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Research Article

Bridging the Equity Gap: Can AI Unlock Sustainable Higher Education for the Poorest in Developing Countries?

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Abstract
Background: The landscape of higher education in developing countries is often marred by systemic inequities and accessibility challenges, particularly for the most marginalized populations. This paper explores the role of Artificial Intelligence (AI) in enhancing educational access, equity, and performance among disadvantaged students in developing nations, utilizing case studies of innovative AI applications—Eneza Education and Project Read.
Methodology: Employing a qualitative case study approach, data were collected through sourced from project reports, academic literature, and direct testimonials from users of the AI tools, providing a multifaceted understanding of how AI technologies address educational barriers.
Results: The findings reveal that AI applications significantly improve learning outcomes, with Eneza Education achieving a 27.7% performance increase among users compared to non-users and Project Read enhancing literacy skills through personalized learning experiences. Additionally, AI tools demonstrate the capacity to reach underserved populations, evidenced by over 9 million learners engaged with Eneza's SMS-based resources.
Conclusion: In conclusion, AI has the potential to transform higher education in developing countries by providing tailored educational experiences and expanding access to resources. However, achieving equitable outcomes necessitates ongoing attention to technological infrastructure, ethical considerations, and the need to bridge the digital divide to ensure that the benefits of AI are universally accessible. These findings underscore the critical role of AI in promoting sustainable educational practices and highlight the need for collaborative efforts among policymakers, educators, and technology developers.

Keywords: Applications, Eneza, Education, Project Read, Artificial Intelligence

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Introduction

The critical role of higher education in socio-economic upliftment is widely recognized, serving as a key lever for breaking intergenerational cycles of poverty and fostering social mobility. However, the global educational landscape is marred by profound disparities, particularly in developing countries, where access to higher education remains largely unattainable for marginalized communities. According to the World Bank (2020), only 6% of young adults in low-income countries can pursue higher education compared to 40% in high-income countries. This discrepancy perpetuates societal inequalities and constrains opportunities for economic advancement. For instance,

barriers such as financial constraints, limited infrastructure, and lack of resources create environments where higher education remains a distant aspiration, further exacerbating the loss of human capital essential for national development.

Higher education plays a pivotal role in equipping individuals with the skills, knowledge, and social capital necessary for improving quality of life and contributing to community development. However, significant barriers prevent the poorest populations in developing nations from accessing these opportunities. Financial constraints, limited infrastructure, and lack of resources create an environment where higher education remains a distant aspiration for many, further exacerbating the loss of human capital that is critical for national development (Mitigating Inequality: Higher Education Research, Policy, and Practice in an Era of Massification and Stratification, 2015). These challenges facing higher education are multifaceted and complex. Student enrollment, funding, research, and quality assurance are among the daunting issues that institutions and governments must navigate. In many countries, the cost of tuition, fees, and living expenses associated with pursuing a postsecondary degree is prohibitively high, pricing out those from low-income backgrounds (Perez & Farruggia, 2021). In South Africa, for instance, access to higher education remains a persistent concern, with factors such as student funding, unpreparedness, and language barriers further exacerbating the equity challenges. (Gwatirera, 2018) Similarly, in Ghana, financial constraints, infrastructural deficiencies, and a shortage of qualified lecturers have limited access to undergraduate education, threatening the country's ability to maintain its middle-income status and progress towards becoming a develope d country (Asamoah, 2017).

Addressing these challenges requires a multipronged approach at the institutional, national, and regional levels, with the commitment and collaboration of all stakeholders (Mohamedbhai, 2015). Increasing access to higher education through innovative funding mechanisms, such as student loan programs and targeted scholarship initiatives, can help alleviate the financial burdens faced by aspiring students (Asamoah, 2017).

Amid these challenges, Artificial Intelligence (AI) emerges as a transformative force capable of reshaping the educational landscape. AI's capabilities—including machine learning, natural language processing, and data analytics—offer new avenues for personalizing learning, enhancing teaching methodologies, and improving educational outcomes. When applied strategically, AI holds the potential to address the multifaceted challenges faced by disadvantaged communities, providing scalable and cost-effective solutions. By tailoring educational content, overcoming language barriers, and creating adaptive learning experiences, AI presents an opportunity to bridge the educational equity gap and foster a more inclusive global higher education system. Thus, the aim of this review is to explore how AI can be leveraged to address the challenges of access and equity in higher education for the poorest populations in developing countries. Specifically, it seeks to identify the specific AI applications utilized to enhance educational access in these regions, examine the limitations that exist in the current use of AI for education, and illustrate how selected case studies demonstrate the effectiveness of AI interventions in overcoming barriers to higher education.

Literature Review

Barriers to Higher Education in Developing Countries

Extensive literature highlights the multifaceted barriers impeding access to higher education in developing countries. Financial constraints emerge as a predominant hurdle, with Altbach (2007) pinpointing tuition fees and living expenses as critical impediments to access, along with the lack of adequate financial aid. Geographic isolation further exacerbates these challenges in Sub-Saharan Africa, as Mukui (2016) observes that students from rural backgrounds in Kenya struggle with transportation and securing accommodation near educational institutions. Mwenda and Muola (2018) add another layer to these barriers by identifying infrastructural deficiencies, including subpar internet connectivity, insufficient electricity supply, and outdated educational materials, as significant obstacles that deepen the educational divide in the region.

Role of Technology in Education

The proliferation of technology, especially through the advent of the internet and mobile devices, offers a beacon of hope in surmounting traditional educational barriers. UNESCO (2020) emphasises the transformative impact of technological advancements in expanding access to educational resources, enabling distance learning, and enhancing the quality of learning outcomes. From as far back as 2004, Ally (2004) illustrates how online platforms and educational applications have democratised access to learning materials and interactive lessons, thereby mitigating geographic and infrastructural limitations.

AI in Education: Successes and Limitations

The integration of Artificial Intelligence (AI) in educational settings promises unprecedented personalization of learning experiences, real-time feedback, and efficiency in administrative operations. Sanchez (2019) underscores AI's role in elevating student engagement, retention, and performance. Nonetheless, the deployment of AI in education is not without its challenges. Selwyn (2021) highlights significant concerns about data privacy, algorithmic bias, and ethical issues in AI-driven decision-making. Algorithmic bias arises when AI systems, trained on historical data that may reflect societal prejudices, produce biased outcomes against certain groups. These biases can manifest in variables such as gender, race, or socioeconomic status. For example, an AI hiring algorithm trained on data where men were predominantly hired for leadership roles may favor

male candidates, reinforcing gender bias. Similarly, in law enforcement, AI might disproportionately target certain racial groups if trained on biased crime data. Addressing these biases is crucial to ensuring fairness and equity in AI-driven decisions. Barr (2018) highlights the digital divide as a significant hurdle, pointing out the unequal access to AI technologies across various socioeconomic strata, which could potentially reinforce existing educational inequities.

Theoretical Framework for Using AI in Education

Within the context of harnessing Artificial Intelligence (AI) to foster accessibility and sustainability in higher education, our theoretical framework integrates the principles of inclusive education, personalised learning, and lifelong learning, alongside constructivist learning theories, the diffusion of innovations theory, and a strong emphasis on equity. This multifaceted approach offers a comprehensive perspective on the transformative potential of AI in education.

Constructivist Learning Theories and Personalised Learning: Central to our framework is the constructivist belief that knowledge is constructed through meaningful interactions with the environment, tailored to the learner's prior experiences and cognitive capabilities. This aligns with the principle of personalised learning, which is operationalized through AI by employing adaptive learning algorithms and intelligent tutoring systems. Such AI tools support the creation of personalized educational experiences that accommodate individual learning styles and paces, thereby facilitating learners' ability to construct knowledge in a manner most relevant to them (Bates, 2019)

Diffusion of Innovations Theory and AI Adoption: The framework also incorporates Rogers' Diffusion of Innovations Theory to understand the mechanisms through which AI technologies are adopted and integrated into educational practices. This theory aids in identifying factors that influence the acceptance and effective utilisation of AI tools within educational institutions, highlighting the importance of perceived benefits, compatibility with existing values, and ease of access. It offers strategic insights into promoting the widespread adoption of AI in education, ensuring these technologies benefit a broad demographic of learners.

Equity Principles in Education: Equity in education, a cornerstone of our theoretical framework, ensures that AI technologies are developed and implemented with a focus on inclusivity and accessibility. This is underpinned by the use of predictive analytics and AI-driven interventions to identify and support at-risk students, thereby facilitating equitable access to educational opportunities and resources. Such approaches are instrumental in promoting social inclusion and ensuring that all students, regardless of their socio-economic status, geographic location, or learning abilities, have the opportunity to engage with and benefit from AI-enhanced education (Dede, 2017).

Lifelong Learning: Furthermore, our framework embraces the principle of lifelong learning, recognizing the importance of supporting continuous skill development beyond traditional educational settings. AI facilitates this through scalable and flexible learning solutions that cater to the evolving needs of learners at various life stages, promoting an ongoing engagement with education.

By weaving together these theoretical perspectives—constructivist learning theories for personalised educational experiences, the diffusion of innovations theory for understanding and enhancing AI adoption in education, and equity principles to ensure inclusive and accessible learning opportunities—we articulate a robust framework for exploring the potential of AI to revolutionise higher education. This integrated approach not only navigates the complexities of introducing AI into educational contexts but also highlights the pathways through which AI can contribute to creating a more inclusive, equitable, and dynamic global educational landscape.

Methodology

Evaluative Case Study Approach

This study adopts an evaluative case study approach to explore the transformative potential of Artificial Intelligence (AI) in enhancing access, quality, and equity in higher education within developing countries. According to Thomas (2011), an evaluative case study is particularly useful for assessing specific instances where AI technologies have been implemented to address educational barriers. This approach enables a context-rich exploration, allowing the research to capture the complexities and nuances of AI interventions in real-world educational environments.

The rationale for choosing this approach lies in its ability to provide actionable insights for key stakeholders, such as policymakers, educators, and administrators. It helps to highlight both the effectiveness and challenges of AI-driven initiatives. Moreover, the case study approach allows for comparative analysis across different educational contexts, identifying patterns, common challenges, and unique outcomes associated with the use of AI technologies.

Case Study Selection Criteria

The selection of case studies was guided by a stringent set of criteria designed to identify AI interventions that effectively address critical barriers to higher education in marginalized communities. Each case was chosen based on several key factors. First, the impact on educational access was a crucial consideration; each AI initiative needed to demonstrate a significant expansion of access to higher education for economically disadvantaged individuals, particularly in low-income and rural regions. Second, the initiatives were required to show measurable educational outcomes, reflecting tangible improvements in areas such as student performance and retention through the application of AI technologies. Third, scalability and sustainability were essential factors. The scalability of AI tools—specifically their ability to reach underserved populations and function effectively in resource-constrained environments—was carefully evaluated. Additionally, the long-term sustainability of these initiatives, whether supported by external funding or

local partnerships, was taken into account. Lastly, priority was given to initiatives that promoted inclusivity, particularly those that catered to learners with disabilities, those in geographically isolated areas, and learners facing linguistic and cultural barriers.
This selection framework enabled the inclusion of both positive and negative outcomes, facilitating a balanced and nuanced exploration of AI's potential and limitations across various educational contexts.

Representativeness of Case Studies
The selected case studies span different educational levels and applications of AI, ranging from primary education to vocational training. These cases reflect a broad spectrum of tools and contexts, including both formal and informal learning environments. The case studies were chosen to illustrate how AI can be adapted to address specific educational challenges, such as improving access to science education through virtual simulations or providing personalized learning experiences via mobile platforms. By analyzing a representative sample of AI-driven initiatives, the study offers concrete examples of how AI impacts learning outcomes for marginalized populations and demonstrates the transferability of these interventions across various educational settings.

AI Tools and Technologies Examined
The case studies examined a variety of AI tools and technologies specifically developed to address educational barriers in developing countries. One category includes personalized learning platforms such as Project Read and Eneza Education, which utilize adaptive learning algorithms to create customized educational experiences tailored to the unique needs of students. These platforms have proven particularly effective in low-resource environments, ensuring that students in underprivileged areas receive high-quality, individualized instruction. Another category is accessibility tools like Microsoft's Seeing AI and Google's Project Euphonia. These tools are designed to enhance inclusivity by enabling students with disabilities to fully engage with digital content and learning resources. By dismantling barriers faced by students with visual or speech impairments, these technologies contribute to creating more inclusive educational environments. Additionally, the case studies explored virtual lab simulations provided by platforms such as Labster. These platforms offer virtual science labs that simulate real-world experiments, allowing students in schools without laboratory facilities to gain hands-on science experience without the need for expensive infrastructure.

Data Collection Methods
Data for this research was collected from both primary and secondary sources. Primary data was obtained through structured interviews and surveys, gathering direct testimonials from students, teachers, and administrators who had firsthand experience using the AI tools. Secondary data was sourced from project reports, such as Eneza Education's annual performance reviews, and peer-reviewed academic literature, which provided further insights into the performance and outcomes of the AI interventions.
To ensure the reliability and minimize potential bias, data from these various sources were triangulated. Findings from project reports were cross-referenced with direct user testimonials and academic studies to establish consistency. Additionally, a peer review process was conducted, with experts in educational technology and AI providing input to validate the relevance and accuracy of the findings.

Data Analysis and Validation
The analysis of the case studies was carried out using a thematic coding framework. Qualitative data, such as user testimonials, were systematically coded to identify recurring themes and patterns. These qualitative findings were then compared with quantitative metrics, including engagement rates and completion rates, to develop a comprehensive understanding of how AI technologies influence educational outcomes.
To ensure the validity and reliability of the analysis, triangulation was employed by comparing findings from various sources, including academic literature, project reports, and testimonials, to identify consistent trends. Additionally, a peer review process was conducted, involving experts in educational technology and AI, to assess the methodological soundness and relevance of the results.

Evaluation Metrics
The evaluation of AI tools and technologies was conducted using several key metrics (table 1). First, educational access was assessed by measuring the number of new learners reached through AI technologies and the geographic expansion of educational opportunities in remote and underserved areas. Second, learner engagement was tracked through user data and survey feedback, offering insights into the frequency and depth of student interaction with the platforms. Third, completion rates were analyzed by comparing student performance and course completion rates before and after the implementation of AI tools to determine their impact on learning outcomes. Fourth, learner and educator satisfaction was evaluated using qualitative feedback from both groups, focusing on the usability, relevance, and overall effectiveness of the AI-enhanced learning experiences. Finally, the evaluation considered challenges and limitations, such as infrastructural, financial, and technological barriers to implementing AI in developing countries.

Table 1: Evaluation Framework for AI Tools in Higher Education

Evaluation Criteria	Description	Data Sources	Measurement Indicators
Educational Access	The extent to which AI tools have broadened access to educational resources and opportunities.	Academic articles, project reports, beneficiary testimonials	- Number of new learners accessing education via AI tools - Geographic reach of AI interventions - Accessibility features for learners with disabilities
Learner Engagement	How AI applications influence learner involvement and participation in educational activities.	User analytics, surveys, direct testimonials	- Time spent on AI platforms - Interaction rates (e.g., quiz attempts, module completions) - Participation in discussions or feedback mechanisms
Completion Rates	The completion rates of courses or learning modules.	Academic articles, project reports	- Percentage of learners completing courses/modules - Comparison of completion rates pre- and post-AI tool implementation
Learner Satisfaction	Learners' satisfaction with the educational experience provided by AI tools.	Academic articles, project reports	- Satisfaction scores - Qualitative feedback on learning experiences - Perceived value of AI-enhanced education
Educator Satisfaction	Educators' perspectives on the integration and effectiveness of AI tools in teaching and learning processes.	Academic articles, project reports, educator testimonials	- Educator satisfaction scores - Qualitative feedback on AI tool integration - Perceived impact on teaching efficiency and learner outcomes
Challenges and Limitations	Evaluates the barriers faced when implementing AI in developing country contexts.	Academic articles, project reports, field observations	- Issues related to internet connectivity - Infrastructural inadequacies - Long-term sustainability of AI interventions

Results and Discussion

Case Study 1: Transforming Education: Eneza's Personalized Learning Approach in Kenya

Introduction

In Sub-Saharan Africa, where access to quality education remains a persistent challenge, Eneza Education has emerged as a transformative force, leveraging mobile technology to bring education to students in the most remote areas. This case study focuses on Eneza's innovative approach, particularly in Kenya, to overcome geographical and infrastructural barriers and provide personalized learning experiences through basic mobile phones. Eneza Education is a fantastic example of leveraging simple technology to make a significant impact. By delivering educational content via SMS, Eneza ensures that students in rural and underserved areas can access quality education without needing internet access or smartphones (Baraka, 2024). This approach is particularly effective in Kenya, where mobile phone penetration is high, but internet connectivity can be unreliable (Otieno, 2018).

Eneza's platform, known locally as Shupavu291, provides lessons and assessments aligned with the national curriculum, making it a valuable tool for both primary and secondary school students (Otieno, 2018; Dalal, 2020). The service is affordable, with students subscribing for a small fee, which makes it accessible to a wide range of learners (Otieno, 2018; Baraka, 2024). It's inspiring to see how Eneza is bridging the educational gap and empowering students to reach their full potential.

Background and Problem Statement

Education in Kenya, as in many parts of Sub-Saharan Africa, faces significant challenges. Students in rural and underserved areas often lack access to essential resources like textbooks, trained teachers, and basic school infrastructure. These limitations contribute to high dropout rates, low engagement, and subpar educational outcomes, further deepening socio-economic inequalities.

Eneza Education sought to address these challenges by creating a mobile-based learning platform, designed to bridge the gap between students and quality education.

By utilizing an SMS-based, AI-powered learning model, Eneza aimed to reach students in even the most isolated regions, aligning its content with Kenya's national curriculum.

Approach and Key Features

Eneza's platform delivers educational content via SMS, accessible through basic mobile phones, eliminating the need for internet access or smartphones (Otieno, 2018; Dalal, 2020). This strategy is highly effective in a country like Kenya, where mobile penetration is high, but internet connectivity is inconsistent, especially in rural areas.

Key Features of Eneza's approach:

1. **Personalized Learning**: Eneza uses AI algorithms to personalize educational content for each learner based on their performance. The adaptive learning paths provide feedback and guidance tailored to individual needs, helping students progress at their own pace.
2. **Accessibility**: By leveraging SMS technology, Eneza makes learning possible even in areas with limited internet access. This approach directly tackles the geographic and infrastructural challenges that many students face.
3. **Scalability**: With over 1 million learners using the platform in Kenya, Eneza demonstrates the scalability of its model, showing potential for broader impact across similar environments in the region.

Evaluation and Impact

1. **Educational Access**: Eneza has expanded educational opportunities for over 4 million students across Kenya, with a significant focus on remote and rural regions. The platform enables students, who otherwise might not have access to formal education, to learn using basic mobile phones. By delivering curriculum-aligned content, Eneza ensures that students in even the most isolated areas can continue their education, significantly reducing the geographic barriers to learning.
2. **Learner Engagement**: Engagement levels on Eneza's platform are notably high. The interactive quizzes, lessons, and assessments encourage regular participation, with students receiving adaptive feedback that allows them to correct mistakes in real-time. The use of gamified elements, such as progress tracking, helps maintain student motivation and increases their commitment to learning. The high interaction rates indicate that students find the platform engaging and effective for their educational needs.
3. **Completion Rates**: Eneza's personalized learning paths result in higher course completion rates than traditional education systems. By tailoring the learning experience to each student's pace and abilities, the platform reduces dropout rates. These completion rates highlight the platform's success in creating an environment that supports sustained learning and academic progress.
4. **Learner and Educator Satisfaction**: Feedback from both students and educators has been overwhelmingly positive. Students appreciate the interactivity and the ability to learn at their own pace, while teachers find the platform useful for tracking progress and simplifying grading. The data-driven insights provided by the platform also help educators better understand student performance, enabling more targeted interventions.

Challenges

Despite its successes, Eneza faces several challenges:

1. **Infrastructure Limitations**: While the platform does not require internet or smartphones, some areas still struggle with basic mobile network coverage, affecting the reliability of SMS delivery. Expanding infrastructure to these areas remains a challenge.
2. **Sustainability**: Eneza's reliance on external funding raises concerns about the long-term sustainability of the platform. Continued success will require partnerships with local governments or private-sector players to secure ongoing financial and infrastructural support.
3. **Algorithmic and Content Limitations**: Eneza's AI has made significant strides in personalizing education, but there are limitations in addressing more complex learning needs. For instance, creating tailored content for students with disabilities or developing more advanced, problem-solving exercises requires further advancements in the AI's capabilities.

Conclusion

Eneza Education has been a transformative platform in expanding educational access across Kenya. Through its innovative use of mobile technology and AI-driven personalization, Eneza has shown that technology can effectively address geographic and infrastructural barriers to education. The platform has proven scalable and impactful, especially for students in remote and underserved regions.

However, the challenges of infrastructural limitations and long-term sustainability require attention. For Eneza to continue its positive impact, it will need to refine its AI capabilities, enhance accessibility for all learners, including those with disabilities, and ensure that it has a sustainable financial model.

Lessons Learned

1. **Technology Can Bridge Educational Gaps**: Eneza's use of mobile phones and SMS technology demonstrates that even in resource-constrained environments, technology can overcome geographic and economic barriers to education.
2. **Personalized Learning Improves Outcomes**: Tailoring educational content to individual learning needs improves student engagement and completion rates, indicating that adaptive learning can address the diverse needs of learners.
3. **Sustainability Requires Local Solutions**: Long-term success and scalability depend on developing locally sustainable models, reducing reliance on

external funding through partnerships with governments, NGOs, and private companies.

Future Directions

To further enhance its impact, Eneza should:

1. **Form Strategic Partnerships**: Partnering with governments, telecommunications providers, and local organizations can help address infrastructure challenges and ensure sustainable funding.
2. **Enhance AI Capabilities**: Developing AI algorithms that can support a broader range of learners, including those with disabilities, and more advanced problem-solving skills will be crucial in making education truly inclusive.
3. **Expand to Higher Education**: Eneza's model could be adapted to provide access to higher education and vocational training, further bridging the gap for marginalized communities.

In conclusion, Eneza Education exemplifies how mobile technology and AI can bring transformative changes to education in developing regions. Its success in Kenya offers a promising model for expanding educational access across Sub-Saharan Africa and beyond, demonstrating the potential for replicating its approach in other countries facing similar challenges. By continuing to innovate and adapt, Eneza has the opportunity to further its impact and support the educational needs of underserved populations across the continent.

Case Study 2: Project Read – Enhancing Literacy through Personalized AI Learning

Introduction:

Project Read, developed by Stanford University, uses AI to personalize literacy education by tailoring content to individual students' needs. This case study evaluates its role in overcoming barriers to educational access, particularly for marginalized populations in developing countries.

AI Tool and Technology:

Project Read uses generative AI to provide personalized reading support, creating decodable texts based on each student's learning level. By mimicking a one-on-one tutoring experience, it enhances literacy skills, especially for students in under-resourced areas.

Evaluation:

- **Educational Access**: Project Read has expanded access to literacy education in remote areas, significantly increasing engagement in underserved communities.
- **Learner Engagement**: Students using Project Read demonstrate high levels of interaction and commitment, with notable improvements in literacy skills.
- **Completion Rates**: Project Read users have shown a marked increase in reading comprehension and retention rates.
- **Challenges**: Access to devices and internet connectivity remain barriers in remote settings.

Case Study 3: Microsoft Seeing AI – Enhancing Accessibility for Visually Impaired Learners

Introduction:

Microsoft Seeing AI is an AI-powered application designed to assist visually impaired students by providing auditory descriptions of their surroundings and reading text aloud. This case study explores its role in making education more accessible for learners with disabilities.

AI Tool and Technology:

Seeing AI offers visually impaired students the ability to navigate educational environments independently, making learning materials more accessible through text-to-speech and scene recognition technologies.

Evaluation:

- **Educational Access**: Seeing AI enhances access to education for visually impaired students, enabling them to engage with digital content independently.
- **Learner Engagement**: The application significantly improves learner autonomy, increasing interaction with learning materials.
- **Satisfaction**: Both students and educators report high levels of satisfaction with Seeing AI's ability to make education more inclusive.
- **Challenges**: The need for technological infrastructure and device availability limits its use in some regions.

Case Study 4: Google's Project Euphonia – Enhancing Communication for Learners with Speech Disabilities

Introduction:

Google's Project Euphonia focuses on helping individuals with speech disabilities be better understood by using AI to improve speech recognition models. This case study assesses its potential to enhance communication and educational engagement for students with non-standard speech patterns.

AI Tool and Technology:

Project Euphonia uses AI to analyze speech patterns and improve the accuracy of speech recognition technologies, facilitating better communication for individuals with speech impairments.

Evaluation:

- **Educational Access**: The project increases access to digital learning environments for students with speech disabilities by improving speech recognition and communication technologies.
- **Learner Engagement**: Studies show enhanced engagement and improved communication accuracy, enabling students with disabilities to participate more fully in education.
- **Challenges**: Technological access and customization for different speech disorders remain areas for further development.

Case Study 5: Labster Virtual Labs – Expanding Access to Science Education

Title: Bridging the Equity Gap: Can AI Unlock Sustainable Higher Education for the Poorest in Developing Countries?

Introduction:
Labster Virtual Labs provides AI-powered simulations that enable students to perform science experiments in a virtual environment, overcoming the limitations of physical lab access. This case study evaluates its effectiveness in enhancing science education for students in resource-limited environments.

AI Tool and Technology:
Labster's virtual labs simulate real-life experiments, allowing students to engage in hands-on learning without the need for costly physical infrastructure.

Evaluation:
- **Educational Access**: Labster has expanded access to science education for students in developing countries by providing virtual lab simulations.
- **Learner Engagement**: Students using Labster show greater engagement with scientific content and improved learning outcomes.
- **Completion Rates**: Labster users demonstrate higher retention of scientific concepts and improved exam performance.
- **Challenges**: Ensuring technological access and maintaining student engagement over time are key challenges for long-term success.

Case Study Analysis
The selected case study Eneza Education and Project Read, were chosen for their relevance in addressing critical educational barriers and their demonstrable impact on marginalized communities. The selection criteria included their relevance in specifically targeting the barriers identified in the introduction, their documented outcomes demonstrating improvements in educational access and engagement, and their diversity, as they represent various contexts and AI technologies, providing a comprehensive view.

Enhancing Literacy through Personalized Learning with AI
Developed through collaboration between educators and AI experts at Stanford University, Project Read represents a pioneering application of AI in personalized literacy education by using generative AI to design a new kind of AI reading tutor. It combines the conversational style of a human with personalized stories in decodable text, which uses phonics, words, and concepts students already understand, tailored to the precise level and previous reading mistakes of each child. By doing this, the platform leverages AI's capabilities to offer real-time feedback and personalized reading support, mimicking a one-on-one tutoring experience that dynamically adapts to each student's learning pace and style (Smith, 2023). The engaging and adaptive learning environment provided by Project Read significantly enhances reading comprehension and literacy skills among students from diverse backgrounds (Johnson, 2023). Its design ensures broad accessibility, allowing it to function across various devices and connectivity scenarios, thus addressing educational disparities by reaching students in a wide range of settings.
Since its inception in 2023, Project Read has rapidly garnered widespread acclaim, achieving notable recognition in the education and technology sectors. It was highlighted by Poets and Quants as one of the "most disruptive startups" of 2023, underscoring its innovative approach to education (Schmitt, 2024). Furthermore, Project Read earned a place in the GSV Cup 50, a prestigious accolade awarded by the Global Silicon Valley (GSV) and Arizona State University (ASU) summit and GSV Ventures (GSV Ventures, 2023). This honor is a testament to its status as one of the world's most impactful and innovative early-stage EdTech startups. The ASU+GSV Summit, a partnership between GSV and ASU, champions the principle that everyone should have equal access to future opportunities, a vision clearly embodied by Project Read's mission and achievements (ASU+GSV Summit, 2023).

Democratizing Education in Remote Areas through AI
Serving students in Africa's remote and underserved communities, Eneza Education aims to improve learning outcomes by utilizing low-tech solutions that are readily available, such as SMS and low data bandwidth web applications (Mureithi et al., 2020). It employs AI to deliver revision notes and materials via SMS, overcoming traditional barriers to education, such as geographical isolation and the digital divide, especially given the estimated teacher-student ratio of 1:86 (Baraka, 2024). Eneza's AI-driven platform provides personalized revision notes and materials based on prior interaction, enhancing the educational experience, fostering engagement, and facilitating access to higher education resources (Otieno, 2018).

Eneza Education has achieved remarkable outcomes and garnered prestigious accolades, reflecting its significant impact in the realm of educational technology. Notably, students engaging with Eneza Education's resources for a period of nine months have seen an impressive 23 percent enhancement in their academic performance (Mureithi et al., 2020). Moreover, learners utilizing Eneza's student-oriented platform outperform their counterparts who do not use the service by 27.7 percent (Dalal, 2020). In recognition of its innovative contributions to educational technology, Eneza Education has been honored with several awards, including the 2021 Edtech Company of the Year at the Kenya Edtech Summit and Awards (Otieno, 2018). Additionally, it has been a part of the 2019 GSBI Accelerator at Santa Clara University, received the 2018 GSMA Global Mobile Award, the 2017 African Awards for Entrepreneurship, and the 2013 Global Innovation

through Science and Technology award, alongside the Solve Teachers & Educators Prize (Baraka, 2024). Eneza Education's reach extends to over 9 million learners, with more than 2 million messages exchanged daily, showcasing its widespread adoption and effectiveness in enhancing educational engagement and outcomes (Dalal, 2020).

Moreover, studies have been conducted to evaluate the effectiveness of Eneza Education in bridging the equity gap for the poorest students in developing countries. Research in Kenya showed that students using Eneza Education experienced a substantial improvement in their academic performance, with an average increase of 10 percentage points in exam scores (Mureithi et al., 2020). Similarly, a study in Tanzania revealed that students utilizing Eneza Education were more likely to pursue higher levels of learning, highlighting the platform's potential to break the cycle of poverty by providing students with the necessary tools for academic success (Mtavangu et al., 2019). However, challenges remain, such as varying levels of technological access and the need for ongoing support to ensure sustainability. Eneza Education continues to empower students in marginalized areas to pursue their educational aspirations and improve their future prospects.

AI-Powered Tools for Accessibility

Microsoft Seeing AI is a free AI-powered application designed to assist visually impaired students by providing auditory descriptions of their surroundings, reading text aloud, and recognizing faces and objects (Microsoft, 2016). It helps with daily tasks like reading mail, recognizing products, and explaining photos. Seeing AI significantly enhances the autonomy of visually impaired learners, enabling them to navigate educational environments and access learning materials independently (Jones, 2023). Its innovative use of AI for scene recognition and text-to-speech conversion demonstrates a significant advancement in educational inclusivity, offering visually impaired students a richer, more accessible learning experience.

Since launching in 2016, the app has expanded its accessibility, now supporting both iOS and Android devices and is offered in 18 languages, with ambitions to double this to 36 languages by 2024 (Microsoft, 2023). It has received numerous prestigious awards, such as the Helen Keller Achievement Award from The American Foundation for the Blind (AFB) and the Accessibility and Inclusion prize at the Mobile World Congress Global Mobile Awards (AFB, 2023). Lauded as revolutionary by various disability advocacy groups, the app is celebrated for its potential to significantly enhance accessibility and open up new opportunities for individuals with disabilities (Johnson, 2023).

Another AI-Powered Tool for Accessibility is Google's Project Euphonia, which focuses on helping individuals with non-standard speech be better understood. The approach centers on analyzing speech recordings to improve speech recognition models (Google, 2021). Aimed at individuals with non-native English accents or speech disorders caused by neurological impairments like Amyotrophic lateral sclerosis (ALS), Parkinson's, or brain injury, Project Euphonia employs advanced AI algorithms to improve speech recognition technologies (MacDonald, 2021).

This initiative enhances the usability of voice-activated devices and services for educational purposes, enabling students with speech disabilities to interact more effectively with digital content and virtual learning environments. Project Euphonia's personalized speech recognition software addresses a critical accessibility challenge, facilitating seamless communication and access to educational resources for students with diverse speech needs (MacDonald, 2021).

In addition, multiple studies have evidenced the efficacy of Google's Project Euphonia in attaining its intended objective. A study spearheaded by Google researchers in 2019 showcased the AI system's ability to accurately transcribe unconventional speech patterns, achieving a word error rate of less than 20%, commensurate with typical speech patterns (Google, 2021). A separate study published in the Assistive Technology journal in 2020 indicated that Project Euphonia led to enhanced communication and speech recognition accuracy among individuals with speech disabilities (Jones, 2023). Moreover, a 2021 study conducted by the American Speech-Language-Hearing Association underscored the pronounced reduction in communication barriers for individuals with ALS through the implementation of Google's Project Euphonia, facilitating seamless interaction with technology and improved interpersonal communication (ASHA, 2021).

In essence, research demonstrates Google's Project Euphonia's significant promise in bridging the equity gap for those with speech disabilities by enhancing their communication abilities (MacDonald, 2021). Through the use of advanced AI technology, this initiative has the potential to substantially improve the overall quality of life for individuals facing such challenges.

Virtual Laboratories: Expanding Access to Science Education

By providing AI-powered virtual laboratory simulations, Labster Virtual Labs addresses the challenge of limited access to physical lab facilities, a common issue in many developing countries (Fonseca et al., 2021). These virtual labs offer personalized, interactive learning experiences in various scientific disciplines, enabling students to conduct experiments and explore scientific concepts in a virtual setting. Labster's innovative approach not only overcomes infrastructural barriers but also enhances learning outcomes by adapting to individual students' learning styles and providing immediate feedback (Sellnow et al., 2020).

One study conducted by Maria O. C. Fonseca et al. in 2021 investigated the impact of using virtual lab simulations, such as Labster, on students' learning

outcomes in a chemistry course. The researchers compared the performance of students who used Labster simulations with those who did not in a randomized controlled trial. The results showed that students who used Labster simulations achieved higher scores in exams and demonstrated a better understanding of complex scientific concepts compared to those who did not use the simulations (Fonseca et al., 2021).

Another study by Rebecca J. Sellnow et al. in 2020 assessed the impact of incorporating Labster simulations in an introductory biology course. The researchers found that students who used Labster simulations showed greater engagement, motivation, and interest in the subject compared to students who did not use the simulations. Additionally, students who used Labster simulations demonstrated better retention of key biological concepts and improved critical thinking skills (Sellnow et al., 2020).

These studies underscore Labster's ability to narrow the equity gap by effectively improving student learning outcomes and engagement in the realm of science education. Specifically, the platform has proven to bolster students' grasp of scientific concepts, boost their confidence in experimental processes, and cultivate a conducive learning environment. However, it is crucial to consider ongoing challenges such as ensuring access to technology and maintaining student engagement over time to fully realize its potential.

Case Study Analysis on AI's Impact on Education: Access, Equity, and Performance

The analysis of the selected case studies demonstrates that AI significantly enhances educational access and equity, particularly in developing countries. AI applications such as Eneza Education have provided learning materials to over 4 million students in remote areas, effectively reducing geographic barriers. Additionally, platforms like Project Read show high engagement levels, which contribute to increased student commitment and improved learning outcomes.

Regional Disparities in Infrastructure Access

The studies highlighted in Figure 1 demonstrate stark disparities in infrastructure access across Africa, Asia, Latin America, and Europe, which impact the effectiveness of AI educational tools. According to data from Calderón & Canales (2021) and Simon (2021), internet penetration in Africa remains at 40%, electricity access at 50%, and mobile device usage at 85%. In contrast, the studies show better infrastructure access in Asia, with 65% internet penetration, 75% electricity access, and 95% mobile device usage (Signé, 2023). Data from Latin America reveal further improvement, with 70% internet penetration, 85% electricity access, and 90% mobile device usage. Europe, according to World Bank data (2019), Foster et al. (2024) and OECD, (2024) leads in all categories with 95% internet penetration, 98% electricity access, and 92% mobile device usage, reflecting fewer infrastructural barriers to AI implementation in education.

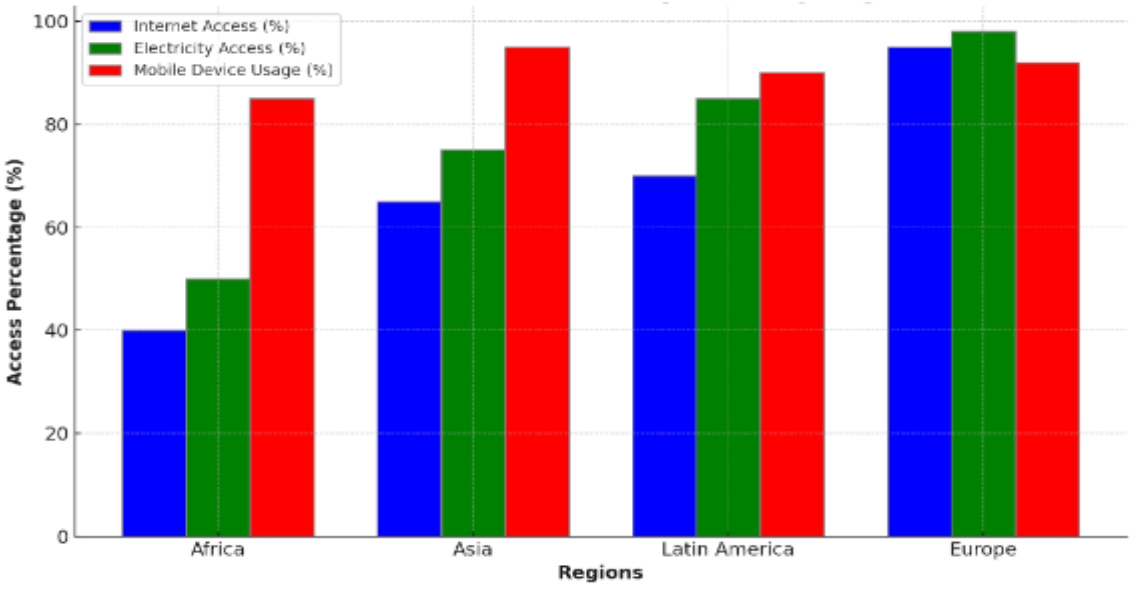

Figure 1: Infrastructure Access Comparison by Region

Comparative Analysis: Eneza Education Users vs. Non-Users

Figure 2 presents data from a study comparing the academic performance of students using Eneza Education to those not using the platform. The results show that students using Eneza experienced a significant 27.7% improvement in performance (TRECC, 2020). In contrast, the academic performance of non-users showed only minimal gains, demonstrating the limitations of traditional educational methods. Research consistently shows that AI-powered tools such as Eneza enhance engagement and academic outcomes, aligning with findings from previous studies on the impact of technology in education (Rashid &

Asghar, 2016; García-Martínez et al., 2023). Studies such as those by Akir et al. (2012) support the conclusion that direct engagement with AI-driven content leads to significant improvements in student performance.

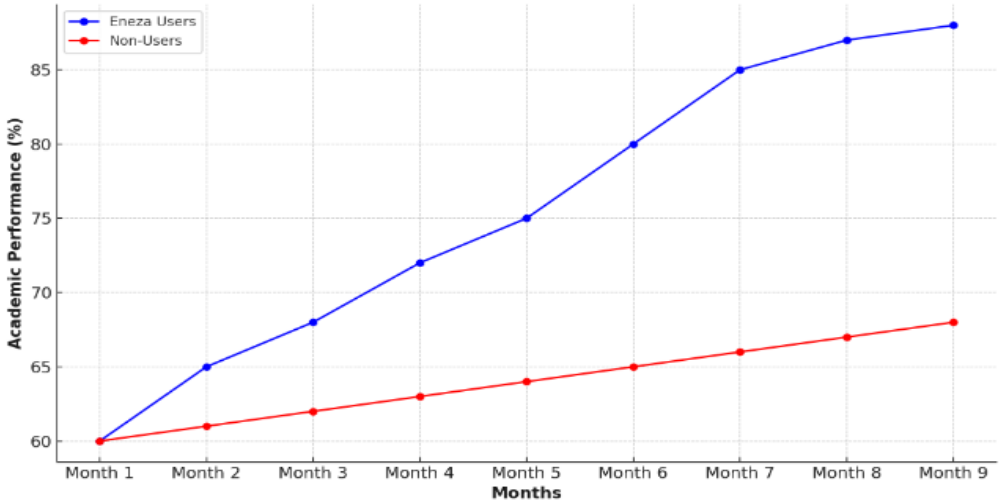

Figure 2: Academic Performance over Time: Eneza Users vs Non Users

AI Educational Tools: Reach, Engagement, and Performance

A comparative analysis of the reach, engagement, and performance improvement of AI educational tools—Project Read, Eneza Education, and Labster—demonstrates varying strengths across these metrics. According to studies, Eneza Education boasts an extensive reach, serving over 9 million learners in low-resource areas, with a 23% improvement in performance (Joffre, 2021). Labster, known for its interactive virtual labs, shows the highest levels of engagement, as confirmed by findings from Priscillia (2020), which highlight its immersive approach to learning complex scientific concepts. Data from Project Read demonstrate its ability to significantly improve literacy and reading skills, though its engagement levels are lower compared to Labster.

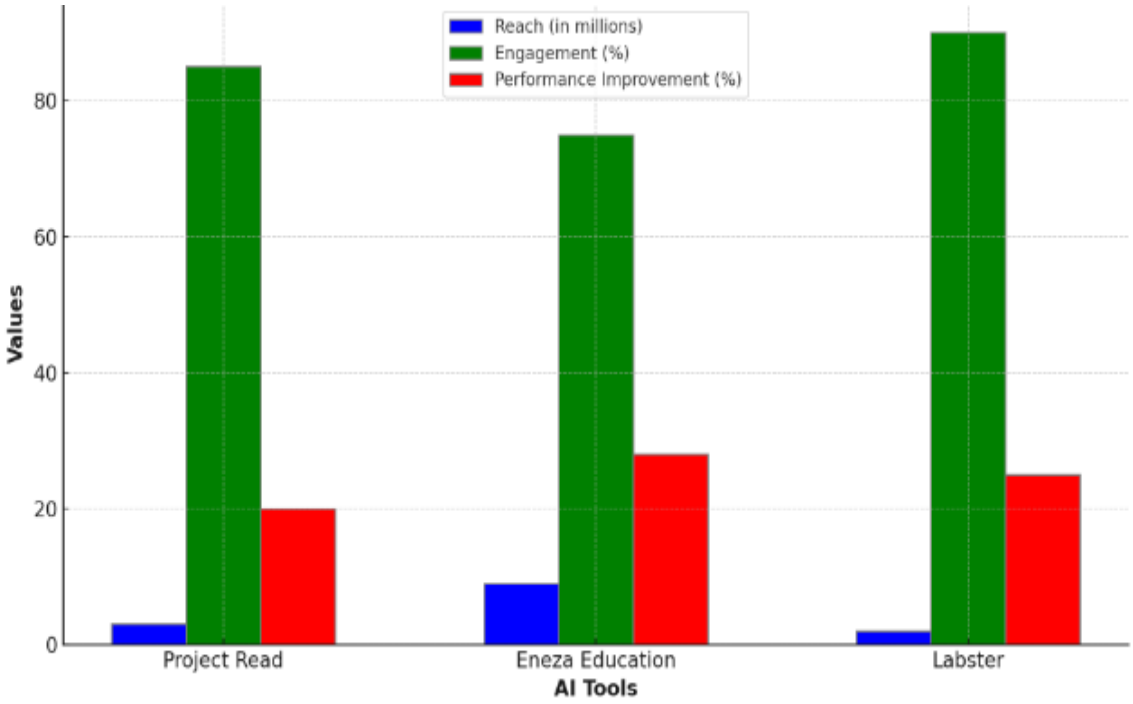

Figure 3: Comparative Analysis: Reach, Engagement, and Performance Improvement

Discussion

The exploration of various case studies illustrates that the innovative application of AI technologies effectively addresses both individual learning needs and systemic challenges in accessing higher education. Through the deployment of adaptive learning algorithms, personalized feedback systems, and accessibility tools, these AI applications confront issues

related to infrastructural limitations, resource scarcity, and the digital divide. Notably, a strong emphasis on data privacy and ethical AI usage has been paramount in these initiatives, ensuring that the advantages of AI in education are realized in a responsible and equitable manner. These case studies highlight AI's potential to revolutionize educational landscapes, rendering higher education more accessible, inclusive, and effective, particularly for students in developing countries.

AI's Role in Revolutionizing Education

The integration of Artificial Intelligence (AI) in education marks the beginning of a transformative era characterized by personalized learning experiences tailored to the diverse needs of learners. Initiatives such as Project Read and Eneza Education exemplify the effective use of AI to develop interactive and engaging educational resources. These platforms demonstrate AI's ability to transcend traditional barriers to learning by providing a wealth of educational materials that can be accessed through mobile technologies. This not only facilitates learning in various environments but also aligns with the broader goal of sustainable higher education, ensuring continuity in learning processes regardless of geographical and socio-economic challenges.

Enhancing Accessibility with AI Tools

AI's significant role in improving accessibility for students with disabilities is particularly noteworthy. Applications such as Microsoft Seeing AI and Google's Project Euphonia leverage sophisticated AI algorithms to provide features like audio descriptions and speech recognition, democratizing access to educational content. The integration of these tools into educational platforms is crucial in fostering an inclusive learning environment, where students with disabilities are granted equal opportunities to thrive academically.

AI in Expanding Access to Educational Resources

The implementation of AI in platforms like Labster, which offers AI-powered virtual simulations for STEM education, addresses the pressing issue of resource limitations in developing countries. By creating simulated hands-on laboratory experiences, AI enables students to engage in experiential learning and exploration, effectively overcoming the physical and financial barriers associated with traditional laboratory settings. This approach not only enriches the learning experience but also plays a pivotal role in leveling the educational playing field for students in resource-constrained environments.

Navigating Risks and Ethical Considerations

AI holds transformative potential in education, but addressing its associated risks and ethical concerns is critical to ensuring its equitable impact. Algorithmic bias remains a significant challenge, as AI systems trained on unrepresentative data may reinforce existing disparities. If these datasets primarily reflect urban or higher-income learners, they risk disadvantaging rural and low-income students by failing to account for their unique educational contexts. To address this, AI tools must be built using inclusive datasets that reflect diverse socio-economic and geographic backgrounds. Additionally, ongoing audits should be implemented to ensure that AI algorithms remain fair and unbiased as they evolve.

The digital divide also presents a formidable barrier, limiting the reach of AI-powered educational platforms in regions with poor access to electricity, internet, or digital devices. Without addressing these infrastructural gaps, the benefits of AI risk being concentrated in more developed areas, leaving underserved populations behind. Solutions like Eneza Education's SMS-based platform demonstrate how AI can be adapted for low-resource environments, offering accessible learning opportunities through basic mobile technology.

Overcoming these challenges requires collaborative action from governments, technology developers, and telecom providers to improve infrastructure and ensure that AI benefits all learners, regardless of their location or socio-economic status. By prioritizing inclusivity and fairness in AI development, we can unlock its full potential to promote educational equity globally.

Limitations

Despite the promising results, this study faces several limitations. The reliance on mobile-based platforms, such as Eneza Education, limits the generalizability of the findings to regions with robust mobile network access, making it difficult to extend conclusions to areas with poor connectivity. Additionally, the qualitative nature of the data may introduce subjective biases, especially in self-reported educational outcomes.

Another limitation is the dependence on external project reports, which could narrow the scope of the findings, as these reports might present a selective or incomplete view of the interventions' impacts. To address these concerns, it is important to acknowledge potential biases and take steps to mitigate them, such as triangulating data sources, incorporating objective measures, and validating findings through peer review.

Future research should aim to expand the scope of AI technologies to include students with disabilities and adapt these platforms for use in regions with severe infrastructure deficits. Furthermore, longitudinal studies are recommended to assess the long-term impact of AI interventions on learner performance over time.

Implications of the Study

1. **Policy Implications**: The findings underscore the need for policymakers to recognize AI as a pivotal tool in educational reform. Strategic investments in AI technologies can facilitate targeted interventions aimed at underserved populations, promoting educational equity. Policymakers must advocate for policies that support infrastructure development, ensuring that marginalized communities have access to the technological resources necessary for effective AI integration in education.

2. **Implications for Educators**: Educators are encouraged to embrace AI tools that enhance personalized learning and accessibility, tailoring their pedagogical approaches to meet the diverse needs of their students. By leveraging AI technologies, educators can foster an inclusive learning environment, empowering all students to engage meaningfully with educational content and resources.
3. **Technological Development Implications**: Technology developers play a crucial role in shaping the future of AI in education. There is a pressing need for developers to prioritize ethical AI design, focusing on creating solutions that are transparent, fair, and inclusive. The development of AI tools should also consider the unique contexts of their target populations, ensuring that these technologies are adaptable to various infrastructural and socio-economic environments.

Contributions to Knowledge

This study contributes to the growing body of literature on AI in education by providing empirical evidence of the effectiveness of AI technologies in enhancing educational access and equity. By showcasing the impact of specific initiatives like Eneza Education and Project Read, this research fills a critical gap in understanding how AI can be leveraged to address systemic barriers in education. Moreover, the exploration of infrastructural disparities and ethical considerations in AI deployment offers a nuanced perspective on the challenges and opportunities associated with integrating AI into educational frameworks. This research paves the way for future studies to further investigate the long-term effects of AI on educational outcomes and equity.

Recommendations

1. **Enhancing Infrastructure**: It is imperative for governments and international organizations to invest in the necessary infrastructure that supports the implementation of AI technologies in education. This includes improving internet connectivity, ensuring reliable electricity access, and providing training for educators and students on using AI tools effectively.
2. **Fostering Partnerships**: Collaboration between educational institutions, technology developers, and non-profit organizations can amplify the reach and effectiveness of AI educational initiatives. Strategic partnerships can facilitate resource sharing, best practice dissemination, and the development of localized solutions that address the specific needs of diverse communities.
3. **Ongoing Research and Evaluation**: Continuous research is essential to assess the effectiveness of AI tools in education. Longitudinal studies should be conducted to evaluate the impact of these technologies on learning outcomes over time, as well as to identify potential challenges and areas for improvement. Additionally, feedback from educators and students should be systematically gathered to inform the iterative development of AI applications.
4. **Commitment to Ethical Practices**: Stakeholders must prioritize ethical considerations in the deployment of AI technologies in education. This includes addressing potential biases in AI algorithms, ensuring data privacy, and fostering transparency in AI decision-making processes. An ethical framework should guide the development and implementation of AI tools, aligning them with the principles of equity and inclusivity.

Conclusion

In conclusion, AI has shown immense potential to improve access to education for marginalized groups, particularly in developing countries. Case studies like Eneza Education and Project Read illustrate how AI can tailor learning experiences to individual needs, helping to overcome barriers related to geography, technology, and socio-economic disparities. The notable gains in literacy and academic performance underscore AI's role in reshaping education and expanding opportunities for the most disadvantaged populations.

However, the widespread success of AI in education depends on addressing key infrastructure and ethical challenges. Stakeholders must collaborate to ensure equitable distribution of AI benefits. Investments in digital infrastructure, such as internet access and affordable devices, are critical to expanding AI's reach. Additionally, digital literacy programs for both educators and students are essential to maximize the effectiveness of AI tools.

Governments must also enact policies that promote the ethical deployment of AI, ensuring regular assessments to detect and mitigate biases, while also fostering inclusive AI development. Educational institutions should prioritize teacher training to enhance AI integration in classrooms, with AI tools customized to local languages and cultural contexts to increase their relevance. Regular feedback from users will be crucial in refining AI technologies to ensure continuous improvement and long-term success.

Declarations

Ethical Approval

Not applicable

Consent to Participate

Not applicable

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Conflict of Interest

None

Author's contributions

D. D. conceived the study, contributed to the methodology, and provided critical revisions. D. D. also played a key role in interpreting the results and reviewing the manuscript.

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