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A scoping review of the integration of artificial intelligence in primary and secondary schools from 2020 to 2024: Policy implications for South Africa

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Abstract

South Africa's education system struggles with challenges highlighted by low student performance in global assessments. Based on Bloom's (1984) personalised instruction model and the Arksey and O'Malley (2005) methodology, this scoping review explores how artificial intelligence (AI) can enhance educational outcomes in South Africa. This analysis of international applications and their implications for South Africa involved a scoping review of SpringerLink, ScienceDirect, Mendeley, and Taylor & Francis databases to identify primary studies on AI in education from 2020 to 2024. Data from 33 articles were charted and summarised according to the research questions. Key findings highlight the potential of AI to provide personalised learning experiences, enhance inclusivity, and support special needs education. However, infrastructure deficiencies pose significant barriers. Effective AI deployment requires educators to develop technical skills and understand AI ethics to address biases and privacy issues. Implications for policy are discussed.

Keywords: AI, education, scoping review, South Africa

Introduction

South Africa's basic education system faces significant challenges, as evidenced by student performances in international assessments (Centre for Development and Enterprise, 2023). The recent Decadal Plan 2022 has also recognised a crisis in mathematics, science, and literacy education that urgently needs to be addressed to prevent further educational decline and to future-proof education (Department of Science and Innovation, 2022). Results from the Progress in International Reading Literacy Study (PIRLS) 2021 revealed that more than 80% of Grade 4 students in South Africa could not read for meaning in any of the country's 11 official languages (Department of Basic Education [DBE], 2023). This issue is compounded by the Trends in International Mathematics and Science Study (TIMSS) 2019 findings, which placed South African Grade 9 students second to last in mathematics, and last in science among all participating countries (Reddy et al., 2022). Thus, poor academic performance at primary and secondary school levels stresses the need for innovative solutions to improve student outcomes, particularly in STEM (science, technology, engineering, and mathematics) areas.

The country's education system struggles with numerous weaknesses affecting its overall effectiveness. A significant challenge is overcrowded classrooms, which complicates teaching efforts and significantly hinders students' ability to learn effectively (Graham, 2023). For instance, Graham found that larger class sizes in South Africa are related to worse mathematics performance. Additionally, the quality of teachers, which includes teacher qualification, instructional clarity, and teaching experience (Matope, 2021), varies widely according to the socio-economic status of schools. This status further exacerbates educational disparities (Reddy et al., 2022). The latter authors found that students who scored their teachers' instructional clarity as high outperformed their counterparts who rated their teachers' instructional clarity as moderate. Furthermore, limited access to educational materials such as textbooks and workbooks also negatively influenced student achievement (DBE, 2023; Reddy et al., 2022). Moreover, the digital divide in South Africa significantly

impacts educational opportunities because many students in lower socio-economic areas lack access to digital devices and reliable internet connections (Makalima et al., 2023). This gap in digital access not only hinders the integration of modern educational technologies such as artificial intelligence (AI) but also limits students' ability to engage with digital learning resources, further widening the educational disparities across different regions and communities (Chisango & Marongwe, 2021).

Integrating AI in the South African education system could be an important step towards remedying current deficiencies and enhancing educational outcomes. AI in education (AIED) refers to the application of AI within the educational sector (Keerthiwansha, 2018). By integrating AI, educators could better identify and address students' individual needs, promote greater engagement, and facilitate a deeper understanding of complex learning areas. This approach aligns with the insights of Bloom (1984), who identified that the optimal learning method involves one-to-one expert tutoring, significantly improving student performance. However, such personalised instruction is often too costly and impractical in traditional classroom settings. Bloom further observed that one-to-one tutoring combined with mastery learning techniques allowed students to perform two standard deviations better than traditional instructional methods. In effect, the students who experienced this form of teaching scored more highly than 98% of those who underwent the traditional form. AI technologies can mimic this high-impact tutoring by offering personalised learning experiences at scale, thus potentially offering a practical solution to the challenges highlighted in the ongoing educational crisis in areas like mathematics and science.

In light of the critical educational challenges faced by South Africa, this study embarks on a scoping review to explore how AI has been integrated into primary and secondary education globally between 2020 and 2024 (April). The limited studies on AI applications within the South African educational sector necessitate a broader examination of international implementations to uncover how AI could be employed locally. Previous literature predominantly focused on isolated AI applications (Celik et al., 2022; Kim & Kwon, 2024) or higher education sectors (Essel et al., 2024; Misiejuk et al., 2024), leaving a significant gap in comprehensive, systemic evaluations at the primary and secondary levels. Consequently, this review aims to fill these gaps by answering the following primary research questions:

1) What are the implications of adopting AI in South African schools, examining its impact on the education system inclusive of staff, learners, and surrounding communities?
2) Additionally, how might AI specifically impact students with special needs in South African schools?
3) What competencies do South African educators require to be proficient adopters of AI in the classroom?
4) What risks and challenges unique to South Africa may arise following the greater adoption of AI in the classroom?

By exploring these questions (see detailed sub-research questions illustrated further down in Figure 1), the study intends to demonstrate how AI could potentially enhance educational

practices, making them more equitable and effective across South Africa's diverse educational landscape.

Method

The study employs the Arksey and O'Malley (2005) framework, which is a widely utilised methodology for conducting scoping reviews in the field of health and social sciences. Scoping reviews aim to map the key concepts underpinning a research area and the main sources and types of evidence available. This framework provides a structured approach to conducting these reviews, ensuring comprehensive coverage of the literature on a particular topic. We applied the following five stages outlined in the Arksey and O'Malley (2005) framework for conducting a scoping review:

Stage 1: Identifying the research question

As discussed in the previous section, the study initially defined four research questions that explore the implications of adopting AI in South Africa's basic education sector. This has implications for policymakers, staff, and students and emerges from the intersection of global AI integration and the South African context. This framing also influences the choices of studies that inform the scoping review process. The scoping review is conducted to highlight key concepts and evidence that can inform policy or research (Dijikers, 2015). It is not an exhaustive search, which was preferred due to the scale of literature published on this topic.

The first research question, which examines the implications of AI adoption in South Africa, is analysed in terms of the DBE's (2024) Strategic Plan 2020–2024, which prioritises access, quality, support, and socio-economic concerns. The second research question, which focuses on implications for special needs learners, examines the access dimension of this strategy, considering the potential for personalised learning experiences suited to the needs of each learner. The third research question, which examines educator competencies, connects to the skills dimension referred to within DBE's strategy, and explores the technical and pedagogical skills requirements. The last research question, which focused on the risks associated with AI adoption, is examined in terms of the infrastructural and socio-cultural challenges described in the strategy that are associated with AI adoption in the classroom. These dimensions are explored further in the Analytical Framework section's Figure 1.

Stage 2: Identifying relevant studies

This study is informed by a collection of primary published studies. This included searching for primary research studies from the following academic publishing platforms, namely, SpringerLink, ScienceDirect, Mendeley, and Taylor & Francis (Journals). These platforms were selected for their coverage of educational technology research and advanced search capabilities to assist with screening literature pertaining to AI-related concerns. While SpringerLink, ScienceDirect, and Taylor & Francis offered papers focused on the education sector, Mendeley provided an interdisciplinary focus that potentially offered a wider range of perspectives related to AI adoption in schools.

For the first research question, key search terms included “artificial intelligence” OR “AI” OR “machine learning” AND “usage” OR “applications” AND “schools” OR “education” OR “K-12” AND “extent.” For the second research question, the search criteria included “artificial intelligence” OR “AI” OR “machine learning” AND “special needs education” OR “inclusive education” AND “disabilities.” For the third research question, the search criteria applied the following search terms: “AI competencies” OR “AI skills” AND “teachers” OR “educators” AND “integration” OR “implementation” AND “education” to locate studies. For the last research question, the search contained key terms such as “risks” OR “challenges” AND “artificial intelligence” OR “AI” OR “machine learning” AND “integration” OR “implementation” AND “education” AND “ethical concerns” OR “limitations.” On the first iteration, more than 1,000,000 results were generated from the various databases, requiring more stringent study selection criteria.

Stage 3: Study selection

Due to the large number of irrelevant studies generated, mainly linked to health sciences and higher education, a set of inclusion and exclusion criteria were applied. This approach narrowed the results to include only journal articles written in English between 2020 and 2024. The year 2020 was selected because many schools were forced to shift from traditional teaching to remote learning and digital learning platforms due to COVID-19, initiating an exploration of technology applications in the classroom. This shift most likely accelerated the adoption and integration of AI in schools and sought new tools to facilitate learning outside the classroom. In this period, there was also rapid development and deployment of AI-driven tools (such as chatbots) to support online learning, student engagement, and personalised education, making it a pivotal year for studying these trends.

Table 1
Scoping review literature selection process

	Initial Scan	**Relevant**	**Selected**
Uses of AI in education	23	18	15
AI for diverse learner needs	12	12	6
AI competencies needed for educators	16	16	7
Risks and challenges to AI integration	20	20	7
Total			33 (2 duplicates across research questions)

In this review, the search criteria excluded review and news articles, conference proceedings, book chapters, and studies from higher education and health sciences. Subsequently, the titles

and abstracts were screened, followed by a full-text review to determine which studies should be included in the review. The search was conducted per the research question, and thereafter, we removed all duplicates sourced from the various publication platforms. Ultimately, 33 studies (across all research questions) were included in this review (see Table 1). References to these studies are indicated with an asterisk (*) in the reference list.

Stage 4: Charting the data

Following the Arksey and O'Malley (2005) framework, the studies were tabulated, presenting pertinent information and answering each research question where applicable. The table included details about the author(s), year of publication, study location, sample, study methods, the purpose of the study, outcomes measured, key findings, and study limitations.

Stage 5: Collating, summarising, and reporting the results

The final stage involved analysing the data and reporting on the extent, nature, and distribution of the research conducted in AIED. First, the results are presented in a narrative form and are then organised according to the four research questions of the study. In analysing this data, the main challenge was attributing the findings from foreign countries to the South African context. Given that AI is a nascent technology, local studies are limited. However, the local context is well reported, with several authors describing the predominant challenges experienced in the country. The following section describes the analytical framework employed to connect the evidence from foreign countries to the South African context.

Analytical framework

The DSI's Decadal Plan for 2022–2032 was published prior to the release of ChatGPT in November 2022. This plan outlines integrating new technologies into the education sector, focusing on future proofing to advance the country's developmental agenda. The following objectives were identified (Department of Science and Innovation, 2022):

- 21st century skills: The plan emphasises the importance of coding and robotics skills in education, highlighting the need for investment in AI and other advanced technologies for digital economy readiness. The Decadal Plan also includes an Innovation and Skills Compact that calls for aligning the education sector to the needs of the digital economy.
- Digital transformation: The plan acknowledges the rapid advancements in technology and emphasises the need for interventions to bridge the digital divide, urging a transformation of the education sector.

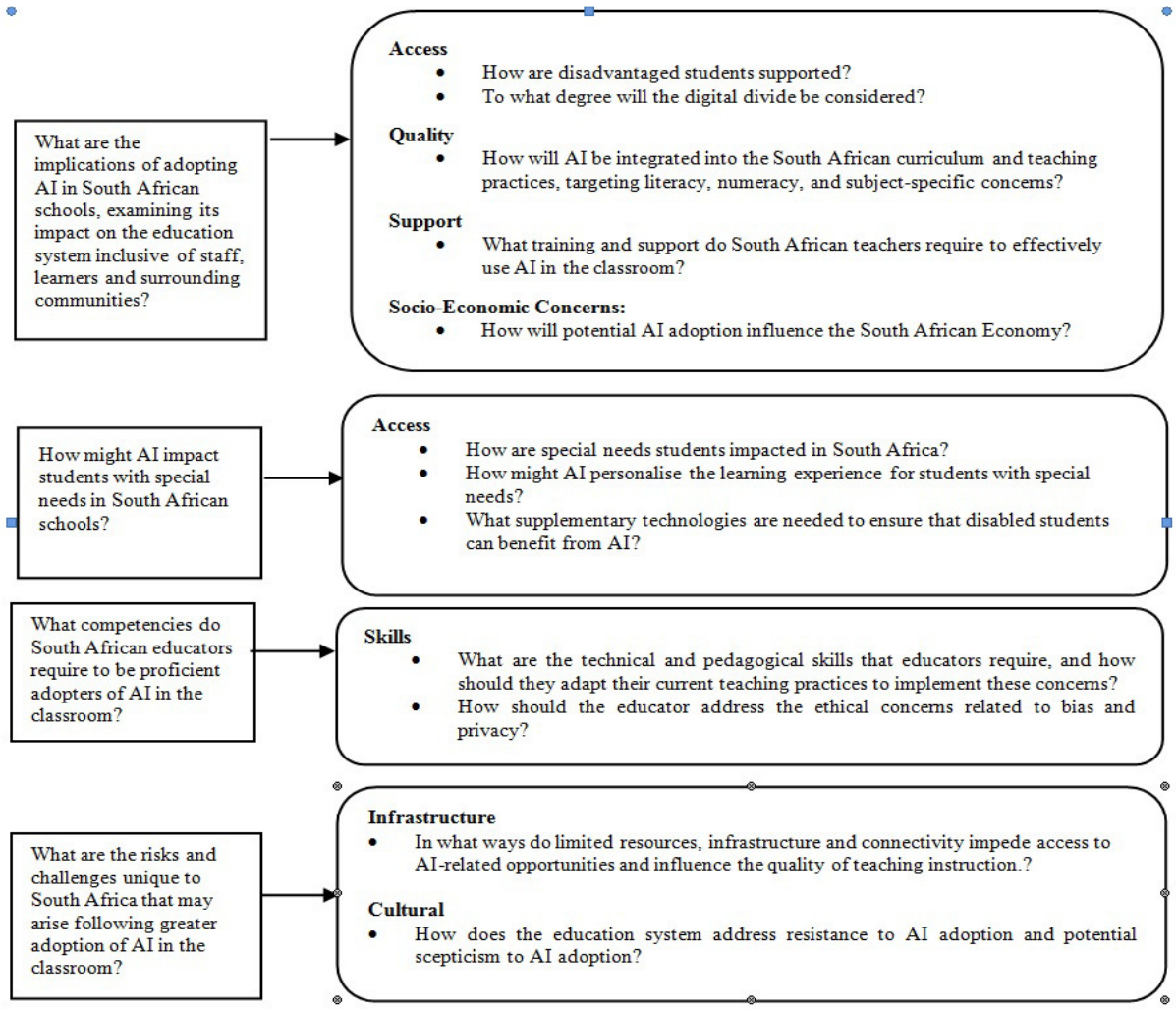
The points emphasise the need to integrate the education system with the digital economy but do not address the challenges faced by the South African basic education sector. To contextualise these concerns, we reviewed the national basic education priorities defined by the DBE in its Strategic Plan for 2020 to 2024. In this document, the department outlines its

priorities and strategy for integrating technology into the teaching and learning process (DBE, 2024). These priorities include the following:

- Access: DBE emphasises the significance of enhancing Early Childhood Development Phase access, and aims to foster inclusivity and equity by accepting all students, regardless of their background or abilities.
- Quality: DBE acknowledges instructional quality issues at various stages of schooling and aims to improve literacy, numeracy, subject-specific interventions, teacher development, and curriculum strengthening.
- Resources: DBE plans to improve school infrastructure by building new schools, renovating existing ones, and providing necessary resources like technology and textbooks for better education.
- Partnerships: DBE plans to strengthen its partnerships with civil society groups and the private sector and improve its engagement with parents.

In this light, to analyse the evidence included within the literature, the following concerns need to be tested per research question (see Figure 1):

Figure 1
Analytical framework mapping the research questions to the South African context



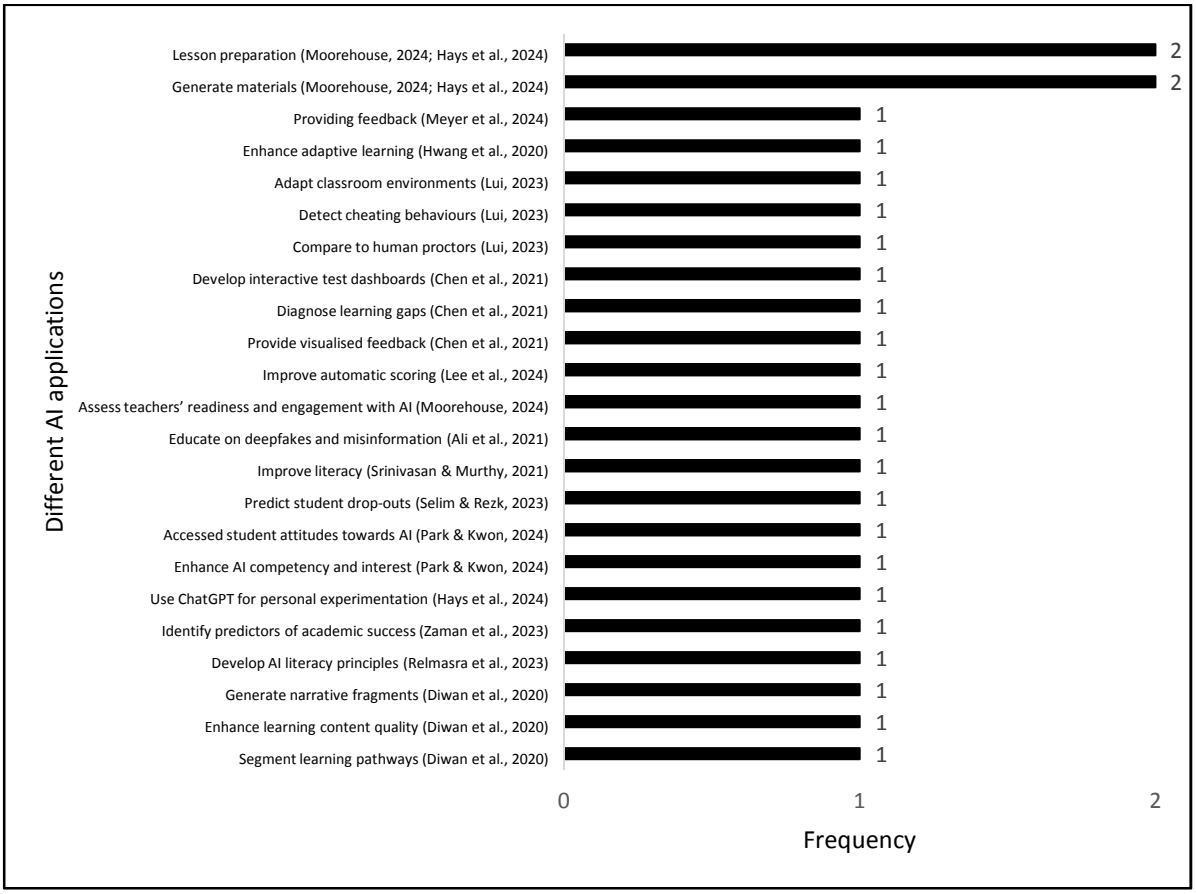
The Decadal Plan aims to modernise the education system and address the digital divide. The emergence of Generative AI in 2022 presented a significant opportunity for South Africa to reverse decades of poor educational performance. Education policymakers have long understood that offering one-to-one student-to-expert tutor contact is the solution to improving educational outcomes. This was Bloom's (1984) finding, where he noted a two-sigma deviation among students who learnt with such support. Unfortunately, no public education system had sufficient resources to provide such opportunities to students. The emergence of AI and rapid technological advances have offered opportunities to solve Bloom's Two Sigma problem. Thus, AI can offer personalised learning opportunities and scalable and accessible teaching. The framework mentioned above can be applied to interpret the evidence discussed in the literature review to test these views.

Scoping review results

Different uses of AIED

Findings from 15 out of 33 articles from the scoping review showed that AI has been applied for varied purposes in schools, revolutionising educational practices and outcomes (see Figure 2).

Figure 2
Different uses of AIED



One significant application of AI is providing feedback to students. Meyer et al. (2024) demonstrated the effectiveness of LLM-generated feedback in enhancing German students' performance on English argumentative essay tasks, highlighting the potential of AI to support personalised learning experiences in secondary education. Transitioning to adaptive learning systems, Hwang et al. (2020) showed that AI can tailor educational content to individual students' needs, improving learning achievements and reducing mathematical anxiety among elementary school students in Taiwan. Expanding the application to language processing, Diwan et al. (2023) employed Natural Language Processing (NLP) and Natural Language Generation (NLG) techniques to generate narrative fragments and segment learning pathways, illustrating the capability of AI to enhance content delivery and coherence in educational resources. Similarly, AI's role in maintaining academic integrity was explored by Liu (2023), who developed an AI-based proctoring system using convolutional neural networks, effectively detecting cheating behaviours in examination settings and surpassing human proctors' performance. In science education, Chen et al. (2021) implemented an interactive test dashboard with diagnosis and feedback mechanisms (ITD-DFM) tool that significantly improved students' learning performance and self-efficacy in physics, demonstrating AI's capacity to identify learning gaps and provide visualised feedback. Further emphasising AI's role in assessment, Lee, G. G et al. (2024) utilised GPT-4 to automatically score middle school science tasks, ensuring robust and interpretable evaluations that inform instructional decision-making. AI's utility in coding student interactions was highlighted by de Araujo et al. (2023), who introduced the ConSent system aimed at fostering collaborative learning environments. Meanwhile, in Hong Kong, Moorhouse (2024) explored AI tools for lesson preparation and material generation, noting a rapid uptake among first-year teachers who used tools like ChatGPT to save time and enhance lesson quality.

Addressing digital literacy, Ali et al. (2021) focused on educating middle school students about deepfakes and misinformation through interactive AI-based activities, underlining the importance of AI in fostering critical media literacy skills. Additionally, Srinivasan and Murthy (2021) demonstrated the impact of an AI-based multi-sensory technology platform in improving literacy among children in India, showcasing AI's potential to address educational disparities and enhance learning outcomes across diverse contexts. In Egypt, Selim and Rezk (2023) applied logistic regression models to predict student dropouts, identifying significant predictors and enabling targeted interventions to support at-risk students. Similarly, Park and Kwon (2024) assessed AI's impact on students' attitudes toward technology and AI competency in South Korea, finding significant improvements in students' interests and career aspirations in technology-related fields. Hays et al. (2024) explored the use of ChatGPT for lesson planning and educational tasks, highlighting its potential to streamline teachers' workflows and enhance instructional quality. In India, Zaman et al. (2023) utilised geospatial AI and machine learning (ML) models to identify predictors of academic success. Finally, Relmasira et al. (2023) investigated AI literacy activities for Grade 5 students in Indonesia, finding that collaborative and creative AI-based tasks effectively engaged students and enhanced their understanding of AI concepts. The diverse applications of AIED, from personalised feedback and adaptive learning to assessment, teacher support, and

infrastructure analysis, demonstrate its transformative potential across various educational contexts. In the next section, we discuss how AI is applied to support special needs education.

AI uses for special needs education

AI is increasingly integrated into special needs education to support student needs (see Table 2). Research evidence highlights several innovative applications. For example, El Naggar et al. (2024) described how AI creates personalised and intellectually stimulating learning experiences for exceptional students in the United Arab Emirates. In addition to personalised learning, AI technologies are used to assist with diagnosis and support for various disabilities. Garg and Sharma (2020) identified the use of robotics, mobile apps, and speech recognition systems to diagnose and provide assistive technologies. These tools help identify specific needs and offer ongoing support, making education more accessible for students with disabilities. Furthermore, AI-driven assistive robots are making significant strides in improving social interactions among students with special needs. As noted by Abbasi et al. (2024), these robots have shown promise in enhancing social interaction for students with autism and other disabilities. This technology helps bridge communication gaps and fosters better peer relationships, which are crucial for social development.

Table 2
Application of AI for special needs students

	Special needs	AI Use in Support of Disability	Country
El Naggar et al. (2024)	Exceptional students	Personalised and intellectually stimulating learning experiences	United Arab Emirates
Garg & Sharma (2020)	Various disabilities	Robotics, mobile apps, speech recognition systems aiding in diagnosis and providing assistive technologies	Not specified
Abbasi et al. (2024)	Autism & various	AI-driven assistive robots improve social interaction	Not specified
Yang (2022)	Dyslexia	Improves reading comprehension through targeted story structure instruction	Not specified
Ahuja et al. (2022)	Learning disabilities	Augmented Reality (AR) content in Intelligent Tutoring Systems enhances learning outcomes.	India
Ojha (2022)	Cerebral palsy & learning disabilities	AI-assisted devices facilitate communication and skill development	Not specified

Source: Authors' summary

AI plays a crucial role in addressing specific learning challenges such as dyslexia. Yang (2022) discussed how AI improves reading comprehension for dyslexic students through targeted story structure instruction. This method helps students grasp complex reading materials more effectively, thus enhancing their overall learning experience. Additionally, integrating augmented reality (AR) in intelligent tutoring systems is another area where AI is making a significant impact. Ahuja et al. (2022) reported that AR content significantly enhances learning outcomes for students with learning disabilities in India. AR helps students better understand and retain educational content by providing an interactive and engaging

learning environment. Lastly, Ojha (2022) highlighted the role of AI-assisted devices in facilitating communication and skill development for individuals with cerebral palsy and learning disabilities. These devices provide essential support, enabling students to communicate more effectively and develop the necessary skills for their academic and personal growth. The integration of AI in special needs education enhances learning and makes education more inclusive and accessible for all students.

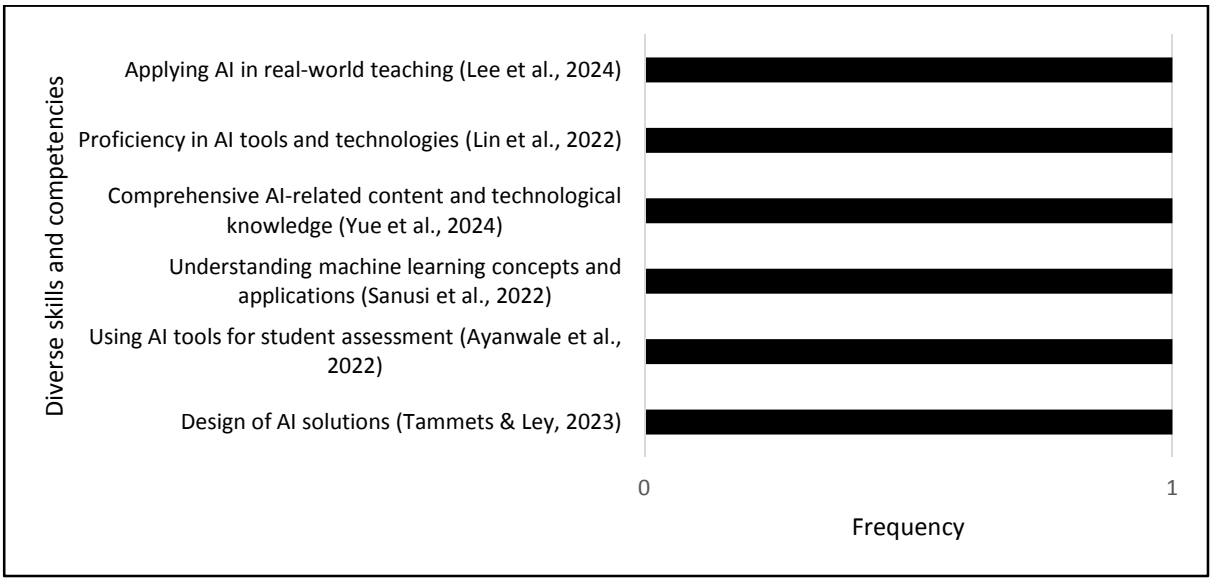
Several challenges emerged despite the integration of AI in special needs education. Many studies lacked country-specific data, making it challenging to assess regional applicability. At the time of our scoping review, we could also not locate studies on AI in special needs education in Africa. Lastly, research focuses on select disabilities like autism and dyslexia, leaving gaps in AI support for conditions such as Attention-deficit/hyperactivity disorder (ADHD) or sensory impairments.

AI skills needed for successful use in education

Educators must develop diverse skills and competencies to integrate AI into education effectively. These skills include a range of technological, pedagogical, and ethical considerations, ensuring that AI can be utilised to enhance educational outcomes (see Figure 3).

Through the scoping review, several key competencies were identified for educators to assist them in integrating AI into their teaching. Lee, Y. J. et al. (2024) and Lin et al. (2022) referred to the technical competencies that educators may require, such as understanding machine learning or data analysis software. Similarly, Yue et al. (2024) emphasised the importance of AI-related concepts and technological understanding. Sanusi et al. (2022) revealed that teachers from Nigeria, Ghana, Tanzania, Kenya, South Africa, and Namibia are interested in professional development in advanced AI concepts such as machine learning and data analytics. Tammets and Ley (2023) discussed the need for developing AI solutions crafted for educational contexts, while Ayanwale et al. (2022) described the AI tools to support student assessments as a critical competence. Park and Kwon (2024) covered a range of topics related to technical competencies, and argued that educators needed technical competencies to engage with their learners meaningfully. They further emphasised the importance of training AI models with the aim of developing AI literacy. These models should demonstrate a sensitivity to the social impacts of AI adoption, and the ethical considerations of AI use, ensuring that they are educationally effective and socially responsible.

Figure 3
Skills needed to integrate AI into teaching and learning successfully

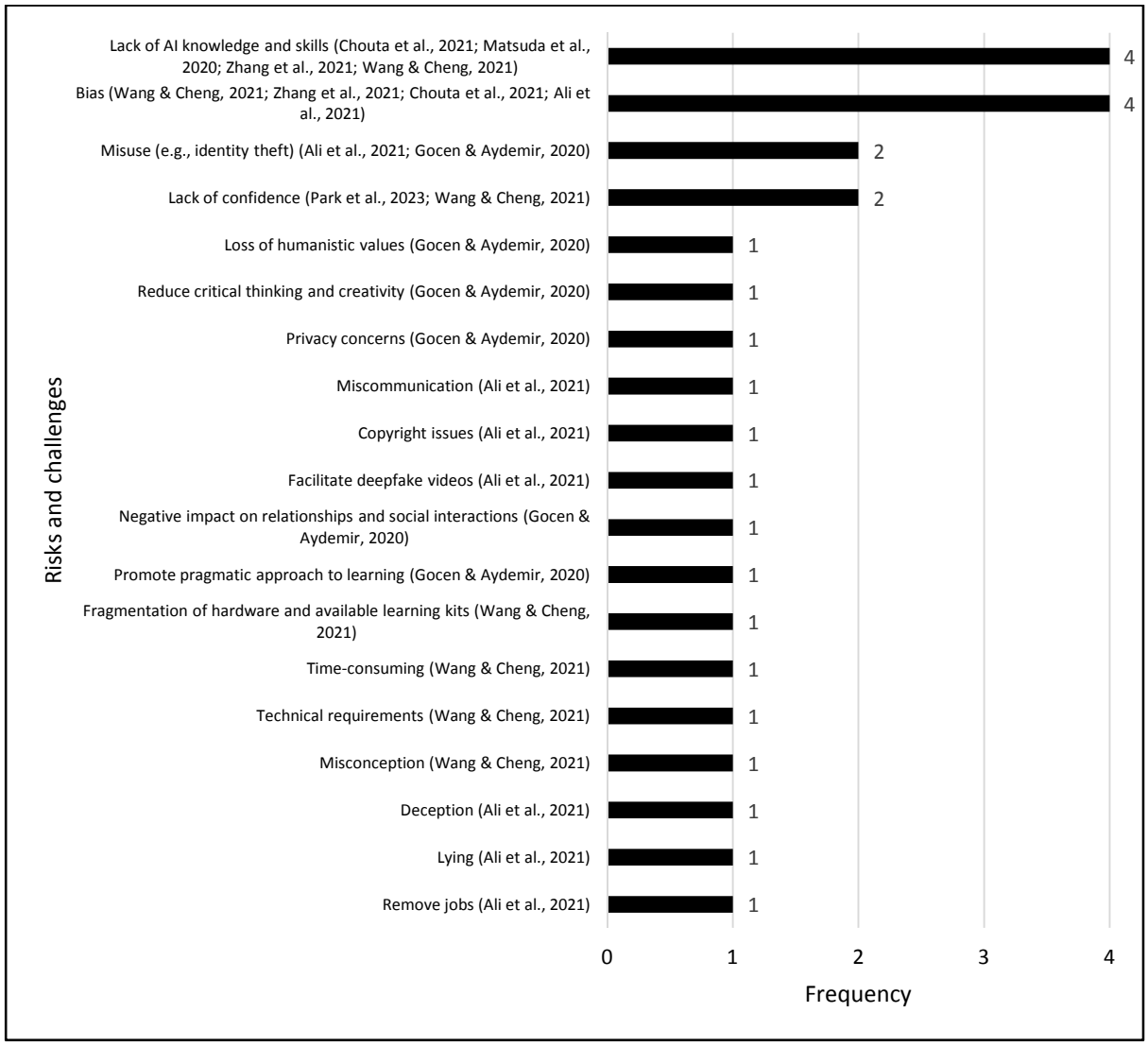


Risks and challenges to the integration of AIED

Rapid AI growth in education promises a paradigm change that could improve learning outcomes and operational efficiency. However, various studies have identified how infrastructural, ethical, and pedagogical constraints have made AI incorporation into education difficult (see Figure 4). While several of these studies predate the arrival of ChatGPT, they demonstrate that research on AI integration in the education sector has developed over time. The studies from Gocen and Aydemir (2020), Wang and Cheng (2021), Zhang et al. (2021), Chounta et al. (2022), Matsuda et al. (2020) and Ali et al. (2021) remain relevant as they address foundational aspects of AI integration, including challenges related to teacher readiness, ethical considerations, and infrastructure. These concerns still apply to newer AI developments.

One significant concern is the potential loss of humanistic values in education. Gocen and Aydemir (2020) found that extensive use of AI in Turkey could lead to a mechanistic approach to processing information, potentially reducing the emphasis on critical thinking and creativity in education. Mechanical thinking encouraged by AI might also suppress intuitive knowledge and replace humanistic values with a utilitarian perspective. Gocen and Aydemir highlighted the ethical dilemmas and security risks associated with using AIED, such as data privacy concerns and the potential misuse of AI technologies. They also referred to the potential negative social effects that could arise from the widespread adoption of AIED, including impacts on interpersonal relationships and social interactions among students. Further noted, were the apprehensions that AI integration might promote a pragmatic approach to learning, focusing more on knowledge acquisition rather than fostering holistic development and critical thinking skills among students.

Figure 4
Risks and challenges associated with AI integration in education



The practical implementation of AIED is also fraught with logistical challenges. Wang and Cheng (2021) found that the significant barriers hindering the incorporation of AI in Hong Kong K-12 schools are complex. The authors found that schools may hesitate to invest in AI adoption in education due to the fragmentation of hardware and available learning kits. Wang and Cheng further illustrated that teachers' perceptions of AI systems being time-consuming and complicated, coupled with biased attitudes towards AI replacing human interaction hindering the incorporation of AIED in schools. Misconceptions about AI, technical requirements, and the need for a comprehensive understanding of AI contribute to teachers' lack of confidence in implementing AIED practices. Zhang et al. (2021) and Chounta et al. (2022) also found that issues such as biased teacher attitudes, incomplete understanding of AI, and difficulty locating and preparing learning materials hinder AI integration in China and Estonia, respectively. In Singapore, Park et al. (2023) noted that a lack of confidence in content mastery and technology requirements further complicates the integration of AI in teaching and learning. As pointed out by Matsuda et al. (2020), limited technological

capabilities exacerbate these challenges, making it essential to provide adequate training and resources to educators.

Moreover, ethical issues such as deception, lying, and the potential for AI to replace jobs are significant challenges. Ali et al. (2021) found that AI can facilitate deepfake videos, identity theft, and bias in Egypt, all undermining trust in educational technologies. Miscommunication and copyright issues add to these ethical concerns, necessitating a robust framework to manage the ethical use of AIED. Ethical issues, practical implementation barriers, and the potential loss of humanistic values must be carefully managed to ensure AI enhances rather than hinders educational outcomes.

Discussion

This section examines how evidence from the sourced literature addresses questions and concerns related to the application of AI in the South African context.

RQ1: What are the implications of using AI in South African schools?

Access

AI technologies support disadvantaged students by offering personalised learning experiences and tailored feedback, addressing diverse proficiency levels and promoting inclusivity (Hwang et al., 2020; Meyer et al., 2024). AI tools also aid students with disabilities and multilingual students through advanced speech recognition, fostering an inclusive environment (El Naggar et al., 2024; Yang, 2022). The DBE's campaigns in South Africa target special needs and gender disparities, promoting mother-tongue instruction (DBE, 2024). However, socio-economic disparities impact access to technology and high-speed internet, especially in rural areas, posing challenges for AI implementation (Mannuru et al., 2023). To address these, the DBE is committed to improving infrastructure and resource allocation while enhancing digital literacy among students and teachers (DBE, 2024).

Integrating AI in South African education must address the digital divide to ensure equitable learner access. With increasing global AI adoption, the digital divide continues to widen. Socio-economic inequalities impact access to technology and high-speed internet, especially in rural areas, posing implementation challenges (Mannuru et al., 2023). The DBE is committed to improving infrastructure and resources (DBE, 2024), but digital literacy gaps among students and teachers persist, necessitating targeted initiatives; and, financial constraints in under-resourced schools highlight the need for targeted funding (Mannuru et al., 2023).

Quality

AI could transform curriculum and teaching practices by delivering personalised content and enhancing literacy and numeracy. Additionally, AI tools provide instant feedback, helping teachers refine strategies and improve instructional quality, which is not possible in South Africa due to large class sizes (Hwang et al., 2020). These tools support linguistic

development and offer innovative solutions for classroom productivity (Lim et al., 2023). Moreover, teacher support through professional development is crucial for effective AI integration because it reduces administrative burdens and optimises teacher roles (Kim & Kwon, 2023). To support this integration, the DBE aims to provide essential resources, including technology, to improve subject-specific learning outcomes (DBE, 2024). AI-empowered learning could also foster critical thinking and personalised learning, thereby enhancing student engagement and outcomes (Ouyang & Jiao, 2021).

Support

South African teachers need comprehensive training and support to effectively use AI in the classroom (Lee, G. G. et al., 2024; Lin et al., 2022). Developing AI literacy and competencies is essential, encompassing critical analysis, engagement with AI tools, and understanding AI applications and ethics (Su, 2024). Professional development programmes should focus on practical applications and align with classroom realities (Tammets & Ley, 2023).

Socio-economic concerns

AI adoption in education can significantly impact the South African economy by preparing students for an AI-driven labour market, enhancing employability, and reducing unemployment (Kim & Kwon, 2023). Additionally, AI can help bridge socio-economic gaps by providing quality education to disadvantaged students and addressing the digital divide (Mannuru et al., 2023). AI offers innovative solutions to educational challenges in rural and under-resourced areas, contributing to regional economic development (Mannuru et al., 2023). Furthermore, AI promotes student innovation and entrepreneurship, which drives economic growth (Cope et al., 2021).

RQ2: How could AI be used to support special needs education?

Access

AI technologies can significantly enhance access to education for students with special needs in South Africa. There is a growing movement towards mainstreaming South African learners with special needs, integrating them into regular educational settings alongside their peers. AI can facilitate this process by providing personalised learning tools and adaptive resources that accommodate diverse learning styles and needs, making education more accessible and effective for all students. Garg and Sharma (2020) identified using robotics, mobile apps, and speech recognition systems to diagnose and support various disabilities. These tools make education more accessible by helping to identify specific needs and offering ongoing support. AI-assisted devices also facilitate communication and skill development for individuals with cerebral palsy and learning disabilities, enabling students to communicate more effectively and develop necessary skills for their academic and personal growth (Ojha, 2022). The DBE's initiatives to promote inclusivity and equity are essential in addressing the unique challenges faced by special needs students (DBE, 2024). Hence, the DBE must explore such opportunities to solve current access challenges.

Personalisation and supplementary technologies

AI can personalise the learning experience for special needs students by adapting educational content to their specific needs and abilities. AI-driven tools such as intelligent tutoring systems, AR content, and multi-sensory platforms can enhance learning outcomes for students with various disabilities, including autism, dyslexia, and cerebral palsy (Ahuja et al., 2022; Ojha, 2022; Yang, 2022). These tools provide tailored instruction that caters to special needs students' unique learning styles and paces, making education more accessible and effective (Harry, 2023).

Substituting technologies is necessary to ensure that disabled students benefit fully from AI. These include AI-driven assistive devices that facilitate communication and skill development, robotics for interactive learning, and mobile apps designed to support various disabilities (Garg & Sharma, 2020; Ojha, 2022). Additionally, integrating AR and virtual reality technologies can provide immersive learning experiences that are both engaging and educational for special needs students (Ahuja et al., 2022). Ensuring access to these technologies requires targeted investments in infrastructure and resources, particularly in under-resourced areas (DBE, 2024).

RQ3: Which AI competencies do teachers need to integrate AIED successfully?

Skills

Kim and Kwon (2023) argued that the COVID-19 pandemic has accelerated technology integration in the education sector, contributing to the increased adoption of AI tools in K-12 education. This adoption has forced educators to adapt their teaching methods. Accordingly, educators require comprehensive technical and pedagogical skills to integrate AI effectively into their teaching practices. Educators need to be proficient in using various AI tools and technologies such as machine learning applications, data analysis software, and educational platforms powered by AI (Lee, G. G. et al., 2024; Lin et al., 2022). They must understand the principles of AI and machine learning to develop and implement AI-based curricula and interpret AI-driven insights to enhance student-learning outcomes. Pedagogically, educators need to be skilled in designing and delivering content that incorporates AI tools, ensuring these tools align with students' educational objectives and developmental stages (Kim & Kwon, 2023).

Given the integration of hybrid education, educators must also be aware of how AI integration happens in the home environment and how learners experiment with new technologies (Kim & Kwon, 2023). This includes creating engaging, interactive learning experiences that leverage AI capabilities to personalise instruction and assessment. Educators should incorporate professional development focused on AI competencies to adapt their current teaching practices. This can include training sessions, workshops, and collaborative learning communities where teachers can share best practices and experiences.

It was also found that digital literacy levels among educators and their confidence in employing such tools had a bearing on their ability to implement and adopt AI. Therefore,

digital literacy is a foundational concern that must be developed (Lin et al., 2022; Park et al., 2023; Wang & Cheng, 2021). Educators should also integrate AI tools gradually, starting with simpler applications and progressively incorporating more complex AI-driven solutions. Thus, learning should be organised in accordance with real-world scenarios and student development stages (Kim & Kwon, 2023; Tammets & Ley, 2023).

Continuous reflection and feedback mechanisms should be established to assess the effectiveness of AI integration and make necessary adjustments. Educators need to demonstrate sensitivity to AI's social impact while being aware of the ethical dimension associated with its usage (Ali et al., 2021; Gocen & Aydemir, 2020). Additionally, educators should foster a classroom environment that encourages experimentation and flexibility, allowing teachers and students to explore and adapt to new AI technologies dynamically.

Ethical considerations in AI education relating to bias and privacy

Educators must also address ethical concerns about bias and privacy when using AI in the classroom. Training should include a strong focus on AI ethics, raising awareness about the implications of AI applications in teaching and ensuring responsible usage (Kim & Kwon, 2023). Teachers need to understand how AI systems can perpetuate biases if not adequately managed, and they should be equipped to critically evaluate and mitigate these biases to ensure fair and equitable learning environments (Ali et al., 2021). Privacy is another critical concern (Gocen & Aydemir, 2020). Educators should be trained on data protection and privacy laws to safeguard sensitive student information. This includes understanding the ethical collection and use of data, obtaining informed consent from students and parents, and ensuring transparency in how AI systems process and utilise data (Kim & Kwon, 2023).

RQ4: What are the risks and challenges when integrating AIED?

Infrastructure

Limited resources, inadequate infrastructure, and connectivity issues significantly impede access to AI-related opportunities and influence the quality of teaching instruction in South Africa. Budget constraints and the lack of appropriate hardware hinder the acquisition of essential technological tools necessary for AI implementation (Wang & Cheng, 2021). High-speed internet connections and advanced computing capabilities are critical for utilising AI systems effectively; however, many schools, especially in under-resourced and rural areas, lack these fundamental infrastructure elements (Ali, 2020; Park et al., 2023). This disparity results in uneven access to AI technologies, widening the educational divide between well-resourced urban schools and under-resourced rural ones, thereby limiting AI's potential to enhance educational outcomes across the country (Mannuru et al., 2023).

Data security and privacy concerns are also critical barriers. Schools need robust safeguarding measures to protect sensitive student information because data security vulnerabilities could expose student data and breach trust, leading to reluctance to adopt AI technologies (Gocen & Aydemir, 2020; Wang & Cheng, 2021). Additionally, the under-user-friendliness of AI systems can render these technologies difficult for teachers and students to

use effectively, particularly in areas with varying levels of technological proficiency (Wang & Cheng, 2021). These infrastructural challenges must be addressed through strategic investments and policies to ensure equitable access to AI-related opportunities and improve the overall quality of teaching instruction (DBE, 2024).

Culture

The education system in South Africa must address resistance to AI adoption and potential scepticism among educators and stakeholders. Teacher attitudes towards AI, often stemming from a fear of redundancy and a lack of understanding of AI technologies, can prevent the effective use and acceptance of these tools in classrooms (Wang & Cheng, 2021; Zhang et al., 2021). Resistance is further compounded by a lack of comprehensive understanding of AI's educational benefits and practical applications, leading to suboptimal usage and hindering AI integration (Park et al., 2023). Linguistic barriers present another cultural challenge given that AI technologies may not adequately support the diverse languages spoken in South African educational settings. This limitation can restrict the usability and effectiveness of AI tools, thereby hampering adoption and integration (Chounta et al., 2022).

Ethical and social implications

Integrating AI into education in South Africa could raise ethical and social concerns, potentially impeding access to AI opportunities and impacting teaching quality. Gocen and Aydemir (2020) warned that AI might foster a mechanical mindset, eroding humanistic values and intuition in learning, which could undermine holistic student development and clash with South Africa's diverse cultural values. Additionally, AI reliance could reduce face-to-face interactions and collaborative learning, harming social dynamics. Practical issues like time constraints, miscommunication, and bias, highlighted by Wang and Cheng (2021) and Ali et al. (2021), further complicate AI integration, risking misunderstandings and perpetuating social inequalities.

Conclusion

This paper contributes to understanding potential AI integration in South African education by employing a scoping review (Arksey & O'Malley, 2005) guided by Bloom's (1984) model of personalised instruction.

AI can enhance personalised learning and inclusivity by providing diverse educational experiences. In classrooms suffering from instructional quality deficits, AI integration can supplement weaknesses in the system. Additionally, AI can significantly support special needs education by adapting learning materials to the unique requirements of students with disabilities. Thirdly, teachers require technical skills and a comprehensive understanding of AI ethics to integrate AI into education successfully. Lastly, findings revealed that the digital divide, privacy concerns, and potential resistance from educators could hinder the integration of AI in schools.

Limited studies on AIED were conducted in South Africa. Therefore, we relied on international sources that may not reflect the country's socio-economic and cultural characteristics. Methodologically, the narrow scope of databases searched might cause selection bias, and the scoping review methodology limits the depth of evidence assessment. Future research should include more diverse sources, and use systematic reviews to analyse AI's impact on South African education comprehensively.

We recommend that policymakers in South Africa prioritise developing and implementing a comprehensive digital literacy and AI competency framework for teachers. This initiative should include continuous professional development opportunities that equip educators with the necessary skills to use AI in the classroom effectively. Additionally, policies should aim to increase investments in technological infrastructure to address the digital divide. Finally, policymakers must establish robust data protection measures and AI usage guidelines to safeguard student privacy. South Africa can fully embrace the transformative ability of AI to improve educational equity and quality by implementing these recommendations and overcoming the mentioned limitations. This will pave the way for a more inclusive and innovative future in education.

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