THE NEED FOR INTEGRATING SCIENCE AND TECHNOLOGY INTO ADULT LEARNING AND EDUCATION

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Abstract
The need for every adult to acquire education at any level or age, upgrade and update their knowledge, skills and capabilities in a science and technology driven world stresses the importance of incorporating science and technology into adult learning and education programmes for relevance, usability of skills and self-reliance. This study therefore, discusses roles of science and technology in the globalised knowledge economy. It highlights the problems confronting science and technology education in congruence with adult learning and education to include; prior learning experience, wide technological divides, accessibility and flexibility modules, inadequate experiential learning, inadequate supportive self-directed learning, outdated curriculum and lack of qualified instructors. To balance theory with practical, global best practices were explored. This study therefore seeks integration of science and technology into adult learning and education programmes, to allow adult learners participate and explore the science and technology driven world economy. Based on these, a number of recommendations were made, which rested majorly on the inclusion of science and technology into adult learning and education curriculum with the aim, to make adult education more adaptable, practical, and aligned with current technological advancements, ensuring adult learners participation in the growth of science and technology driven world.

Keywords: Science, Technology. Gerontology, Adult Learning, Curriculum

Introduction

Adult learning and education (ALE) is a paramount component of lifelong learning, that makes provision for educational needs of an important category of community populace; the adults. Adults are responsible for daily affairs of a nation and they are into various engagements to meet their daily needs and develop their environment. Adults' responsibilities make it unavoidably necessary to develop and acquire new skills, knowledge, and competencies needed for daily living. The recent development and advancement in science and technology (S&T) has brought a paradigm shift in all sphere of human endeavours (Xu, Liu, Cao, Huang, Liu, Qian, & Zhang, 2021). The changes are noticeable in work lives as advanced technology programmed machines that require new skills to get jobs done saturate work organisations. Advanced electronic gadgets are now required for communication, interaction and networking. Learning process itself is fast incorporating technological and AI tools for teaching and learning through blended learning strategies and online

platforms (Lapitan Jr., Tiangco, Sumalinog, Sabarillo & Diaz, 2021). AI tools are fast transforming teaching and learning from traditional teaching methods to online and individualized learning with real-time feedback. The challenge of being technology and science oriented by every adult place a new responsibility on adult learning and education to incorporate and make science and technology an essential integral part of its curriculum (Tan, 2018).

In most ALE programme across Africa, science and technology components are not given the needed space in spite of the relevance of science and technology in modern day society (Ojobanikan, Mandah, & Foyewa, 2024). This omission could result in adult learners been found wanted of the right and necessary knowledge and skills needed to fully engaged and benefit from the digital economy, keep abreast and adapt to technological changes, make informed decisions and turn their situation around.

This article therefore explores potential and challenging areas of by S&T in ALE and thus, argues that integrating by S&T into ALE is *sin qua non* to propagate and advance inclusive, sustainable, and innovative learning opportunities in the world knowledge based economy..

Literature Review

The 21st century has witnessed a paradigm shift in traditional ways of doing things to a modern and sophisticated means through groundbreaking development and advancement in science and technology (Xu, et al., 2021). This new trend has afforded all spheres of human endeavours a new face and transformation with additional pressure and responsibilities on all for compliance and relevance. While concerted efforts are been made on S&T into primary, secondary and higher education curriculum and practices, ALE have been literally left behind ((Lapitan Jr, et al., 2021). This review therefore x-rays the need for integrating S&T into ALE, the potentials challenges and potential strategies for implementation.

1. The Role of Science and Technology in Education

Science and technology (S&T) have played a crucial role in modern education, enhancing accessibility, flexibility and engagement. The integration of digital tools such as e-learning platforms, artificial intelligence, and virtual reality has revolutionized traditional education systems (Merriam & Bierema, 2014). In ALE, S&T have become integral to its transformation and expansion for numerous benefits. Traditionally, adult education was been delivered predominantly through face-to-face interactions, with minimal consideration of S&T. The breakthrough in S&T has brought digital revolution with significant shift approach to education; ALE inclusive. Merriam and Bierema added that the rise of the internet, mobile devices, and multimedia tools significantly expanded access and reshaped learning environments. The growth of Massive Open Online Courses (MOOCs), e-learning platforms, and mobile learning (m-learning) has diversified educational opportunities for adults worldwide (Bates, 2015). The application of information and communication technologies (ICTs) in ALE is being championed by international bodies such as UNESCO and the OECD. ICTs have allowed adults, particularly in marginalized communities, to engage in continuing education and skills development.

Knowle in his theory of andragogy postulated that adults are

self-directed learners who bring prior experiences to their learning situations (Atlamaz, 2021). This lend credence to cognitive science revelations and insights on adult learning theories, providing in-depth knowledge on how adults acquire, process, and retain knowledge. Knowles (1980) opined that incorporating technology into learning environments improves retention, motivation, and learner's autonomy. Technology-enhanced learning environments equipped with adaptive learning systems tailor learning content on the learner's progress, preferences and performance (Johnson, Adams Becker, Cummins, Estrada, Freeman & Hall, 2016). These learning systems rely on S&T to understand learning processes to enhance learning impacts. Thus incorporation of S&T to ALE would enhance the rate of assimilation, retention, individualised learning and learning outcomes of every adult learner.

Importantly, the 21st century is predominantly characterized by rapid technological change thus, the need for continuing education and lifelong learning for re-training, re-skilling and up-skilling for up to date skills, knowledge and job relevance (Ojobanikan, 2025). The concept of lifelong learning embraces continuous learning and skill development throughout an individual's life, currently influenced by digital tools and materials developed through S&T. Hence, digital competence becomes a key component of lifelong learning. It becomes a responsibility for ALE to adapt S&T, to equip adults with skills required in digitalized economy.

Another significant contribution of S&T in ALE is the expansion of access to education. Learning is taken above geographical and temporal barriers through distance learning approaches aided by ICT tools such as computers, mobile devices, and online digital platforms to the reach of the under-served and remote areas. This digital democratization of learning has endowed adults across socio-economic and educational divides, participation in educational opportunities (Motorga, 2023). Highlighting the importance of S&T to ALE, Thompson (2011), stated the potentials of ICT in delivering instructions beyond traditional classrooms with effective cost reduction. Availability of educational technologies such as Open Educational Resources (OER) and Mobile Learning (m-learning) has significant impacts and critical roles in widening access in spite of the infrastructural and policy limitations. They offer autonomy, mastery, and immediate feedback, which are aligned with adult learning theories like andragogy (Knowles, 1980). AI-guided tutoring has been reported to demonstrate positive outcomes in adult education. Holmes, Bialik & Fadel (2019 reported effectiveness of AI-based tutors in promoting learner persistence and decreasing dropout rates in online adult education programmes.

Equally, the concept of digital inclusion underscores that equitable education requires more than infrastructure; it demands digital literacy, cultural relevance, and supportive learning environments (Parveen, Jan, Bashir, Ganie, & Zimik, 2025). OECD (2021) analysis revealed the importance of system-level interventions in infrastructure, pedagogy, and inclusive technology design to closing of digital divides.

Science and technology brought about inclusive pedagogical frameworks through principles such as Universal Design for Learning (UDL), integrate Assistive Technologies to accommodate diverse learner abilities and specialities, extending engagement for those with disabilities. The learning delivery has been enhanced through

digital tools by restructuring instructional methods. Blended learning, combining online and face-to-face approaches have demonstrated improved learner satisfaction and engagement (Sahni, 2019).

The assessment and evaluation strategies become learner-centred. Technology enables more formative assessment through intelligent tutors and analytics that track learning progression and enhances responsiveness in the instructional design. AI-driven tutoring systems enable adaptive and real-time feedback, peer and mentor interaction, thereby reinforcing social support and motivation (Gupta and MacLellan, 2025)

In systemic quality assurance, S&T are not wanted. Its relevance prevails in simplifying the aggregation of data for continuous programme evaluation. It also plays a critical role in detecting academic risk and misconduct. Tools like plagiarism checkers (i.e. turn-it-in) improve academic integrity and originality in the learners output (Suseela, 2016).

Science and technology not only benefit learners but also significantly enhance the effectiveness of educators in adult learning environments. Technology serves as a catalyst for continuous professional development, collaboration, and pedagogical innovation. Digital tools like webinars, MOOCs, and online learning communities enable educators to access up-to-date content and best practices. Bates (2015), emphasized that online professional development provides flexibility for adult educators, many of whom work part-time or in dispersed geographical areas. The integration of LMSs in blended learning models enhances instructional design that promotes active learning and improves communication between instructors and adult learners.

2. Science and Technology in Adult Learning and Education: The Challenges

In spite of the benefits, the integration of S&T into ALE is not without challenges. Adult learners face unique challenges, including time constraints, financial limitations, and lack of digital literacy. According to Brookfield (2015), adults often struggle with adapting to new technologies due to cognitive and psychological barriers. The lack of institutional support in many adult education programmes further exacerbates the problem, limiting the effectiveness of technological integration. Selwyn (2016) warned against uncritical adoption of educational technologies, urging stakeholders to consider whose interests are being served and the broader social implications. Moreover, reliance on technology may inadvertently marginalize individuals with low digital literacy or limited access to digital infrastructure as digital divide remains a persistent issue in design and implementation of technology in ALE. Bridging the digital divide equally remains a critical challenge in ensuring equitable access to adult learning opportunities. The digital divide encompasses gaps in access to devices, internet connectivity, and digital literacy barriers that disproportionately affect marginalized populations (van Dijk, 2020). Thus, S&T must be leveraged alongside inclusive policies and support systems. Initiatives such as community access centres and library-based digital hubs could mitigate these challenges by providing shared access to technology and training.

3. Theoretical Framework

This article is underpinned by the theory of transformative learning by Jack Mezirow, (1991) and andragogy

learning theory by Malcolm Knowles, (1984) that seek to critically explain how adults learn, how technology enhances learning processes, and how access, equity, and quality of education could be addressed in diverse educational contexts.

3.1. The transformative learning theory

This theory posits that adult learning can be a transformative experience that changes individuals' perspectives, values, and behaviors. Integrating S&T into ALE can facilitate transformative learning by promoting adult learners' critical thinking, problem-solving, and innovation as well expose adults to new information, challenging existing assumptions, and facilitating dialogue through digital platforms. Technology can democratize access to transformative learning opportunities, yet there are challenges in ensuring that digital platforms foster genuine critical discourse. Furthermore, cultural and contextual relevance is essential; otherwise, learners may reject information perceived as externally imposed or irrelevant (Taylor & Cranton, 2012).

3.2. Andragogy Theory

At the core of ALE is Malcolm Knowles' theory of andragogy, which posits that adult learners are self-directed, bring prior experiences to the learning process, are motivated by internal factors, and seek learning that is relevant to their lives (Knowles, 1980). This theory supported integration of technology as it aligns with adult learners' need for autonomy and flexibility. Digital platforms and online resources empower adults to control the pace, timing, and content of their learning, thus enhancing motivation and engagement. While andragogy justifies the use of technology in ALE, it often overlooks systemic barriers such as digital literacy gaps, access to infrastructure, and socio-economic disparities. The theory assumes a level playing field where all adults can make autonomous choices, which may not reflect the realities in marginalized or rural communities.

It is crystal clear that incorporating S&T into adult learning and education would bring learner's autonomy, effective engagement and transformation into the life of the adult learners cum relative changes in disposition to issues and assumptions as a result of prior life experiences.

4. The Impact of Technology on Lifelong Learning

There is need to explores the impacts of integrating S&T into ALE, with a focus on crucial thematic areas: digital literacy, scientific literacy, innovation and entrepreneurship, sustainable development, technology-enhanced learning environments, workforce development, and equity and inclusion.

i. Digital Literacy in Adult Learning and Education: Digital literacy refers to the capacity to access, evaluate, and communicate information using digital tools and technologies (Maphosa & Bhebhe, 2019). It extends beyond technical know-how to include critical thinking, information ethics, and creative problem-solving using digital platforms. In adult education, digital literacy is crucial not only for employability but also for full civic and social participation. Ala-Mutka (2011) argued that building digital competence among adults promotes lifelong learning by enabling learners to access a wider range of educational resources and experiences. Furthermore, digital literacy contributes to equity and inclusion in ALE.

ii. Scientific Literacy for Informed Citizenship: Scientific literacy involves the knowledge and understanding of scientific concepts and processes necessary for personal decision-making, civic participation, and economic productivity (Dibner & Snow, 2016). In adult education, fostering scientific literacy is crucial for enabling individuals to engage with contemporary issues such as climate change, public health, and technological innovation. Research indicated that scientifically literate adults are more likely to make informed health decisions, support evidence-based policies, and engage in critical discussions about science-related societal issues (OECD, 2019).

iii: Innovation and Entrepreneurship in Adult Learning: As the nature of work changes due to technological advancements, adults need to be equipped not only with job-specific skills but also with the mindset and tools necessary to innovate, adapt, and create new opportunities. Integrating S&T into adult learning helps individuals become more proactive, self-directed, and resilient in a competitive labour market. Adult education that fosters S&T encourages learners to engage in problem-solving, critical analysis, and the application of new technologies to real-world challenges (Volles, 2016).

iv. Technology-Enhanced Learning Environments in Adult Education: The integration of digital technologies into learning environments has significantly transformed how adults access, engage with, and benefit from education. Technology-Enhanced Learning (TEL) refers to the use of digital tools and platforms to support teaching and learning processes. In the context of adult education, TEL offers opportunities for more flexible, personalized, and inclusive learning experiences. It also enhances the interactivity and engagement of adult education.

v. Workforce Development and Lifelong Learning: One of the key benefits of science and technology in workforce development is the emphasis on science; technology, engineering, and mathematics (STEM) related skills. These skills not only align with job market trends but also foster critical thinking, problem-solving and data literacy competencies essential across various sectors. In addition to technical skills, employers increasingly value soft skills such as communication, collaboration, adaptability, and lifelong learning orientation. Adult education programmes that integrate S&T can embed these competencies through collaborative projects, interdisciplinary learning, and real-world problem-solving tasks (Cedefop, 2017).

vi. Equity, Inclusion and the Digital Divide in Adult Learning and Education: As S&T become central to adult learning, ensuring equity and inclusion has emerged as a critical concern. there is risk of deepening existing social inequalities if access and participation are not carefully addressed. The digital divides in access to technology and digital skills remains a significant barrier for many adult learners worldwide (Van Dijk, 2020). Ensuring equity in ALE means recognizing and addressing structural barriers to participation.

vii. Global Policy Perspectives and Frameworks on Science, Technology and Adult Learning: The growing recognition of the role of S&T in adult learning has led to the

development of several international policy frameworks and initiatives aimed at guiding countries in integrating these elements into adult education systems. These frameworks provide strategic direction, promote best practices, and encourage cross-national collaboration to make lifelong learning more inclusive, relevant, and future oriented. At the heart of global education policy is the 2030 Agenda for Sustainable Development, particularly Goal 4, which aims to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'.(UN, 2015).

5. Exploring best practices in implementing science and technology in adult education

In ensuring appropriateness in the implementation of S&T into adult learning and education, best practices in design must incorporate reliable systems, promote self-efficacy and motivation and foster social and organizational support. Proven Models like Technology Acceptance and Adoption Models (TAM) must be imbibed. The model underscored the perceived usefulness and ease of use that determines users' behavioural intention to adopt technology. It engages variables like instructor and learner capacity, self-efficacy, social norms and system quality, improving explanatory power in positive usage of technology in the educational contexts (Pan, 2020).

Similarly, to bolster empirical evidence and wider reach, particularly in low-resource regions Open Educational Practices (OEP) such as Open Education Resources (OER), open licensing, and shared teaching strategies are to be recognized and use as tools for enhancing accessibility and equity in adult science education and lifelong learning programmes. The repository and Open Educational Resources (OER) is a practice that offers free access to educational materials irrespective of space and time at no cost to the learner. In adult education, it is capable of improving access and innovation especially in vocational training.

In the same vein, learning must be active and challenge-Based as active learning has been reported to yields tremendous success in STEM education. Challenge-based learning, though less quantified in adult education, fosters critical 21st-century skills and engagement. It aligns well with S&T education where learners solve real-world problems in collaborative settings (Sánchez & Cortés, 2024).

Again, blended learning complements online and face-to-face modalities to improve flexibility and satisfaction. In adult education programmes, learners deeply valued initial in-person sessions as a result of benefits like peer networking, flexibility, and reflective time.

The future of adult learning and education in the global world need AI-driven personalization and intelligent tutors. Adaptive learning platforms powered by AI adjust difficulty and pace to support tailored learning especially in vocational science training through intelligent tutoring systems (Gupta & MacLellan, 2025).

The use of Broadcast Media in Low-Resource Contexts has been very instrumental in outreach to rural learners over the years. Post-COVID further underscore the necessity of these models as it offers convenience in learning space. The future of adult learning and education is bright with the incorporation of S&T as a result of numerous benefits.

Conclusion and Recommendation

S&T have revolutionised education as a whole. Its impact is enormously enhancing access, personalizing learning, equity and quality. Thus, integration of S&T into adult learning and education offers potential and powerful strategies for equipping adults to strive and thrive in a rapidly changing knowledge based world digital economy. Its potentials promote inclusive, sustainable and innovative learning opportunities; adaptation to technological changes, fostering of lifelong learning requisite to informed decisions about health, environment and civic engagement. Yet, realizing this goal requires systemic commitment, inclusive strategies, and proactive policies.

To this end, it is therefore recommended that; there should be policy reform and revitalisation. Governments and educational institutions should revise ALE policies to prioritize the integration of science and technology into ALE programs; universal access to digital tools and broadband infrastructure should be created with initiative such subsidizing devices for low-income learners, expanding public internet access points, and ensuring platforms are accessible to individuals with disabilities; ALE programmes should develop curricula that incorporate S&T subjects, such as digital literacy, scientific literacy, and innovation. The curricula should be co-developed with industry partners, scientific institutions and technology firms to ensure alignment with future workforce needs.

Adult education teachers and facilitators should training and educated on integrating S&T into ALE programmes to promote innovative teaching methods and assessment strategies. Huge investment should be made on professional development to ensure digital competence, STEM pedagogy, and inclusive practices. This could also be achieved through Micro-credentials and peer mentoring; ALE programs should engage with local communities, promote partnerships with industries, organizations, and stakeholders to support S&T education. Partnership is *sin qua non* to innovation and global best practices as it could support adequate funding; S&T components imbedded into adult education must recognise the linguistic, cultural and experiential backgrounds of learner's fast track assimilation and prompt usage of knowledge gained.

More so, learning contents and platforms must be flexible, gender-responsive, and intergenerational and intersectional tailored towards learners' specific life and work contexts; Online courses, mobile applications and blended learning approaches should be adapted to cater to diverse adult learning needs and backgrounds.

Implementing the following suggested recommendations will go a long way to influence ALE programmes, to be responsive to the needs of adult learners, promote inclusive, sustainable, and innovative learning opportunities that breed more knowledgeable and technologically competent adult population.

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