

Transforming Education through Generative AI: A Pathway to Equitable Learning and Literacy under SDG4

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ABSTRACT

The advent of Generative Artificial Intelligence (AI) represents a significant advancement in the field of education, particularly in addressing global educational disparities. This paper presents a knowledge transfer programme that integrates generative AI into teaching and learning practices, aligned with Sustainable Development Goal 4 (SDG 4), specifically SDG 4.5 and SDG 4.6. The programme focuses on reducing inequalities in education and improving literacy and numeracy rates among youth and adults, particularly within vulnerable and marginalized communities. The implementation of AI technologies in educational settings demonstrates their potential in fostering inclusive, equitable, and high-quality education, promoting lifelong learning opportunities for all.

INTRODUCTION

Education remains a cornerstone for sustainable development, underpinning the objectives set out in the United Nations' 2030 Agenda. Among these objectives, SDG 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Within this goal, SDG 4.5 seeks to eliminate gender disparities in education, while SDG 4.6 emphasizes the need for youth and adults to achieve literacy and numeracy by 2030 (SDG4). Despite global progress, significant disparities remain, particularly in marginalised communities where access to quality education is limited.

The knowledge transfer programme discussed in this paper addresses these disparities by leveraging generative AI technologies. Through strategic workshops and curriculum integration, the programme aims to enhance teaching and learning processes, ultimately contributing to the reduction of educational inequalities and improving literacy outcomes.

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GENERATIVE AI IN EDUCATION: NEW PARADIGM

Generative AI, a subset of artificial intelligence that can autonomously generate content such as text, images, and simulations, is increasingly being integrated into educational environments. These AI technologies offer significant potential in personalising education, supporting educators, and addressing the specific learning needs of students.

Enhancing Learning Materials

AI-driven technologies can create adaptive learning environments that respond to the unique needs of each student. For example, generative AI can generate customised reading materials tailored to the literacy levels of individual learners, which is particularly useful in addressing the specific challenges faced by students from marginalised communities. Studies have shown that AI-generated content improves student engagement and outcomes, particularly in subjects such as mathematics and reading.

Inclusive Learning for Marginalised Populations

Generative AI can also contribute to more inclusive education by developing learning resources in multiple languages and formats, thereby catering to students with disabilities and those in remote or underserved regions. This directly supports SDG 4.5's goal of ensuring equal access to education for vulnerable groups, including persons with disabilities and indigenous populations (SDG4).

RESEARCH GAP

While generative AI has been widely acknowledged for its potential to revolutionize education, its empirical application in structured academic interventions—particularly in higher education settings in developing countries—remains limited (Zawacki-Richter et al., 2019; Enholm et al., 2022). Most studies focus on theoretical potentials or early-stage adoption rather than measuring quantifiable learning improvements resulting from AI-assisted tools (Mozelius & Humble, 2024).

Moreover, existing research rarely examines AI's impact on student confidence, research skills, and motivation, despite these being key indicators of educational engagement and success (Fendos et al., 2022; Kakupa & Xue, 2019). There is also a notable lack of empirical work documenting how AI interventions can specifically address SDG 4.5 and 4.6 objectives in low-resource, post-pandemic academic contexts (Alqahtani et al., 2023; Denecke et al., 2023).

Thus, this study addresses a critical research gap by providing measurable evidence on how generative AI can be systematically integrated into postgraduate education through a knowledge transfer model to improve research proficiency and contribute toward achieving the broader SDG 4 targets.

METHODOLOGY

Implementing Learning the Knowledge Transfer Programme

The knowledge transfer programme, titled 'AI Nexus YIK 2024: Embracing Generative AI in Teaching and Learning', was a collaborative initiative with a local state government agency to empower educators through generative AI. The programme targeted SDG 4, specifically aiming at reducing educational disparities (SDG 4.5) and improving literacy and numeracy proficiency (SDG 4.6). Sixty teachers and representatives from each school in the state participated in this intensive three-day training course, making it a comprehensive and large-scale knowledge transfer programme.

Training Design and Structure

The training programme was meticulously structured into three phases over three days, each with specific objectives, learning outcomes, and hands-on activities. The curriculum was designed to build foundational knowledge on AI, provide hands-on experience with generative AI tools, and equip teachers with strategies for integrating AI into their classrooms effectively.

Day 1: Understanding Generative AI and Its Potential in Education The first day introduced participants to the basics of generative AI, including how it functions, its current applications, and potential future impacts in education. Key topics covered included:

- **Overview of AI and Generative AI:** Participants were introduced to AI's fundamental concepts, with a focus on generative models. Real-world examples were used to illustrate how AI can generate text, images, and interactive content tailored for educational purposes.
- **Ethical Considerations in AI:** Teachers were briefed on the ethical implications of using AI in classrooms, covering topics such as data privacy, AI bias, and the responsible use of AI in teaching. This discussion aimed to create awareness around the importance of implementing AI ethically to avoid reinforcing existing biases in educational materials.
- **Exploration of Padlet Resources:** Participants accessed curated resources through Padlet, including articles, videos, and interactive tools. These resources provided foundational knowledge about generative AI, covering aspects relevant to educators, such as AI-driven content creation, personalised learning, and adaptive assessments.

This foundational day ensured that participants understood the potential of AI in transforming education while considering the ethical aspects. By grounding teachers in these basics, Day 1 set the stage for a deeper dive into practical applications on the following day.

Day 2: Hands-On Experience with Generative AI Tools for Education The second day was dedicated to practical, hands-on experience with generative AI tools. This phase of the training aimed to enhance literacy and numeracy, directly addressing SDG 4.6 by enabling educators to create personalised learning materials. Key activities and learning objectives included:

- **Tool Demonstrations and Exercises:** Teachers were introduced to several AI tools capable of generating text, quizzes, visual aids, and interactive exercises. Each tool was demonstrated, followed by guided practice where teachers used the tools to create resources aligned with literacy and numeracy standards.
- **Creating AI-Generated Content for Literacy and Numeracy:** Teachers learned to generate AI-driven reading materials and math exercises, customized for varying proficiency levels. By tailoring content, educators could better support students who struggle with traditional learning materials, ensuring that resources are accessible and relevant to their unique needs. For example, teachers created simplified reading passages and math problems for lower proficiency students, thereby contributing to the goal of functional literacy and numeracy for all.
- **Incorporating AI-Enhanced Differentiation:** Participants explored how generative AI could support differentiated instruction. Using AI to create diverse learning materials allowed teachers to cater to individual learning paces and styles, thus fostering an inclusive classroom environment. This approach aligns with SDG 4.6's objective of achieving proficiency in literacy and numeracy across a range of skill levels, moving away from a one-size-fits-all model of education.

Through these activities, teachers gained firsthand experience in creating adaptable and engaging content. The focus on literacy and numeracy reinforced the importance of using AI as a tool to bridge educational gaps and ensure no learner is left behind.

Day 3: Curriculum Integration and Long-Term Implementation Strategies The final day focused on integrating AI-generated content into existing curricula and developing long-term strategies to ensure sustained impact. With an emphasis on SDG 4.5, the programme addressed how AI could help eliminate gender disparities and improve access to quality education for marginalised groups. Key components of the day included:

- **Collaborative Lesson Planning:** Teachers worked in groups to develop lesson plans incorporating AI-generated materials. These lesson plans were designed to be inclusive and accessible, with considerations for students with disabilities, language barriers, and gender-specific challenges. By focusing on curriculum integration, teachers learned to apply AI in a way that complements and enhances existing teaching methods.
- **Addressing Gender Disparities and Inclusion:** In line with SDG 4.5, the programme highlighted strategies to use AI tools to reduce gender-based disparities in education. For instance, teachers were encouraged to create AI-generated materials that are sensitive to cultural and gender contexts, ensuring that both boys and girls have equal access to high-quality learning resources. Discussions included the need to tailor materials to engage girls in STEM subjects, where they are traditionally underrepresented, and to support boys in areas where they may face disadvantages.
- **Developing an Inclusive Learning Environment:** Teachers were trained to create AI-driven resources that are accessible to students with disabilities. The programme provided insights into generating content in multiple formats, such as audio, visual, and simplified text, making learning accessible to students with various needs. This approach ensured that AI tools contribute to an equitable learning environment that accommodates all students, including those in vulnerable situations.
- **Long-Term Implementation and Sustainability:** The session concluded with a focus on long-term implementation strategies. Teachers received guidance on integrating AI into daily lesson plans and received templates for periodic assessment of AI tools' effectiveness in achieving literacy and numeracy goals. Emphasis was placed on continuous professional development, encouraging teachers to stay updated on evolving AI technologies and to adapt their strategies accordingly.

Programme Evaluation and Participant Feedback

To assess the effectiveness of the training, a structured evaluation framework was employed, incorporating both quantitative metrics on literacy and numeracy improvements and qualitative feedback from participants. The overall response to the programme was overwhelmingly positive, with diverse reactions reflecting participants' enthusiasm, aspirations for future implementations, and a desire for additional training.

- **Positive Reception and Enthusiasm:** A significant number of participants expressed that the training exceeded their expectations, praising the interactive and hands-on nature of the sessions. Many teachers found that the generative AI tools were not only practical but also transformative, opening new possibilities for personalised and engaging learning experiences in their classrooms. One participant noted, "This is a game-changer. I can already see how these tools will make my lessons more accessible and interesting for my students."
- **Requests for Additional Support and Practice Time:** While the majority embraced the potential of AI in education, some participants expressed that they would benefit from additional time and practice to master the AI tools. They appreciated the foundational skills gained during the three-day programme but felt that follow-up sessions or refresher workshops would enhance their confidence and proficiency. A participant shared, "The training was fantastic, but I would need a bit more time to fully integrate AI tools into my teaching routine."

- **Interest in Expanding the Training at School Level:** Several teachers showed keen interest in expanding the knowledge transfer programme to benefit their respective schools. They expressed a desire to train other teachers and staff within their schools, advocating for a more widespread adoption of AI in the curriculum. This enthusiasm for scaling the programme reflects a recognition of the value of generative AI in fostering inclusive, effective learning environments. One participant said, "This training is too valuable to keep to myself. I'd love to bring this back to my school and see how it can benefit other classes."
- **Emphasis on Positive Educational Impact:** Across the board, participants noted the potential impact of AI-driven resources on student engagement and learning outcomes, particularly for those who struggle with traditional educational methods. Many teachers anticipated that the individualised and differentiated AI-generated content would improve literacy and numeracy skills among students who require additional support, aligning directly with SDG Targets 4.5 and 4.6.

The overwhelmingly positive feedback and constructive insights highlight the programme's success and areas for potential enhancement. Based on participants' input, plans for follow-up support and expanded training at the school level are being considered to maximise the programme's reach and effectiveness.

Continuous Monitoring and Evaluation

The programme employed a robust evaluation framework to monitor the effectiveness of AI tools in improving educational outcomes. Key performance indicators included improvements in literacy and numeracy skills, particularly among students from vulnerable populations.

RESULTS AND DISCUSSION

This study examined the impact of generative AI tools on students' self-assessed research proficiency through a structured Triple-E intervention. A total of 24 participants participated in a pre- and post-assessment design to evaluate their research capabilities.

Improved Literacy and Numeracy

SDG Target 4.6 emphasizes the importance of ensuring that all youth and a substantial proportion of adults achieve functional literacy and numeracy by 2030. Unlike traditional views of literacy as a simple divide between 'literate' and 'illiterate', SDG 4.6 advocates for literacy as a continuum of proficiency levels. This perspective acknowledges that literacy and numeracy involve varying degrees of capability, ranging from basic to advanced, which are essential in different contexts.

Therefore, the generative AI initiative in this programme focuses on achieving relevant and recognized proficiency levels in functional literacy and numeracy skills for learners. By creating AI-driven, personalized content that adapts to individual learning paces and literacy levels, the programme aligns with SDG 4.6's objective of making education effective and inclusive for all students. In practice, this approach ensures that students who have previously been underserved by traditional educational resources can engage in meaningful learning experiences that address their unique literacy needs.

Quantitative Results: Research Capability Gains

Participants rated their research skills using nine structured items before and after the intervention. As illustrated in Figure 1, the mean scores for all nine indicators increased significantly post-intervention, with pre-intervention means ranging from 3.08 to 3.88 and post-intervention means from 4.54 to 4.96. A paired sample t-test revealed that these improvements were statistically significant across all items ($p < 0.001$),

demonstrating a meaningful enhancement in students' self-assessed research abilities following exposure to AI tools.

The standard deviation of score differences ranged from 0.721 to 1.32, with standard errors between 0.140 and 0.269, indicating consistency in the magnitude of change across the sample. These results confirm that the intervention yielded a robust and reliable improvement in key areas such as research formulation, topic alignment, and confidence in conducting research.

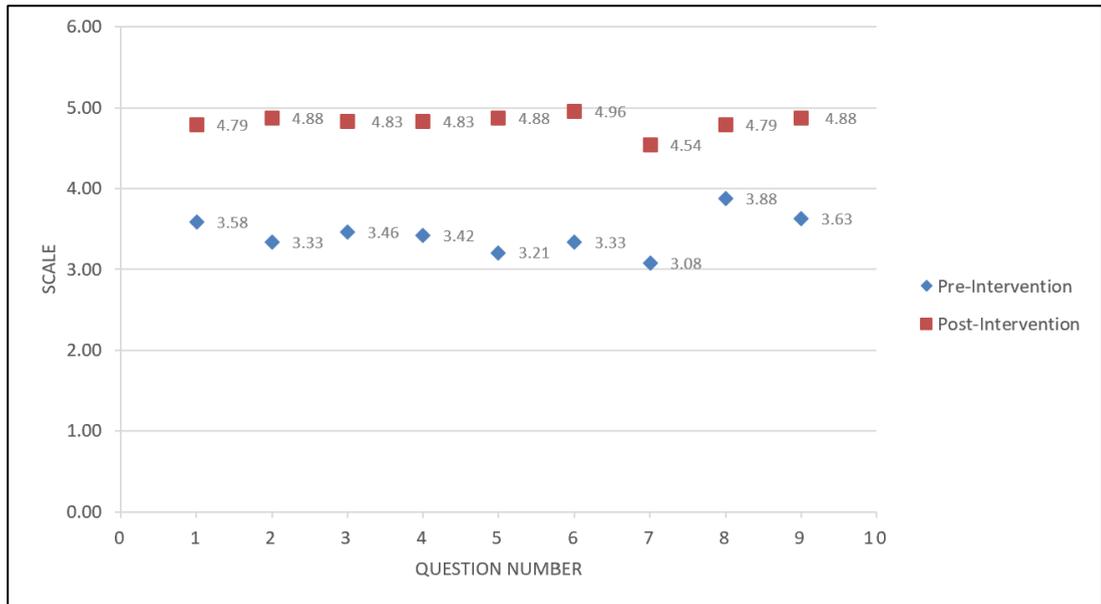


Fig. 1. Students's research capability pre- and post-experiment using AI tools

Promoting Gender Equality in Education

In alignment with SDG Target 4.5, this programme also aims to eliminate gender disparities in education and ensure that all students, regardless of gender, have equal access to high-quality educational opportunities. Target 4.5 underscores the importance of inclusion and equity, ensuring that education reaches everyone irrespective of factors such as sex, age, race, disability, or socioeconomic background. It particularly highlights the need to provide equitable educational access for vulnerable groups, including persons with disabilities, indigenous peoples, and children in vulnerable situations.

To address these disparities, the programme's generative AI tools produce diverse and inclusive content that caters to different cultural, linguistic, and cognitive needs. This inclusive approach not only supports girls and women, who may face barriers such as gender-based violence, early marriage, and heavy domestic responsibilities, but also provides targeted strategies for boys in contexts where they may be disadvantaged. By focusing on equitable access, the programme promotes a learning environment that is sensitive to the needs of all genders, in alignment with SDG 4.5's commitment to gender equality and inclusion in education.

Perceived Impact of AI Tools in Research

Beyond the quantitative outcomes, students were asked to assess the perceived contribution of AI tools to their research activities. Using a 6-point Likert scale, students rated their agreement with the statement “AI supports my research process” with an average score of 5.42, reflecting strong consensus on the tools’ positive impact.

To further understand this impact, qualitative feedback was collected and thematically analysed. Student responses to open-ended questions were grouped into four major themes, as illustrated in Figure 2:

- (i) Assistive (N=11): AI tools helped structure ideas, improve grammar, and clarify arguments
- (ii) Efficient (N=6): Highlighted time savings in literature review and information extraction
- (iii) Transformative (N=4): Described the interpretation of AI as fundamentally changing their approach to research
- (iv) Fascinating (N=3): Expressed a sense of curiosity and inspiration sparked by AI use.

This thematic insight affirms that AI not only enhanced technical research skills but also positively influenced students’ attitudes toward research.

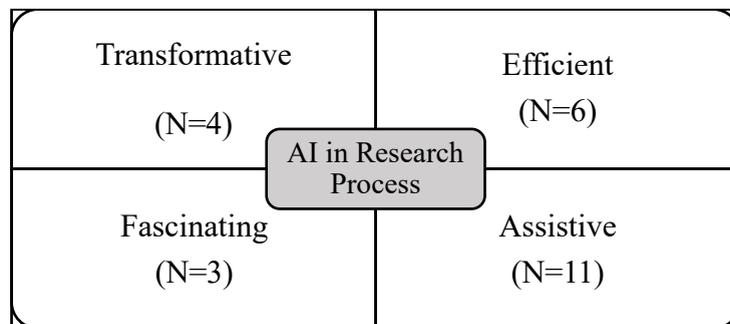


Fig. 2. AI Experience Themes

Enhanced Inclusivity for Vulnerable Groups

The integration of AI in research-based learning environments demonstrates strong potential to uplift research confidence, improve output quality, and streamline academic tasks. The statistically significant improvements across all measured indicators and the positive experiential feedback suggest that AI tools can serve as effective pedagogical enhancers in postgraduate education.

These findings contribute to the broader discourse on innovation in higher education by illustrating how thoughtfully implemented AI tools can drive both cognitive and affective learning outcomes. This supports the strategic adoption of generative AI in educational frameworks aligned with digital competency and research excellence.

Enhanced Inclusivity for Vulnerable Groups

The programme focus on creating AI-generated content in various languages and accessible formats ensured that students with disabilities and those from remote areas were not left behind. The use of AI technologies also allowed for the creation of culturally relevant educational materials, which fostered greater engagement among indigenous students.

Challenges and Future Directions

While the programme demonstrated considerable success, several challenges emerged during its implementation:

Technological Barriers

Access to technology, particularly in remote and underserved regions, remains a significant barrier. Many schools lacked the necessary infrastructure, such as reliable internet connections and access to AI tools. Addressing these barriers will require concerted efforts to improve digital infrastructure in marginalized communities.

Educator Training and Support

Ensuring that educators have the necessary skills to integrate AI technologies into their classrooms is critical for the programme's long-term success. Ongoing professional development and support are required to help educators navigate the complexities of AI tools and to address potential ethical concerns.

Ethical Considerations

The use of AI in education raises important ethical questions, particularly regarding data privacy and the potential for AI systems to reinforce existing biases. It is essential to develop ethical guidelines and frameworks to ensure that AI technologies are used responsibly in educational settings.

CONCLUSION

Generative AI offers transformative potential for addressing the challenges outlined in SDG 4, particularly in reducing educational inequalities and improving literacy and numeracy outcomes. The knowledge transfer programme discussed in this paper illustrates the ways in which AI can be harnessed to create more inclusive and equitable educational environments. By continuing to invest in AI-driven educational initiatives, we can make significant progress toward achieving the global goals for education and lifelong learning.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Nur Arfah Mustapha conceptualised the main research idea and led the writing of the manuscript. Zurina Ismail was responsible for designing the methodology and conducting the analysis. Nor Irvoni Mohd Ishar carried out the data analysis and contributed to interpretation of results. Zoel-Fazlee Omar contributed to the literature review and provided an overview of the study context. Mior Harris Mior Harun reviewed the

overall content and provided critical input on manuscript structure and coherence. All authors reviewed and approved the final version of the manuscript.

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