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Leveraging Artificial Intelligence for personalised Mathematics Education: Applications in Teaching, Research, and Community Engagement in South African Secondary Schools

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ABSTRACT

This study examined the transformative impact of artificial intelligence (AI) on mathematics education, with a specific focus on its applications in teaching, research, and community engagement. Grounded in Constructivist Learning Theory, the study adopted a qualitative case study design involving three (3) secondary schools in the Eastern Cape. The participants included six mathematics teachers and six Grade 11 learners from each school, offering diverse perspectives on the integration of AI in education. The findings revealed that AI has the potential to personalise learning by adapting to individual learner needs, thereby improving conceptual understanding and learner engagement. Furthermore, AI enhances mathematical modelling by enabling learners to simulate complex real-world problems and engage with abstract concepts in meaningful ways. It also broadens access to digital resources, offering learners exposure to global educational opportunities. Despite these benefits, the study identified significant barriers, including poor infrastructure, unreliable internet connectivity, and the limited availability of offline AI-enabled tools, particularly in rural settings. Teachers' inadequate training further constrains effective integration, while community engagement efforts are hindered by limited awareness and scepticism toward AI. The study recommends developing offline AI tools and providing continuous professional development for teachers, with support from the Department of Basic Education. The study contributes to scholarship by providing a contextual, school-based account of how AI can be used equitably in under-resourced mathematics classrooms.

Keywords: Artificial Intelligence, Community engagement, Research, Personalised, Mathematics Education.

INTRODUCTION

Recent studies affirm that the rapid evolution of Artificial Intelligence (AI) has brought about significant changes across sectors, with education among the most affected.[1] AI reshapes conventional instructional

[1] Uma Yadav and Urmila Shrawankar, "Artificial Intelligence across Industries: A Comprehensive Review with a Focus on Education," *AI Applications and Strategies in Teacher Education*, 2025, 275–320.

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strategies in tertiary education by supporting more flexible, effective, and data-responsive teaching methodologies. According to recent studies, the structured, sequential nature of mathematics provides a robust foundation for implementing AI-based tools and systems.[2] These technologies facilitate personalised learning experiences by continuously identifying individual learning patterns, adapting content delivery accordingly, and offering real-time feedback, addressing persistent issues such as learner disengagement, conceptual gaps, and unequal achievement levels.

AI's influence in mathematics education extends beyond classroom differentiation, contributing meaningfully to institutional mandates for research and outreach.[3] In the academic environment, AI is used for advanced data processing, trend forecasting, and automating complex analytical procedures, enabling scholars to investigate novel dimensions of mathematics and pedagogy.[4] In parallel, AI technologies have enhanced universities' capacity to design community-focused programs that address the educational challenges faced by underserved populations, particularly those lacking access to quality mathematics education.[5]

The Fourth Industrial Revolution (4IR), characterised by convergence in AI, data analytics, machine learning, and IoT, necessitates a fundamental rethinking of how higher education equips students with essential quantitative and digital proficiencies relevant to today's job market. Institutions are increasingly expected to adapt learning pathways to enhance equity, redesign curricula, and promote research-led teaching practices.[6] This research critically explores how AI is being applied to personalise mathematics learning in higher education, with particular emphasis on its contributions to instruction, academic scholarship, and societal engagement.[7] By evaluating emerging practices and technologies, the study aims to demonstrate how AI can improve academic performance, support research innovation, and strengthen institutional links with local communities. The integration of AI in mathematics education is thus not merely a technical development but a strategic necessity for ensuring relevance, quality, and inclusiveness in 21st-century higher learning.

Although South Africa has witnessed notable technological progress and growing access to digital tools, substantial obstacles persist within mathematics education. These include underperformance among learners, limited professional development opportunities for educators, and pronounced resource inequalities between urban and rural schools. These enduring challenges have resulted in consistently low mathematics outcomes in national and international evaluations, restricting learners' access to science, technology, engineering, and mathematics (STEM) pathways and broader socioeconomic advancement.[8] Artificial Intelligence (AI) offers a potentially transformative approach to these issues by enabling customised learning experiences, generating data-informed feedback, and supporting adaptive instruction.

As highlighted, AI technologies such as intelligent tutoring systems and predictive analytics can support early interventions and create individualised learning routes tailored to diverse learner needs.[9] Additionally, AI can enhance teaching by automating assessment, generating instructional materials, and offering ongoing professional development content to support instructional improvement. However, despite these potentials, the application of AI in South African mathematics classrooms, particularly in

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[2] Emmanuel Nti-Asante, "Engaging Students in Making Artificial Intelligence Tools for Mathematics Education: An Iterative Design Approach," *Journal of Mathematics Education* 17, no. 1 (2024): 16–37.

[3] Doris Chasokela, "Harnessing Artificial Intelligence: Transformative Technologies in Contemporary Higher Education," *Journal of Computers for Science and Mathematics Learning* 2, no. 1 (February 10, 2025): 26–37, https://doi.org/10.70232/jcsml.v2i1.15.

[4] Khanssa Mohammed Elam, "Exploring the Challenges and Future Directions of Big Data and AI in Education," *Journal of Artificial Intelligence General Science (JAIGS) ISSN:3006-4023* 1, no. 1 (June 18, 2024): 81–93, https://doi.org/10.60087/jaigs.v1i1.173.

[5] Anil Kumar Chikatimarla and T Naga Prasada Rao, "AI in Rural Development: A Study on the Monitoring and Impact Evaluation of AI Initiatives," in *Seminar Proceedings*, 2024.

[6] Joshua Kim and Edward J Maloney, *Learning Innovation and the Future of Higher Education* (JHU Press, 2020).

[7] Bharath Kumar Nagaraj et al., "The Emerging Role of Artificial Intelligence in STEM Higher Education: A Critical Review," *International Research Journal of Multidisciplinary Technovation*, August 14, 2023, 1–19, https://doi.org/10.54392/irjmt2351.

[8] Fatma Kayan-Fadlelmula et al., "A Systematic Review of STEM Education Research in the GCC Countries: Trends, Gaps and Barriers," *International Journal of STEM Education* 9, no. 1 (2022): 2.

[9] Olga Tapalova and Nadezhda Zhiyenbayeva, "Artificial Intelligence in Education: AIEd for Personalised Learning Pathways.," *Electronic Journal of E-Learning* 20, no. 5 (2022): 639–53.

underserved communities, remains underexplored.[10] There is a scarcity of empirical research investigating how AI can be contextually adapted to align with the linguistic diversity, socio-cultural realities, and infrastructural limitations of local educational environments.

The importance of critically examining AI implementation's ethical, educational, and societal dimensions to prevent reinforcing existing disparities.[11] Therefore, it is imperative to study how AI can be applied equitably and effectively to personalise mathematics education in South Africa.[12] This includes its use in classroom teaching, educational research, and outreach initiatives. Such inquiry is essential for crafting inclusive, culturally responsive AI strategies that enhance learner achievement, empower educators, and foster meaningful community participation in educational transformation. The study seeks to find answers to these research questions:

- What are mathematics teachers' current practices and perceptions regarding using AI tools to personalise instruction in South African schools?
- What role does Artificial Intelligence play in supporting data-driven research on learner performance and engagement in mathematics education?
- How can AI tools strengthen school-community partnerships to improve mathematics education outcomes?
- What community-based challenges affect the integration of AI technologies in under-resourced or rural South African schools?

LITERATURE REVIEW

The rapid progression of AI has significantly impacted all facets of higher education, including curriculum delivery, academic research, and community-focused educational initiatives. The findings underscored that Mathematics, often characterised by abstract concepts and individualised learning trajectories, might significantly benefit from the personalisation opportunities offered by AI.[13] This literature review analyses the various applications of AI in personalised mathematics education inside secondary schools, focusing on three main pillars: instruction, research, and community engagement.

AI in Personalised Mathematics Teaching

Studies have identified adaptive learning as one of the most impactful uses of Artificial Intelligence (AI) in education, particularly because it can adjust learning materials in real time based on individual learner progress and preferences.[14] The research demonstrated that platforms such as Learning and Squirrel AI apply machine learning techniques to generate customised learning experiences that align with each student's unique mathematical strengths and areas needing improvement.[15] Intelligent Teaching Support Systems (ITSS) are designed to simulate the interactive features of one-on-one tutoring by offering progressive feedback, guidance, and formative assessments. Evidence suggests that Intelligent Tutoring Systems such as ASSISTments and MATHia significantly enhance student comprehension, especially in advanced mathematical areas, including algebra and calculus.[16] These tools use natural language processing and Bayesian models to track learners' problem-solving methods and adapt instructional content accordingly. Furthermore, AI enables the collection and interpretation of extensive educational datasets through learning analytics, allowing educators to track academic development and forecast

[10] B. C. Agbata et al., "Everyday Uses of Mathematics and the Roles of a Mathematics Teacher," *Science World Journal* 19, no. 3 (2024): 819–27.

[11] S. Ramnani, "Exploring Ethical Considerations of Artificial Intelligence in Educational Settings: An Examination of Bias, Privacy, and Accountability," *International Journal of Novel Research and Development* 9, no. 2 (2024): b173–91.

[12] Felix Oromena Egara and Mogege Mosimege, "Exploring the Integration of Artificial Intelligence-Based ChatGPT into Mathematics Instruction: Perceptions, Challenges, and Implications for Educators," *Education Sciences* 14, no. 7 (July 6, 2024): 742, https://doi.org/10.3390/educsci14070742.

[13] Vijeta Iyer and J Dhivya, "From Numbers to Narratives: Weaving Stories into Learning Mathematics for 21st Century," *Transforming Education for the 21st Century-Innovative Teaching Approaches*, 2024, 84.

[14] Nurulhayah Muhamad et al., "Teachers' Pedagogical Approaches, Motivation, and Time Management as Determinants of Mathematics Achievement among Malaysian Secondary School Students," *International Journal of Research and Innovation in Social Science* 9, no. 10 (November 15, 2025): 5543–58, https://doi.org/10.47772/IJRISS.2025.910000454.

[15] Sourabh Rajput, "AI-Powered Distance Estimation for Autonomous Systems: A Monocular Vision Approach," 2024.

[16] Taekwon Son, "Intelligent Tutoring Systems in Mathematics Education: A Systematic Literature Review Using the Substitution, Augmentation, Modification, Redefinition Model," *Computers* 13, no. 10 (2024): 270.

performance outcomes. It was highlighted that predictive AI systems can identify students at risk of underperforming in mathematics courses early in the academic term, supporting timely instructional or advisory interventions to improve success rates.[17]

AI in Mathematics Education Research

AI has significantly reshaped research practices in mathematics education by automating tasks such as qualitative data analysis, pattern recognition across large datasets, and the creation of simulated learning environments.[18] Tools powered by Natural Language Processing (NLP) have been employed to interpret spoken interactions in mathematics classrooms. Several studies revealed that neural network systems are being applied to anticipate learners' emotional and cognitive responses throughout the instructional process.[19] Integrating big data with AI has contributed to educational research by supporting advanced statistical approaches and deep learning techniques.[20] These technological innovations have enabled scholars in mathematics education to explore areas such as students' problem-solving behaviour, the development of conceptual knowledge, and learning trajectories over time. AI-enhanced tools, including text mining and automated meta-analysis systems, facilitate the organisation and evaluation of vast scholarly work.[21] This streamlines access to information and supports researchers in managing the exponential growth of academic literature in the field.

AI in Community Engagement and Outreach

AI is increasingly pivotal in reshaping how institutions engage with communities, especially across education, public health, environmental advocacy, and social development sectors. In higher education and non-governmental organisations, AI-enabled systems support the identification of community priorities by processing extensive datasets, including population statistics, online discourse, and participant feedback. This analytical capacity enhances the development of responsive and targeted interventions.[22] AI-powered chat interfaces and natural language processing (NLP) frameworks facilitate meaningful exchanges between institutions and the public by delivering timely answers to questions, circulating essential updates, and enabling greater inclusion in planning and policy discussions.[23] Moreover, predictive modelling enables organisations to anticipate community risks, identify vulnerable groups, and make informed decisions about resource allocation.

In marginalised or rural settings, AI-based innovations have been applied to bridge service gaps, for instance, through mobile apps designed for agricultural guidance, health awareness, and foundational literacy.[24] However, the impact of these technologies is influenced by several critical factors, including ethical deployment, sensitivity to cultural and local contexts, user digital competence, and fair access to digital infrastructure. Consequently, while AI offers vast potential to advance community engagement through data-informed strategies, its success depends on participatory design and active collaboration with local stakeholders to ensure contextual appropriateness and long-term viability.

Challenges and Ethical Considerations

Although AI offers transformative educational opportunities, many challenges hinder its effective integration. Key issues include safeguarding learners' data, ensuring the transparency and comprehensibility of AI-generated outputs, addressing potential algorithmic discrimination, and

[17] Mohammad Rashedul Hasan and Bilal Khan, "An AI-Based Intervention for Improving Undergraduate STEM Learning," *PLOS ONE* 18, no. 7 (July 19, 2023): e0288844, https://doi.org/10.1371/journal.pone.0288844.

[18] Gwo-Jen Hwang and Yun-Fang Tu, "Roles and Research Trends of Artificial Intelligence in Mathematics Education: A Bibliometric Mapping Analysis and Systematic Review," *Mathematics* 9, no. 6 (March 10, 2021): 584, https://doi.org/10.3390/math9060584.

[19] Vinıcius Botelho, "Equilibrium Effects of Higher Education Subsidies to Public Schools," 2024.

[20] Nitin Rane, Saurabh Choudhary, and Jayesh Rane, *Contribution of ChatGPT and Similar Generative Artificial Intelligence for Enhanced Climate Change Mitigation Strategies* (SSRN 4681720 , 2024).

[21] Svajune İstikbal, "The Effects of Digital Tools on the Development of English Language Skills: Meta-Analysis" (Maltepe University (Turkey), 2024).

[22] Irene Solaiman et al., "Evaluating the Social Impact of Generative AI Systems in Systems and Society," *ArXiv Preprint ArXiv:2306.05949*, 2023.

[23] Roberto Martinez-Maldonado, "Human-Centred Learning Analytics: Four Challenges in Realising the Potential," *Learning Letters* 1 (2023): 6.

[24] Fengchun Miao and Wayne Holmes, "Artificial Intelligence and Education. Guidance for Policy-Makers," 2021.

preventing the over-reliance on machines that may reduce the human element in teaching and learning.[25] For AI to be used responsibly in educational settings, systems must strongly emphasise fairness, ethical use, and accountability. Educators, in particular, require comprehensive training to develop competence in understanding, applying, and evaluating AI tools in a pedagogically sound and ethically responsible manner.[26] According to Msomi and Mthethwa, their use in higher education, especially in mathematics teaching, is expected to expand significantly as AI capabilities evolve.[27] Future investigations may explore interpretable AI systems, emotional recognition technologies, and integrated learning analytics that draw on various data sources to support more tailored educational experiences. Equally important is the active collaboration between academic professionals, software developers, and policy decision-makers to ensure that AI tools enhance learning outcomes and align with societal values and educational goals.[28]

THEORETICAL FRAMEWORK

This research is grounded in Constructivist Learning Theory, which posits that learners cultivate their understanding of the world through experiences and subsequent reflection. [29] In AI-enhanced mathematics education, AI tools such as intelligent tutoring systems (ITS), adaptive learning platforms, and machine learning algorithms foster environments where learners actively engage with tailored information, receive quick feedback and augment their existing knowledge.

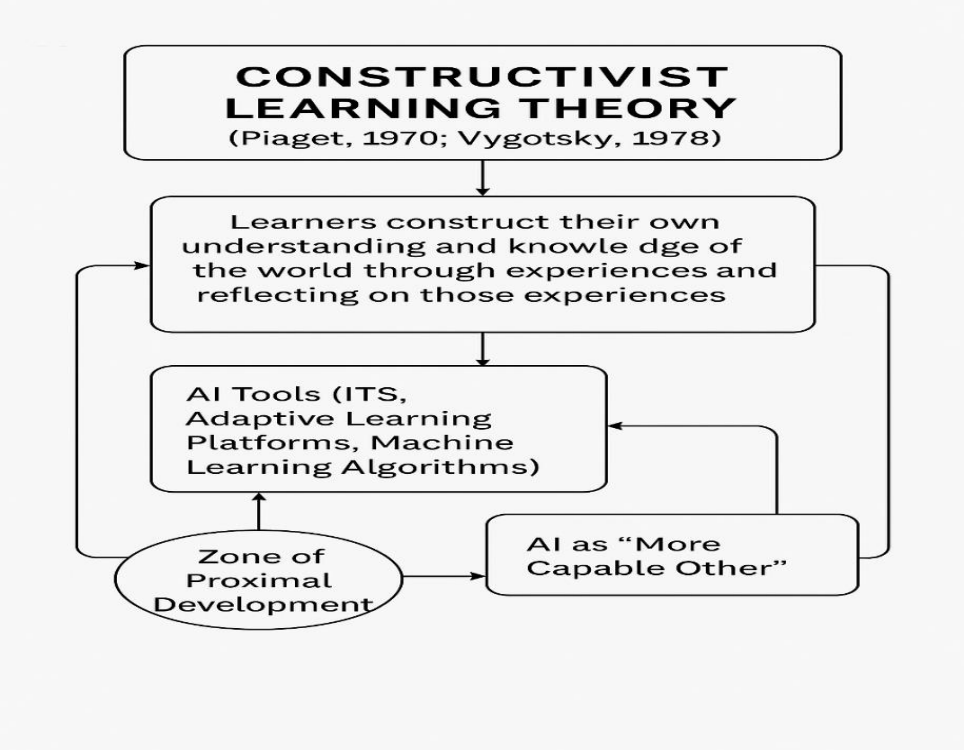

Figure 1: Constructivist Learning Theory

[25] Ben Williamson and Rebecca Eynon, "Historical Threads, Missing Links, and Future Directions in AI in Education," *Learning, Media and Technology* (Taylor & Francis, 2020).

[26] Olaf Zawacki-Richter et al., "Systematic Review of Research on Artificial Intelligence Applications in Higher Education – Where Are the Educators?," *International Journal of Educational Technology in Higher Education* 16, no. 1 (December 28, 2019): 39, https://doi.org/10.1186/s41239-019-0171-0.

[27] Alfred Mvunyelwa Msomi and Themba Mngomeni Mthethwa, "Artificial Intelligence in Higher Education Mathematics: A Systematic Review of Trends, Benefits, and Challenges," in *The Focus Conference (TFC 2024)* (Atlantis Press, 2024), 88–118.

[28] Krishna Chaitanya Rao Kathala, Ivon Arroyo, and Nishith Reddy Mannuru, "Role of Ethical and Responsible AI in Education for Next Generation Inventors," in *International Conference on Artificial Intelligence in Education* (Springer, 2024), 71–78.

[29] Eleanor Duckworth, "Piaget Rediscovered," *The Arithmetic Teacher* 11, no. 7 (1964): 496–99.

The Constructivist Learning Theory emphasises that learners actively construct knowledge through experiential engagement and reflective thought rather than passively receiving it.[30] Rooted in Piaget's theory of cognitive development and Vygotsky's sociocultural perspective, this approach views learning as a dynamic, interpretive process in which individuals build on existing knowledge frameworks through continuous interaction with their surroundings. According to Piaget, cognitive development unfolds through two central processes: assimilation, in which new information is integrated into existing mental models, and accommodation, in which these models are adjusted to incorporate novel experiences. This underscores the importance of active participation and exploration in learning contexts.

Vygotsky, on the other hand, highlights the role of culture and social engagement in learning. He introduces the concept of the Zone of Proximal Development (ZPD), which describes the range of tasks learners can achieve with guidance from more capable peers or mentors. These theoretical foundations are increasingly relevant in today's educational landscape, particularly with the emergence of Artificial Intelligence (AI) tools that complement constructivist principles. Govender suggests that AI applications can significantly support personalised and exploratory learning in mathematics education.[31]

Modern AI-powered technologies, such as adaptive learning platforms, Intelligent Tutoring Systems (ITS), and data-driven learning analytics, facilitate customised educational experiences that resonate with constructivist pedagogy.[32] These technologies enable learners to interact with content in personally meaningful ways, fostering deeper understanding as they progress. For example, adaptive systems continuously monitor learner performance and adjust the level and type of content, ensuring that tasks remain suitably challenging and within the learner's ZPD.[33] This flexibility supports the gradual advancement from foundational to more complex mathematical ideas.

In addition, intelligent tutoring platforms provide immediate, tailored feedback, encouraging learners to reflect on their thinking, revise strategies, and deepen their conceptual understanding, a process central to metacognitive development and reflective learning.[34] Gunawardena et al. noted that AI promotes collaborative learning through virtual environments that simulate peer interaction and cooperative problem-solving, echoing Vygotsky's emphasis on shared knowledge construction.[35] Furthermore, AI-based learning analytics provide educators with real-time insights into students' learning trajectories, difficulties, and emotional engagement, informing timely, responsive pedagogical interventions.[36] These tools reinforce formative learning by providing continuous feedback and facilitating scaffolded instruction aligned with constructivist ideals.

METHODOLOGY

Research Approach

This study adopted a qualitative interpretivist approach to explore how mathematics teachers and Grade 11 learners understood and experienced the use of AI tools for personalised mathematics education in South African secondary schools. The interpretive stance recognises that knowledge is not objective but constructed through interaction, discourse, and context-specific understanding. The approach was appropriate because the study focused on participants' meanings, perceptions, practices, and contextual

[30] Jean Piaget, "Inteligencia y Adaptación Biológica," *Los Procesos de Adaptación* 1, no. 1 (1970): 69–84; Lev S Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*, vol. 86. (Harvard University Press, 1978).

[31] Rajendran Govender, "A Reflection on the Use of Artificial Intelligence Tools for the Meaningful Learning of Mathematics," *Pythagoras-Journal of the Association for Mathematics Education of South Africa* (AOSIS, 2024).

[32] Muralidhar Kurni and Srinivasa KG, "Technology-Based Learning Experiences with IoT in Education," in *The Internet of Educational Things: Enhancing Students' Engagement and Learning Performance* (Springer, 2024), 113–33; L Vygotsky and M Cole, "Lev Vygotsky: Learning and Social Constructivism,"*Learning Theories for Early Years Practice. UK: SAGE Publications Inc*,2018,68–73.

[33] Minglong Li et al., "A Systematic Review of AI Technology-Based Service Encounters: Implications for Hospitality and Tourism Operations," *International Journal of Hospitality Management* 95 (2021): 102930.

[34] Didem Akyuz and Michelle Stephan, "Co-Teaching Practices That Build Autonomy for Students with Learning Disabilities in Mathematics," *International Journal of Mathematical Education in Science and Technology* 53, no. 4 (2022): 920–47.

[35] Komadamperuge Gunawardena, "Examining the Impact of Customer Digital Literacy and Artificial Intelligence Literacy on the Adoption of AI-Enabled Mobile Banking Services," 2025.

[36] Tarun Kumar Vashishth et al., "AI-Driven Learning Analytics for Personalized Feedback and Assessment in Higher Education," in *Using Traditional Design Methods to Enhance AI-Driven Decision Making* (IGI Global Scientific Publishing, 2024), 206–30.

challenges rather than on measuring the effect of a single AI intervention. Data collection methods, such as semi-structured interviews, were used to obtain detailed insights into participants' lived experiences. These methods facilitated access to in-depth views that would likely be inaccessible through quantitative inquiry, especially when dealing with context-specific educational practices and perceptions.

An interpretive qualitative methodology enabled flexibility in identifying emerging patterns and themes throughout the data analysis. This adaptability was essential for understanding how AI technologies influence the design and delivery of tailored mathematics instruction and engagement initiatives. The methodological choices ensured that the study produced credible and contextually meaningful findings.

Research Design

This research adopted a multiple-case study approach to explore the integration of AI technologies across different secondary schools, following Yin's guidance.[37] The three cases were secondary schools in the OR Tambo Inland District, Eastern Cape. Using multiple cases enabled the examination of schools' practices in authentic settings and the drawing of insights from varied contexts. This methodology enabled a comprehensive understanding by integrating multiple data sources, thereby enhancing the credibility and contextual richness of the findings.

This design was appropriate for examining situations in which the phenomenon under investigation is intertwined with the surrounding context, as is the case in everyday educational and organisational research.

Sampling Strategy

Purposive sampling was employed to select participants and schools involved in AI-driven mathematics education initiatives. The sample included six (6) mathematics teachers and six (6) Grade 11 learners, two from each of the secondary schools in the OR Tambo Inland District in South Africa. The sample size was considered adequate for a qualitative multiple-case study because it allowed detailed interviews, focus-group engagement, and cross-case comparison while keeping the dataset manageable for in-depth thematic analysis. Participants were required to have experience or understanding of AI applications in secondary school mathematics instruction.

Data Collection Methods

Data were collected through semi-structured teacher interviews and learner focus group discussions. The interview and focus-group guides explored current AI practices, perceived benefits, barriers to use, data and ethical concerns, school-based research possibilities, and community engagement. Teacher interviews were conducted in quiet rooms at the participating schools at agreed-upon times and lasted approximately 30 to 45 minutes. Learner focus group discussions lasted approximately 40 to 60 minutes. With permission, discussions were audio-recorded and supported by field notes. The chosen research paradigm plays a central role in shaping the data collection strategy, influencing the methods applied, the goals pursued, and the nature of the phenomena under examination. Semi-structured interviews offered structure and flexibility, allowing for consistent exploration of key themes while accommodating emergent topics. Participants were recruited through purposive sampling to ensure data were collected from individuals with direct, meaningful experience relevant to the investigation's focus.

Data Analysis

Thematic analysis is a widely used qualitative method that facilitates the discovery and interpretation of patterns in data. It is valued for its adaptability to complex, diverse qualitative datasets.[38] These authors outlined a six-phase process that guides researchers through systematically analysing qualitative data. A crucial initial step involved the accurate transcription of verbal data, such as interviews and focus group discussions, to ensure a deep understanding of the content. Once transcribed, meaningful data

[37] Robert K Yin, *Case Study Research and Applications*, vol. 6 (sage Thousand Oaks, CA, 2018).

[38] Ashley Castleberry and Amanda Nolen, "Thematic Analysis of Qualitative Research Data: Is It as Easy as It Sounds?," *Currents in Pharmacy Teaching and Learning* 10, no. 6 (June 2018): 807–15, https://doi.org/10.1016/j.cptl.2018.03.019.

segments were identified and labelled with concise codes that reflect their core ideas. These codes were then organised into candidate themes, allowing the researcher to explore their interconnections and meanings.

The refinement stage involved reviewing the themes to assess their internal consistency and alignment with the broader dataset. Each theme was clearly defined, named, and contextualised with respect to the central research problem. Presenting themes involved linking them to existing literature and supporting them with direct evidence from the data. To enhance the credibility and trustworthiness of the findings, techniques such as triangulation, member checking, and peer debriefing were applied. Thematic development in this study followed an inductive approach, ensuring that themes emerged organically from participants' lived experiences.

Ethical Considerations

The Department of Basic Education granted ethical clearance for the study. The research process was conducted in full compliance with established ethical principles regarding the protection of personal information. To preserve participant anonymity, all data were coded, and pseudonyms were assigned, with any identifying details removed to safeguard confidentiality. Information was securely stored on password-protected devices and backed up in encrypted digital storage systems accessible only to authorised research team members. The data collected were used solely for academic purposes, including analysis, scholarly reporting, and publication, in accordance with ethical research protocols. Furthermore, the study upheld all participants' respect, dignity, and autonomy. Measures were taken to ensure a culturally sensitive, inclusive, and non-coercive research environment. Participants were assured that their responses would not have adverse consequences and that the research posed no risk of physical, psychological, or reputational harm. These ethical safeguards contributed to the study's credibility, trustworthiness, and integrity.

PRESENTATION OF FINDINGS

Table 1: Empirical evidence supporting the findings. Source: Authors' synthesis from teacher and learner data.

Theme	Empirical pattern across participants	Interpretive meaning
Current AI use and readiness	Teachers reported uneven exposure to AI tools. Some had attempted to use AI-supported platforms, while others lacked training and infrastructure. Learners who had used AI tutors described them as useful for breaking down difficult problems.	AI adoption is emerging, but it remains dependent on teacher readiness, device access, and school support.
Pedagogical adaptation	Teachers described a shift toward more interactive, data-informed and learner-centred mathematics support when AI tools were available.	AI can support personalised instruction when teachers use learner performance data to guide explanations and practice tasks.
Challenges and ethical concerns	Teachers and learners identified poor connectivity, lack of devices, limited digital skills, generic feedback, and concerns about the storage of learner data.	Infrastructure and ethics are not peripheral issues; they shape whether AI improves equity or deepens existing inequalities.
Community engagement	Participants suggested local applications, such as modelling water use and transport routes, but reported weak collaboration among schools, the Department of Basic Education, and communities.	AI can connect mathematics with community problem-solving, but partnerships must be intentionally developed.

Analysis of Teacher Perspectives on AI in Mathematics Education: Current Teaching Practices and AI Integration

Teachers' Perspectives: Integrating AI into mathematics instruction is an emerging trend among university teachers.

A lecturer stated, "*I attempted to introduce my students to algebra lessons but was unsuccessful due to inadequate resources."* I have not employed an AI-driven learning management system due to my lack of experience integrating AI into my classes. This method personalises instruction by recommending practice problems based on individual performance. A participant remarked: *"...this enables the personalisation of content and pace for every student."* This signifies that shifting from standardised teaching approaches to a more tailored pedagogical approach facilitated by AI is difficult.

Student Perspective:

From the student's perspective, AI serves a supportive and adaptive function in the educational process: *"I have utilised an AI tutor embedded within our Learning Management System, which assists in deconstructing intricate problems."* It feels like having a constant assistant who understands my learning preferences. This illustrates the perceived worth of AI tools as accessible, personalised learning aids.

From the perspective of an EdTech specialist, AI researchers emphasised the increasing prominence of adaptive learning technologies, asserting*: "Adaptive learning platforms, intelligent tutoring systems, and AI-driven analytics dashboards can lead the way if teachers undergo Professional Development Programmes."* These tools enable real-time content modification based on learner behaviour, which is fundamental to personalised education.

Pedagogical Adaptations

Teacher perspective: The integration of AI is transforming teaching methodologies. A participant stated: *"It has redirected my emphasis from conventional lecture-based instruction to more interactive and adaptive methodologies."* This signifies a shift towards learner-centred methodologies. A teacher underscored the use of AI-generated data: *"I now employ data from AI tools to discern learning deficiencies and customise in-class discussions accordingly."* This exemplifies a data-driven instructional paradigm that adjusts responsively to student requirements.

Challenges in AI Adoption

Teacher Concerns: Notwithstanding the advantages, obstacles remain. A participant remarked: *"A significant challenge is the absence of support for training and infrastructure."* A digital equality issue exists: *"Not all students possess the same proficiency with digital tools, impacting the consistency of implementation."* This underscores differences in digital knowledge and access, which may impede the egalitarian implementation of AI technologies.

Reflections of Students: Students articulated apprehensions over the quality of feedback and data privacy: *"Occasionally, the feedback is overly generic or fails to elucidate the reasons for an incorrect answer with sufficient detail." "I am concerned about the extent of my learning data storage and its security."* These remarks emphasise the need for greater transparency, comprehensive AI solutions, and stringent data governance protocols.

Contribution to Sustainable Development Goals (SDGs)

Teacher Perspective: AI is considered an instrument for promoting SDG 4, Quality Education. An instructor observed*: "AI can enhance equity by delivering personalised education to underprivileged students, particularly in rural and marginalised areas."* This corresponds with initiatives to promote inclusive and equitable education.

Student Perspective: Pupils acknowledged AI's capacity to enhance accessibility: *"It could assist students in rural or remote regions lacking consistent access to instructors."* This reinforces the concept of AI as a conduit for bridging educational disparities.

Community Engagement Through AI in Mathematics

Teacher Perspective: AI can contextualise mathematics education by connecting it to community realities: *"AI can be utilised to create community-relevant learning modules, such as data analytics for local enterprises or environmental monitoring initiatives."* This indicates a pedagogical transition towards place-based, socially pertinent education.

Student Enthusiasm: Students are keen to implement AI in practical scenarios: *"Perhaps modelling water consumption in our municipality or optimising transportation routes through mathematical algorithms."* This indicates a significant potential for AI to link academic education with societal influence.

Teachers' View: Teachers indicated passive collaboration with the Department of Basic Education and communities: **"***There are minimal partnerships with the Department of Basic Education and communities to establish research programmes in which students co-create AI tools." "Collaboration with local communities to create AI applications to address educational or social issues was minimal."* These collaborations highlight the lack of community involvement in AI-enhanced education.

DISCUSSION

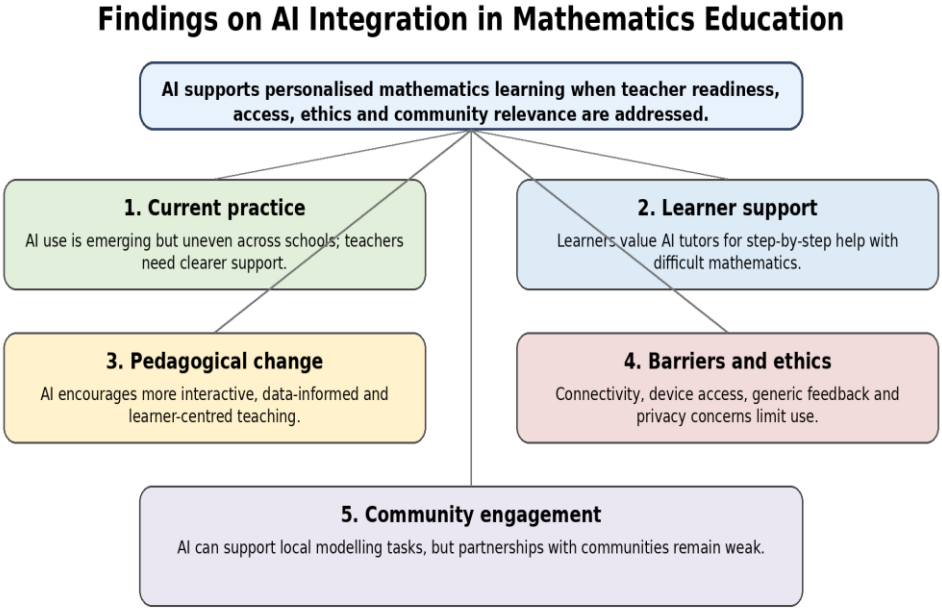

Figure 1: Findings on AI integration in mathematics education.
Source: Authors' own construct based on the thematic findings from teacher and learner data.

AI in mathematics education is an emerging trend, though unevenly adopted, among secondary school mathematics teachers. While numerous teachers acknowledge the potential of AI in education, others face significant limitations due to insufficient resources and a lack of competence.[39] A substantial deficiency in skills and resources for implementing AI technology in secondary school education has been identified. Goswami asserts that AI enables the shift from traditional, uniform teaching methods to more personalised, learner-focused educational approaches.[40] Findings indicate that transformation entails several challenges, including the complexity of adapting the curriculum to incorporate AI tools and the need for support at the school- and department-level. The findings indicated that while teachers

[39] Mohammed Alwaqdani, "Investigating Teachers' Perceptions of Artificial Intelligence Tools in Education: Potential and Difficulties," *Education and Information Technologies* 30, no. 3 (February 2, 2025): 2737–55, https://doi.org/10.1007/s10639-024-12903-9.
[40] Kangkan Goswami et al., "Machine Learning-Based Study of Open-Charm Hadrons in Proton-Proton Collisions at the Large Hadron Collider," *Physical Review D* 110, no. 3 (2024): 034017.

recognise the need for AI integration in personalised instruction, they often lack the technological and pedagogical support required for effective implementation.[41] Learners perceive AI as a valuable, adaptable tool that enhances their educational experience. Artificial intelligence is recognised for solving complex mathematical problems and providing ongoing assistance. This highlights the perceived worth of AI as an accessible, learner-centred support system, particularly in large classes or independent learning environments.[42] Teachers believe that incorporating AI facilitates a fundamental shift from traditional to interactive, data-driven educational methods.

These reflections demonstrate the evolution of pedagogy towards flexible, evidence-based techniques. Implementing AI is hindered by infrastructure and capacity constraints, despite its benefits. Moreover, digital inequality poses a substantial challenge, as not all children have equal access to or proficiency with digital tools. These disparities pose a risk of exacerbating educational imbalances if left unaddressed. Learners expressed concerns about the quality of AI-generated feedback and the privacy of their learning data. These concerns highlight AI systems' need to provide thorough, pedagogically sound feedback and adhere to rigorous data governance norms to ensure ethical use and cultivate learner trust.[43] Teachers and learners widely recognise Artificial Intelligence as a catalyst for advancing Sustainable Development Goal 4, Quality Education. Learners acknowledged AI's potential to assist learners in rural or remote regions with limited access to teachers. These perspectives affirm AI's ability to reduce educational disparities and enhance inclusiveness in line with the global development goals.[44] Both learners and teachers recognised AI's ability to contextualise mathematical instruction to meet community needs. These instances illustrate AI's capacity to connect scholarly knowledge with real-world societal applications. Despite its transformative potential, AI-enhanced education is impeded by inadequate collaboration with external partners. The lack of school-community integration hinders the joint development of significant, locally pertinent AI solutions and obstructs the potential for socially integrated education.

The findings show that teachers' use of AI in mathematics education is still developing, although they recognise its value in personalising practice tasks, explaining difficult concepts, identifying learner challenges, and supporting data-informed teaching. AI can help teachers analyse patterns in learner performance and engagement, but it should support rather than replace teacher judgement, classroom observation, learner explanations, and contextual knowledge. Participants also viewed AI as useful for connecting mathematics to community issues such as water use, transport routes, and local data, although weak collaboration between schools, communities, and external partners limits this potential. Overall, the study shows that AI can promote equity and personalised mathematics learning only when supported by infrastructure, teacher development, privacy safeguards, offline options, and context-sensitive implementation within secondary school realities.

RECOMMENDATIONS

The recommendations below are directly linked to the empirical themes identified in the study: teacher readiness, learner access, ethical concerns, community engagement, and the need for evidence-based implementation.

Table 2: Alignment between findings and recommendations. Source: Authors' synthesis from the study findings.

Finding	Recommendation	Responsible stakeholders
Teachers reported limited	Provide continuous professional development on AI-supported mathematics pedagogy, prompt use,	Department of Basic Education, school management teams and teacher education providers

[41] Jialong Li et al., "Generative AI for Self-Adaptive Systems: State of the Art and Research Roadmap," *ACM Transactions on Autonomous and Adaptive Systems* 19, no. 3 (2024): 1–60.

[42] Renu Yadav and Atul Kumar Verma, "The Role of Artificial Intelligence in Enhancing Information Accessibility and Accuracy," *Idealistic Journal of Advanced Research in Progressive Spectrums (IJARPS) EISSN–2583-6986* 4, no. 04 (2025): 99–102.

[43] Maria Rehan, "The Impact of Disruptive Technologies on Corporate Business Strategy," *Eye-The International Social Science Review* 3, no. 2 (2025): 11–20.

[44] Jon Truby, "Governing Artificial Intelligence to Benefit the UN Sustainable Development Goals," *Sustainable Development* 28, no. 4 (2020): 946–59.

confidence and training.	assessment, curriculum alignment and ethical classroom use.	
Learners and teachers experienced unequal access to devices and connectivity.	Prioritise offline AI-enabled resources, shared-device models, connectivity support and school-based digital support hubs.	Schools, districts, provincial education departments and ICT partners
Participants raised concerns about the quality of feedback and learner data privacy.	Develop clear protocols for checking AI feedback, protecting learner information and explaining data use to learners and parents.	Schools, education departments and technology providers
Community engagement around AI was weak.	Co-design community-based mathematics tasks, such as local data modelling projects, with parents, community organisations and external partners.	Schools, communities, the Department of Basic Education and local stakeholders

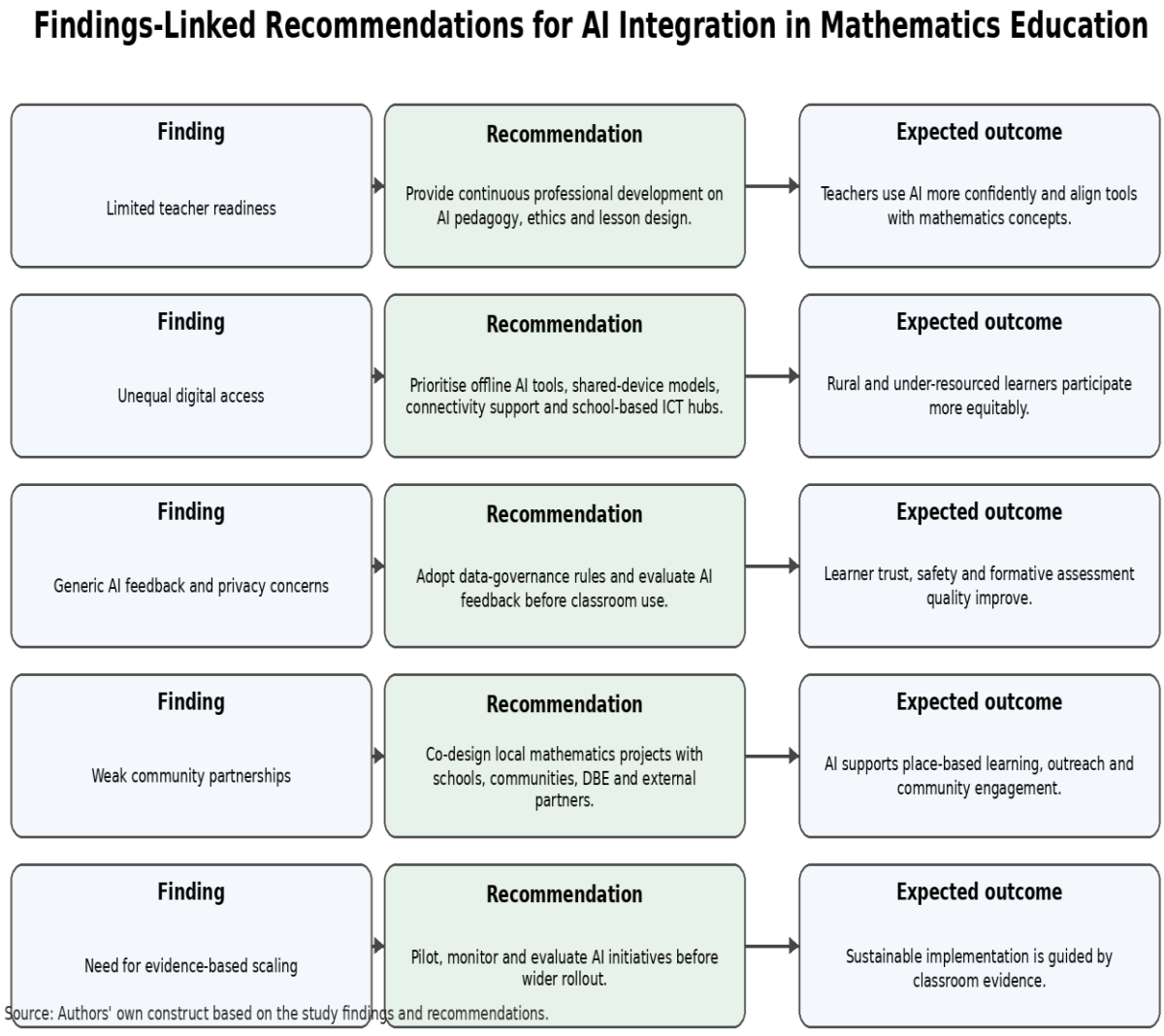

Figure 2: Recommendations based on AI integration in mathematics education. Source: Authors' own construct based on the study findings and recommendations.

In collaboration with external partners, the lack of school-community integration hinders the joint development of significant, locally pertinent AI solutions and obstructs the potential for social innovation.

To support the integration of AI in mathematics education and advance Sustainable Development Goal 4 (SDG 4), schools must adopt a comprehensive, inclusive approach. Central to this is the ongoing professional development of mathematics educators, equipping them with technical knowledge and ethical awareness related to AI in pedagogy. Collaborative peer networks should also be fostered to promote shared learning and problem-solving around AI use. Investing in infrastructure is essential, especially for marginalised groups. Schools should prioritise procuring AI-compatible tools and establish dedicated support hubs offering technical assistance and pedagogical guidance. At the curriculum level, there is a need for redesign to incorporate AI-driven, learner-centred approaches that support personalised learning and feedback mechanisms. AI adoption must also be underpinned by strong data governance policies that safeguard privacy and ensure ethical practice. To promote equitable participation, digital access initiatives must focus on expanding connectivity, device access, and digital literacy training, particularly in rural or under-resourced areas. These efforts should be supported by differentiated learning support, including multilingual resources and tailored digital scaffolding. Furthermore, collaborative partnerships with government bodies, industry, and communities are necessary to co-develop contextually appropriate AI tools and curriculum materials. Embedding service-learning projects into AI-enhanced curricula can increase community engagement and relevance. Lastly, schools should regularly assess the effectiveness of AI integration through continuous research, pilot testing, and evaluation mechanisms to ensure alignment with national priorities and global education objectives.

CONCLUSION

The integration of AI into secondary school mathematics education marks a shift from conventional teaching models toward more dynamic, personalised, and data-informed approaches. Aligned with Sustainable Development Goal 4 (SDG 4), AI was viewed by teachers and learners as a potentially transformative tool that can support understanding of complex mathematical concepts and provide learner-specific feedback in real time. AI may also reduce educational inequalities by expanding access to quality mathematics resources in underserved and rural areas.

However, the study identified substantial barriers to effective AI implementation. These include poor digital infrastructure, unequal access to AI-compatible devices, teachers' limited technical and pedagogical readiness, concerns about data privacy, and questions about the reliability of AI-generated feedback. Limited collaboration among schools, communities, and external partners also impedes the development of locally relevant AI applications that connect mathematics learning to community needs.

To unlock the full potential of AI, a multi-level strategy is required. This includes sustained professional development, infrastructure investment, inclusive curriculum redesign, ethical data-governance frameworks, and partnerships that support context-specific AI solutions. Ongoing research and monitoring are necessary to ensure that AI technologies advance personalised instruction, equity, innovation, and long-term sustainability in South African secondary school mathematics education.

Limitations

This study has been subject to several limitations. Firstly, the contextual focus on South African schools, particularly rural and township settings, may limit the generalisability of findings to more resourced or international contexts. Infrastructure challenges such as unreliable electricity, poor connectivity, and limited access to digital devices also introduce confounding variables, while sampling biases arising from the participation of more innovative or better-resourced schools may affect representativeness.

Measurement constraints, including the reliance on learner performance and usage logs, may fail to capture deeper cognitive, metacognitive, and equity-related outcomes. In addition, the short duration of interventions does not adequately reflect long-term impacts on learning and sustainability, and variations in teacher digital literacy and implementation fidelity introduce uncontrolled heterogeneity. Learner diversity in terms of language, prior achievement, and special needs also moderates outcomes

but may not be fully captured in the analysis. Algorithmic opacity, bias in training data, and changes in proprietary AI systems pose challenges for reproducibility, while issues of data governance, ethics, and compliance with the Protection of Personal Information Act (POPIA) restrict the extent of data collection. Furthermore, the high costs of AI adoption and limited alignment with CAPS curricula and school ICT systems threaten scalability and sustainability. Community engagement is constrained by parents' and guardians' uneven digital readiness, and the presence of researchers may produce Hawthorne effects. Finally, limited support for indigenous languages, potential cybersecurity risks, and challenges in integrating quantitative and qualitative data further complicate the study, underscoring the need for cautious interpretation and future research to address these gaps.

BIBLIOGRAPHY

Agbata, B C, W Obeng-Denteh, P A Kwabi, S Abraham, S O Okpako, S S Arivi, F Asante-Mensa, and Gyamfi W K Adu. "Everyday Uses of Mathematics and the Roles of a Mathematics Teacher." *Science World Journal* 19, no. 3 (2024): 819–27.

Akyuz, Didem, and Michelle Stephan. "Co-Teaching Practices That Build Autonomy for Students with Learning Disabilities in Mathematics." *International Journal of Mathematical Education in Science and Technology* 53, no. 4 (2022): 920–47.

Alwaqdani, Mohammed. "Investigating Teachers' Perceptions of Artificial Intelligence Tools in Education: Potential and Difficulties." *Education and Information Technologies* 30, no. 3 (February 2, 2025): 2737–55. https://doi.org/10.1007/s10639-024-12903-9.

Botelho, Vinıcius. "Equilibrium Effects of Higher Education Subsidies to Public Schools," 2024.

Castleberry, Ashley, and Amanda Nolen. "Thematic Analysis of Qualitative Research Data: Is It as Easy as It Sounds?" *Currents in Pharmacy Teaching and Learning* 10, no. 6 (June 2018): 807–15. https://doi.org/10.1016/j.cptl.2018.03.019.

Chasokela, Doris. "Harnessing Artificial Intelligence: Transformative Technologies in Contemporary Higher Education." *Journal of Computers for Science and Mathematics Learning* 2, no. 1 (February 10, 2025): 26–37. https://doi.org/10.70232/jcsml.v2i1.15.

Chikatimarla, Anil Kumar, and T Naga Prasada Rao. "AI in Rural Development: A Study on the Monitoring and Impact Evaluation of AI Initiatives." In *Seminar Proceedings*, 2024.

Duckworth, Eleanor. "Piaget Rediscovered." *The Arithmetic Teacher* 11, no.7(1964):496–99.

Egara, Felix Oromena, and Mogege Mosimege. "Exploring the Integration of Artificial Intelligence-Based ChatGPT into Mathematics Instruction: Perceptions, Challenges, and Implications for Educators." *Education Sciences* 14, no. 7 (July 6, 2024): 742. https://doi.org/10.3390/educsci14070742.

Elam, Khanssa Mohammed. "Exploring the Challenges and Future Directions of Big Data and AI in Education." *Journal of Artificial Intelligence General Science (JAIGS) ISSN: 3006- 4023,* 1, no. 1 (June 18, 2024): 81–93. https://doi.org/10.60087/jaigs.v1i1.173.

Goswami, Kangkan, Suraj Prasad, Neelkamal Mallick, Raghunath Sahoo, and Gagan B Mohanty. "Machine Learning-Based Study of Open-Charm Hadrons in Proton-Proton Collisions at the Large Hadron Collider." *Physical Review D* 110, no. 3 (2024): 034017.

Govender, Rajendran. "A Reflection on the Use of Artificial Intelligence Tools for the Meaningful Learning of Mathematics." *Pythagoras-Journal of the Association for Mathematics Education of South Africa*. AOSIS, 2024.

Gunawardena, Komadamperuge. "Examining the Impact of Customer Digital Literacy and Artificial Intelligence Literacy on the Adoption of AI-Enabled Mobile Banking Services," 2025.

Hasan, Mohammad Rashedul, and Bilal Khan. "An AI-Based Intervention for Improving Undergraduate STEM Learning." *PLOS ONE* 18, no. 7 (July 19, 2023): e0288844. https://doi.org/10.1371/journal.pone.0288844.

Hwang, Gwo-Jen, and Yun-Fang Tu. "Roles and Research Trends of Artificial Intelligence in Mathematics Education: A Bibliometric Mapping Analysis and Systematic Review." *Mathematics* 9, no. 6 (March 10, 2021): 584. https://doi.org/10.3390/math9060584.

İstikbal, Svajune. "The Effects of Digital Tools on the Development of English Language Skills:

Meta-Analysis." Maltepe University (Turkey), 2024.
Iyer, Vijeta, and J Dhivya. "From Numbers to Narratives: Weaving Stories into Learning Mathematics for 21st Century." *Transforming Education for the 21st Century-Innovative Teaching Approaches*, 2024, 84.
Kathala, Krishna Chaitanya Rao, Ivon Arroyo, and Nishith Reddy Mannuru. "Role of Ethical and Responsible AI in Education for Next Generation Inventors." In *International Conference on Artificial Intelligence in Education*, 71–78. Springer, 2024.
Kayan-Fadlelmula, Fatma, Abdellatif Sellami, Nada Abdelkader, and Salman Umer. "A Systematic Review of STEM Education Research in the GCC Countries: Trends, Gaps and Barriers." *International Journal of STEM Education* 9, no. 1 (2022): 2.
Kim, Joshua, and Edward J. Maloney. *Learning Innovation and the Future of Higher Education*. JHU Press, 2020.
Kurni, Muralidhar, and Srinivasa KG. "Technology-Based Learning Experiences with IoT in Education." In *The Internet of Educational Things: Enhancing Students' Engagement and Learning Performance*, 113–33. Springer, 2024.
Li, Jialong, Mingyue Zhang, Nianyu Li, Danny Weyns, Zhi Jin, and Kenji Tei. "Generative AI for Self-Adaptive Systems: State of the Art and Research Roadmap." *ACM Transactions on Autonomous and Adaptive Systems* 19, no. 3 (2024): 1–60.
Li, Minglong, Dexiang Yin, Hailian Qiu, and Billy Bai. "A Systematic Review of AI Technology-Based Service Encounters: Implications for Hospitality and Tourism Operations." *International Journal of Hospitality Management* 95 (2021): 102930.
Martinez-Maldonado, Roberto. "Human-Centred Learning Analytics: Four Challenges in Realising the Potential." *Learning Letters* 1 (2023): 6.
Miao, Fengchun, and Wayne Holmes. "Artificial Intelligence and Education. Guidance for Policy-Makers," 2021.
Msomi, Alfred Mvunyelwa, and Themba Mngomeni Mthethwa. "Artificial Intelligence in Higher Education Mathematics: A Systematic Review of Trends, Benefits, and Challenges." In *The Focus Conference (TFC 2024)*, 88–118. Atlantis Press, 2024.
Muhamad, Nurulhayah, Maryam Mohd Esa, Rusyda Yahya, Norzaimah Zainol, Nadiah Ishak, and Nazila Ishak. "Teachers' Pedagogical Approaches, Motivation, and Time Management as Determinants of Mathematics Achievement among Malaysian Secondary School Students." *International Journal of Research and Innovation in Social Science* 9, no. 10 (November 15, 2025): 5543–58. https://doi.org/10.47772/IJRISS.2025.910000454.
Nagaraj, Bharath Kumar, Kalaivani A, Suraj Begum R, Akila S, Hemant Kumar Sachdev, and Senthil Kumar N. "The Emerging Role of Artificial Intelligence in STEM Higher Education: A Critical Review." *International Research Journal of Multidisciplinary Technovation*, August 14, 2023, 1–19. https://doi.org/10.54392/irjmt2351.
Nti-Asante, Emmanuel. "Engaging Students in Making Artificial Intelligence Tools for Mathematics Education: An Iterative Design Approach." *Journal of Mathematics Education* 17, no. 1 (2024): 16–37.
Piaget, Jean. "Inteligencia y Adaptación Biológica." *Los Procesos de Adaptación* 1,no.1(1970): 69–84.
Rajput, Sourabh. "AI-Powered Distance Estimation for Autonomous Systems: A Monocular Vision Approach," 2024.
Ramnani, S. "Exploring Ethical Considerations of Artificial Intelligence in Educational Settings: An Examination of Bias, Privacy, and Accountability." *International Journal of Novel Research and Development* 9, no. 2 (2024): b173–91.
Rane, Nitin, Saurabh Choudhary, and Jayesh Rane. *Contribution of ChatGPT and Similar Generative Artificial Intelligence for Enhanced Climate Change Mitigation Strategies*. SSRN 4681720 , 2024.
Rehan, Maria. "The Impact of Disruptive Technologies on Corporate Business Strategy." *Eye-The International Social Science Review* 3, no. 2 (2025): 11–20.
Solaiman, Irene, Zeerak Talat, William Agnew, Lama Ahmad, Dylan Baker, Su Lin Blodgett, Canyu

Chen, Hal Daumé III, Jesse Dodge, and Isabella Duan. "Evaluating the Social Impact of Generative AI Systems in Systems and Society." *ArXiv Preprint ArXiv:2306.05949*, 2023.

Son, Taekwon. "Intelligent Tutoring Systems in Mathematics Education: A Systematic Literature Review Using the Substitution, Augmentation, Modification, Redefinition Model." *Computers* 13, no. 10 (2024): 270.

Tapalova, Olga, and Nadezhda Zhiyenbayeva. "Artificial Intelligence in Education: AIEd for Personalised Learning Pathways." *Electronic Journal of E-Learning* 20, no. 5 (2022): 639–53.

Truby, Jon. "Governing Artificial Intelligence to Benefit the UN Sustainable Development Goals." *Sustainable Development* 28, no. 4 (2020): 946–59.

Vashishth, Tarun Kumar, Vikas Sharma, Kewal Krishan Sharma, Bhupendra Kumar, Rajneesh Panwar, and Sachin Chaudhary. "AI-Driven Learning Analytics for Personalized Feedback and Assessment in Higher Education." In *Using Traditional Design Methods to Enhance AI-Driven Decision Making*, 206–30. IGI Global Scientific Publishing, 2024.

Vygotsky, L., and M. Cole. "Lev Vygotsky: Learning and Social Constructivism." *Learning Theories for Early Years Practice. UK: SAGE Publications Inc.*, 2018, 68–73.

Vygotsky, Lev S. *Mind in Society: The Development of Higher Psychological Processes*. Vol. 86. Harvard University Press, 1978.

Williamson, Ben, and Rebecca Eynon. "Historical Threads, Missing Links, and Future Directions in AI in Education." *Learning, Media and Technology*. Taylor & Francis, 2020.

Yadav, Renu, and Atul Kumar Verma. "The Role of Artificial Intelligence in Enhancing Information Accessibility and Accuracy." *Idealistic Journal of Advanced Research in Progressive Spectrums (IJARPS) EISSN–2583-6986* 4, no. 04 (2025): 99–102.

Yadav, Uma, and Urmila Shrawankar. "Artificial Intelligence across Industries: A Comprehensive Review with a Focus on Education." *AI Applications and Strategies in Teacher Education*, 2025, 275–320.

Yin, Robert K. *Case Study Research and Applications*. Vol. 6. Sage, Thousand Oaks, CA, 2018.

Zawacki-Richter, Olaf, Victoria I. Marín, Melissa Bond, and Franziska Gouverneur. "Systematic Review of Research on Artificial Intelligence Applications in Higher Education – Where Are the Educators?" *International Journal of Educational Technology in Higher Education* 16, no. 1 (December 28, 2019): 39. https://doi.org/10.1186/s41239-019-0171-0.

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Generative AI Statement

As the author(s) of this work, we used the AI tools ChatGPT and Grammarly in a limited and responsible manner. ChatGPT was used to support idea organisation, improve clarity of expression, and refine academic phrasing, while Grammarly was applied for language editing, grammar correction, and proofreading. These tools were not used to generate original research content, data, or analysis. After

applying these tools, we carefully reviewed and verified the final version of the manuscript to ensure accuracy, integrity, and compliance with academic standards. The authors take full responsibility for the content and conclusions presented in this work.

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