resource-constrained areas, a concrete pathway to gradually implement AI in a way that aligns with local needs and capacities. By providing specific policy recommendations for educational stakeholders and policymakers, the study lays out the foundations for achieving sustainable and equitable AI adoption in education. Table 5 presents these policy recommendations, detailing the milestones necessary for effective AI integration, ensuring that the process remains equitable and impactful.

Table 5. Policy recommendations and phased approach

Stage	Action	Milestone	Link to Findings
Stage 1: Raise awareness and promote AI literacy	Launch targeted AI literacy campaigns for educators, policymakers, and students.	Develop and distribute AI literacy materials within 6 months. Establish 50 regional AI literacy workshops within the first year.	Emphasizes the need for continuous professional development and teacher empowerment in AI literacy (Akgun & Greenhow, 2022; Pedro et al., 2019).
Stage 2: Implement small-scale pilot programs	Implement small-scale AI pilot projects in selected schools to test AI tools' effectiveness and address practical barriers.	Launch at least 5 pilot programs in diverse educational settings (e.g., rural and urban schools) within the first year.	Aligns with findings on the importance of hands-on learning and iterative feedback through practical experiences (Luckin et al., 2022).

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Stage 3: Develop ethical, culturally relevant AI guidelines	Engage stakeholders including educators, learners, and policymakers in the co-design of AI tools to ensure cultural relevance and ethical standards.	Publish the first draft of national AI ethics and integration guidelines by the end of Year 2, incorporating feedback from 200 educators.	Directly informed by findings on co-designing culturally relevant and ethically sound AI tools (Holstein et al., 2019; Luckin et al., 2022)
Stage 4: Improve infrastructure for AI integration	Prioritize investments in AI-compatible devices, internet access, and training materials, especially in rural and underserved areas.	Complete infrastructure assessments in 100 schools and ensure 70% of these schools have AI-compatible infrastructure by the end of Year 3.	Supports the findings on the importance of infrastructure development, particularly for resource-limited regions (Mhlongo et al., 2023; Pedro et al., 2019).
Stage 5: Scale AI integration and ensure long-term sustainability	Expand successful AI pilot programs into full-scale implementations, with ongoing professional development and policy evaluation.	Scale AI implementation in 200 schools and provide at least two AI literacy training sessions per year for educators.	Highlights the need for continuous development and teacher engagement for successful AI implementation (Chen et al., 2023; Pagano et al., 2023).

The success of these recommendations relies on the active collaboration of governments, educational institutions, technology developers, and communities to address systemic challenges and ensure inclusive and impactful AI integration. Further research is needed to evaluate the long-term effects of AI in education, including metrics to assess outcomes like improved literacy rates, reduced teacher workloads, and expanded technology access. Future studies should also explore innovative solutions to emerging challenges, such as adapting AI tools for indigenous languages and offline environments. By implementing the strategies outlined in this study, stakeholders can use AI to promote equitable and inclusive educational opportunities, positioning education as a transformative force in an AI-driven future.

7. Limitation of the Study

While this study provides valuable insights into inclusive AI integration strategies, it is not without limitations. The reliance on a literature review, which synthesizes findings from secondary sources, limits the inclusion of real-world implementation data. Future research could address this by adopting mixed-methods approaches, including interviews, focus groups, and case studies involving educators, students, and policymakers, to provide deeper, context-specific insights. Additionally, the study's focus on South Africa, while addressing the region's unique socio-economic and cultural landscape, may limit the generalizability of findings. Comparative studies in similar regions, such as Sub-Saharan Africa or other developing contexts, could evaluate the transferability of these findings and refine the recommendations for broader application. Addressing these limitations will enable future research to validate and refine the study's recommendations, fostering the equitable and effective integration of AI technologies across diverse educational settings.

Declarations

Author Contributions. K.E.: Conceptualization and design, literature search, writing – original draft and final draft. T.Z.: Writing – review & editing. All authors have read and approved the published on the final version of the article.

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