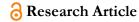
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## Leveraging AI and ICT for Greener Education in the Face of Climate Change in Smart Classrooms

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#### Abstract

Artificial Intelligence (AI) and Information and Communication Technology (ICT) are reshaping educational approaches to sustainability and climate action, fostering environmentally responsible attitudes among students. The study seeks to find how the integration of Artificial Intelligence and Information and Communication Technology in Higher Education Institutions (HEIs) affects the promotion of sustainability and climate action among students and the extent to which these technologies enhance student engagement with sustainability concepts, facilitate diverse perspectives on climate issues and contribute to the overall reduction of the carbon footprint of educational institutions. Many academic institutions struggle to effectively integrate these technologies into their curricula, which may hinder the potential to engage students in meaningful ways regarding sustainability and climate action. Educators can personalise learning by utilising AI-driven analytics and ICT tools, making sustainability concepts more engaging. AI can assess learning patterns to deliver tailored content that highlights environmental stewardship, while ICT provides access to global resources, allowing students to explore climate issues from diverse perspectives. Smart technologies like IoT devices and virtual learning platforms are crucial for reducing the carbon footprint of educational institutions. Online learning minimises the need for physical infrastructure, reducing travel-related carbon footprints. By incorporating these technologies into curricula, institutions can cultivate a generation of informed, environmentally-conscious citizens. This study employs a qualitative approach to evaluate AI and ICT's impact on promoting sustainability in university education. Data were collected through interviews with students and lecturers. Students reported increased engagement through AI-enhanced platforms. Lecturers indicated that the universities that use IoT energy monitoring reduce energy consumption. Recommendations include investing in lecturer training for AI and ICT integration, developing interdisciplinary curricula focused on sustainability, improving IoT infrastructure for energy management, encouraging crossdepartmental collaboration on climate issues, and promoting student participation in sustainability-focused research projects. These steps can significantly enhance educational strategies and foster student commitment to climate action.

**Keywords:** Artificial Intelligence, Climate Change, Greening Education, Information and Communication Technology, Smart Classrooms, Sustainable Development

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#### 1. INTRODUCTION

As the tangible repercussions of climate change threaten ecosystems, economies, and human societies on a global scale, there is a rising imperative for the integration of sustainability and climate action within education (Dwivedi et al., 2022; Mochizuki & Bryan, 2015). Recent media coverage and scientific reports illuminate the urgent need for immediate action, making it clear that educational institutions,



especially Higher Education Institutions (HEIs), have a crucial role to play (Dzvimbo et al., 2022; Leal Filho et al., 2021). Not only do HEIs shape the minds of future leaders, innovators, and problem solvers, but they also stand as exemplary models by incorporating sustainable practices into their curriculum and operations. The societal expectations surrounding educational institutions have shifted dramatically, with stakeholders including students, parents, and local communities demanding more environmentally responsible practices. It is no longer sufficient for educational programs to merely discuss climate issues; they must actively engage students in projects and practices that promote sustainability. The United Nations' 2030 Agenda underscores education as a fundamental pillar in achieving the Sustainable Development Goals (SDGs), particularly Goal 4, which emphasises Quality Education, and Goal 13, which advocates for Climate Action (Manokore et al., 2022; Mhlanga et al., 2022; Shava et al., 2024). There is a growing recognition that education for sustainable development (ESD) is essential for fostering an environmentally aware populace. However, the challenges posed by climate change cannot be adequately addressed through isolated disciplines. Instead, an interdisciplinary approach that weaves environmental considerations throughout various subjects is crucial for nurturing a holistic understanding of sustainability. This is where technological advancements, particularly in Artificial Intelligence (AI) and Information and Communication Technology (ICT), come into play. These digital tools offer unique opportunities to enhance sustainability education, allowing for diverse information access and innovative learning experiences that transcend traditional classroom boundaries.

The future workforce must be prepared to confront complex sustainability challenges, necessitating that educational systems adapt and equip students with the skills required for emerging green jobs and sustainable practices (Mian, et al., 2020). As governments and industries increasingly prioritize sustainability, educational institutions that adopt responsible practices can benefit from enhanced funding and partnership opportunities while drawing the interest of the next generation of environmentally conscious students. Ultimately, educating students about sustainability cultivates a generation of informed citizens committed to climate action and fosters long-term behavioral changes that reverberate throughout society (Levy et al., 2023). By harnessing the capabilities of AI and ICT within smart classrooms, educators can create a dynamic and engaging learning environment that empowers students to contribute meaningfully to the pressing climate challenges of our time, thereby securing a greener future for all. The study is underpinned by the following research questions:

- i. How do AI and ICT contribute to sustainability and climate action among students?
- ii. How do these technologies enhance student engagement with sustainability concepts?
- iii. To what extent can they facilitate diverse perspectives on climate issues?
- iv. What role do they play in reducing the carbon footprints of educational institutions?

#### 1.1. Literature Review

The quest for greener education amidst the climate crisis is rooted in a robust theoretical framework that empowers educators to effectively integrate technology into their teaching practices while fostering student sustainability awareness. Central to this framework is the concept of Technological Pedagogical Content Knowledge (TPACK), which emphasises the symbiotic relationship between technology, pedagogy, and content knowledge (Koehler et al., 2014). TPACK serves as a guiding principle for educators to navigate the complexities of integrating AI and ICT into the curriculum, ensuring that technology enhances rather than detracts from meaningful learning experiences. In the context of sustainability education, educators must possess a deep understanding of environmental issues and challenges while employing pedagogical methods that engage students meaningfully. Furthermore, they must be adept at leveraging technological innovations such as AI-powered simulations, interactive platforms, and digital learning resources to create immersive learning experiences that illuminate the complexities of sustainability. For instance, an educator teaching about climate change could use AI tools to analyse real-time environmental data, helping students visualise the impact of human actions on ecosystems. By integrating technology in this manner, educators not only enhance student engagement but also promote critical thinking and problem-solving skills essential for tackling real-world sustainability challenges.

In addition to TPACK, the framework draws upon models of smart learning environments and educational spaces that utilize advanced technologies to create personalised and flexible learning experiences. Smart classrooms are at the forefront of this paradigm, employing tools such as adaptive

learning technologies, data analytics, and collaborative platforms to foster an engaging and interactive educational atmosphere. These environments facilitate the integration of sustainability education by enabling students to explore ecological issues in a variety of contexts and collaborate on projects that address local and global challenges. A smart classroom could incorporate IoT (Internet of Things) devices to monitor energy usage, allowing students to conduct real-time energy audits and develop strategies for reducing waste on campus. This hands-on approach not only deepens students' understanding of sustainability but also empowers them to make tangible contributions to their communities.

Moreover, the theoretical framework encompasses engagement theories focused on sustainability education. These theories emphasise the importance of active participation and collaborative learning as essential components for fostering a sense of responsibility and agency among students. By engaging students in experiential learning opportunities such as collaborative projects, sustainability challenges, and community outreach they can connect theory to practice and witness the real-world impact of their efforts. Incorporating project-based learning that centers around local environmental issues enables students to actively engage with their community, fostering a sense of ownership over the solutions they propose. Engagement theories advocate for co-learning and peer-to-peer teaching, where students take on leadership roles, share their insights, and collectively brainstorm innovative approaches to sustainability. The theoretical framework that underpins the integration of AI and ICT for greener education encompasses TPACK, models of smart learning environments, and engagement theories related to sustainability. By aligning technology, pedagogy, and content knowledge, educational institutions can cultivate a learning environment that empowers students to become informed advocates for climate action. This holistic approach not only enhances the educational experience but also fosters a generation of environmentally conscious individuals equipped with the skills and knowledge necessary to navigate the complexities of the climate crisis and contribute to a sustainable future

# 1.1.1. Contribution of AI and ICT to Sustainability and Climate Action among Lecturers and Students in Higher Education

Artificial Intelligence (AI) and Information and Communication Technology (ICT) are becoming instrumental in promoting sustainability and climate action within higher education institutions (HEIs) (Leal Filho et al., 2024). These technologies enable lecturers and students to access vast resources and data analytics that inform sustainable practices and climate-sensitive decision-making (Baron, 2023; Kukulska-Hulme et al., 2024). For instance, AI-driven platforms can help analyse energy consumption patterns in campus facilities, optimizing energy use and reducing waste (Alijoyo, 2024). According to Wu et al. (2018), ICT facilitates communication and collaboration among students and faculty, allowing them to partake in global sustainability initiatives and research projects aimed at mitigating climate change. By harnessing these technologies, HEIs not only promote awareness and education around climate issues but also demonstrate their commitment to sustainability in practice.

# 1.1.2. How Technologies Enhance Student Engagement with Sustainability Concepts in Higher Education

Technological tools significantly enhance student engagement with sustainability concepts in higher education by providing interactive and immersive learning experiences (Bizamu et al., 2023). Online platforms, virtual simulations, and Augmented Reality (AR) applications allow students to visualize complex environmental issues and solutions in real-time (Chasokela, 2024). For example, using GIS (Geographic Information Systems) technology, students can actively map community resources and analyse their sustainability. Furthermore, gamified learning experiences foster competition and motivation, encouraging students to explore sustainability challenges creatively (Haque et al., 2024). The ability to collaborate with peers globally through ICT creates a richer, more nuanced understanding of sustainability, as students are exposed to diverse perspectives and approaches, fostering a sense of global responsibility.

#### 1.1.3. Extent Technologies Can Facilitate Diverse Perspectives on Climate Issues

Technologies are crucial in facilitating diverse perspectives on climate issues by connecting individuals across geographical and cultural boundaries (Kohler et al., 2019). According to Dwivedi (2022), social media platforms, online forums, and collaborative tools allow students and researchers from varied backgrounds to share their insights and experiences regarding climate change and sustainability efforts. This exchange of ideas promotes a multidimensional understanding of climate challenges and solutions, crucial

for addressing this global issue effectively. Moreover, digital libraries and global datasets enable access to a wide array of research and case studies, allowing students to examine different cultural approaches to climate action, thereby enriching their educational experience and fostering inclusive discussions (Borgman et al., 2015).

# 1.1.4. The Role Played by Technologies in Reducing the Carbon Footprints of Educational Institutions

Technologies are instrumental in helping educational institutions reduce their carbon footprints through energy management, efficient resource utilization, and sustainable practices (Maksimovic, 2018). Smart building technologies, such as IoT sensors, monitor energy consumption in real-time, allowing institutions to optimize heating, cooling, and lighting systems based on actual usage (Jia et al., 2019). Additionally, digital learning environments reduce the need for physical resources, such as paper and textbooks, by promoting online resources and digital assignments (Haleem et al., 2022). Furthermore, cloud computing enables efficient data storage and processing, minimizing the need for on-site data centers that contribute to carbon emissions (Shuja, 2026). By integrating these technologies, HEIs can significantly contribute to reducing their overall environmental impact.

#### 1.1.5. Current Challenges to Effective Technology Integration in HEIs

Despite the potential benefits, effective technology integration in higher education institutions faces several challenges (Bubou & Job, 2021; Chasokela & Moyo, 2024; Chasokela et al., 2024). One significant barrier is the digital divide, where access to technology and internet connectivity is unequal among students, particularly in marginalised communities (Mathrani et al., 2022). Additionally, faculty may lack the necessary training and support to incorporate new technologies into their teaching practices effectively (John, 2015). Resistance to change and the inertia of traditional educational models can further hinder the adoption of innovative technologies (Preet & Chahal, 2024). Finally, the high costs associated with implementing and maintaining advanced technological systems can strain institutional budgets, limiting the scope and sustainability of technology integration efforts in HEIs (Hmoud et al., 2023).

# 1.1.6. Previous Studies on the Impact of AI on Personalized Learning and the Use of ICT in Accessing Global Climate Resources

Previous studies indicate that AI significantly enhances personalized learning experiences in higher education by analysing individual learning patterns and tailoring educational content accordingly (Bhutoria, 2022; Kabudi, 2021; Maghsudi et al., 2021). Through adaptive learning technologies, AI can identify students' strengths and weaknesses, providing customized resources that cater to their unique needs (Kolluru et al., 2018). Moreover, ICT has proven effective in expanding access to global climate resources, allowing students and educators to tap into a wealth of information from diverse platforms and organizations (West, 2012). This access not only enriches the curriculum but also fosters a more comprehensive understanding of global climate initiatives and strategies. Collectively, these findings demonstrate the powerful potential of AI and ICT to transform learning about climate issues and promote informed, engaged global citizens.

### 2. METHODS

A qualitative (QUAL) approach design was used for the study. A qualitative study was chosen for this research because it allows for an in-depth exploration of the complex and often subjective experiences of students interacting with AI and ICT in the context of sustainability and climate action. The research questions focus on understanding how these technologies contribute to sustainability, enhance engagement, facilitate diverse perspectives, and reduce carbon footprints. Qualitative methods, such as interviews and focus groups, enable researchers to gather rich, detailed insights into students' thoughts, feelings, and behaviors as they navigate these technologies. This approach is particularly effective for capturing the nuances of how students engage with sustainability concepts and how their individual and collective experiences shape their understanding of climate issues. Moreover, qualitative research provides a platform for participants to express their views and share diverse perspectives, which is crucial for addressing the multifaceted nature of climate action. Ultimately, the qualitative approach aligns well with the goal of

exploring lived experiences and fostering a deeper understanding of the impact of AI and ICT in promoting sustainability within educational settings.

### 2.1. Research Design

A case of a university of technology was studied by the researchers. The case study design was employed in the study. The case study involved gathering qualitative data from students and lecturers, analysing it, and then interpreting it. Interviews and focus group discussions were used as instruments to collect data.

#### 2.2. Participants

The lecturers and students are involved in leveraging AI and ICT in smart classrooms therefore the right participants for the study. The sample constituted 5 lecturers and 2 focus groups with 5 students in each group. The researcher concentrated on STEM disciplines, to select the lecturers and undergraduate students. The researcher encouraged females and males to take part. The participants were selected according to availability and willingness to participate. Access to participants was not a challenge as the researcher collected data at an easily accessible location lecturers assisted in mobilizing their students. The research asked the participants to complete a consent form to take part in the study. The participants were also assured to be kept anonymous and to ensure voluntary participation.

#### 2.3. Research Instruments

The study used interview guides as instruments to interview lecturers and in the focus group discussions.

#### 2.4. Procedures

The lecturers were interviewed on one on one and the time allocated for each session was 15 minutes. Each focus group was allocated 30 minutes. In focus groups, students can dominate the discussion and influence other participants' responses. Students can also provide answers they think the researcher wants to hear and there may be a lack of diversity. To overcome all these the researcher gave clear instructions to ensure the participants understood the purpose of a focus group. The participants were assured of anonymity to reduce the influence of power dynamics.

### 2.5. Data Analysis

Data for the study as analysed in themes.

#### 3. RESULTS

#### 3.1. How AI and ICT Contribute to Sustainability and Climate Action among Students

The lecturers cited that AI and ICT have profound implications for fostering sustainability and climate action among students. Both students and lecturers recognise that these technologies serve as essential tools for enriching educational experiences related to environmental issues. Through AI algorithms that tailor learning experiences and ICT platforms that facilitate collaboration, students are not only able to acquire knowledge about sustainability but are also encouraged to actively engage in addressing climate change. By bridging theoretical concepts with practical applications, lecturers shared the same sentiments that these technologies motivate students to apply their learning in real-world contexts, effectively moving beyond passive absorption of information to active participation in sustainability efforts.

#### 3.2. How Technologies Enhance Student Engagement with Sustainability Concepts

Students and lecturers have noted that AI and ICT greatly enhance engagement. Digital tools such as virtual simulations, gamified learning experiences, and online discussion forums create stimulating environments where students can explore sustainability challenges collaboratively. For instance, many students reported enjoying simulations that allow them to manage resources or develop sustainable practices in a virtual setting, making abstract concepts more tangible and relatable. Lecturers also emphasized the value of ICT in facilitating open access to diverse educational resources, such as e-learning modules, webinars, and podcasts, which feature experts and case studies on sustainability. This engagement not only deepens the understanding of environmental issues but also fosters a sense of community among students as they collaborate on projects and share insights.

#### 3.3. The extent to which Technologies can Facilitate Diverse Perspectives on Climate Issues

Both students and lecturers highlighted the remarkable capacity of AI and ICT to facilitate diverse perspectives on climate issues by connecting individuals from various backgrounds and locales. Digital platforms enable students to interact with peers and experts worldwide, allowing for the exchange of ideas and cultural viewpoints concerning environmental challenges. Many students expressed appreciation for online forums and collaborative projects that bring together students from different disciplines and countries, enriching their understanding of global sustainability practices. Lecturers noted that such collective inquiry promotes communication and critical thinking and helps students appreciate the complexity of climate issues, ultimately preparing them to contribute more effectively to global discussions and solutions.

### 3.4. The Role Played by Technologies in Reducing Carbon Footprints of Educational Institutions

Students and lecturers alike observe that AI and ICT play a vital role in minimizing the carbon footprints of educational institutions. By implementing smart technologies like IoT sensors, institutions can optimize energy consumption for heating, cooling, and lighting, leading to more sustainable campus operations. Students reported noticing the differences in energy usage awareness fostered by real-time data analytics displayed on campus dashboards, making them more mindful of their resource consumption. Additionally, the shift to online learning and digital resources, accelerated by the pandemic, has significantly reduced the need for physical materials, such as paper and printed textbooks, which contributes to lowered waste. Lecturers underscored that embracing these technologies fosters an institutional culture of sustainability, as both students and faculty become increasingly conscious of their environmental impact and take active steps toward minimizing it.

#### 4. DISCUSSION

The findings regarding the contributions of AI and ICT to sustainability and climate action among students illustrate a transformative shift in educational environments and are consistent with previous research (Leal Filho et al., 2024). As students and lecturers alike recognise the powerful role of technology in shaping their understanding of environmental issues, it becomes clear that these tools not only enhance learning experiences but also serve as catalysts for personal and collective action (Baron, 2023; Kukulska-Hulme et al., 2024).

The findings on enhanced engagement with sustainability concepts via interactive learning modalities mark a significant departure from traditional lecture-based education is the same as what was noted by (Bizamu et al., 2023). The use of virtual simulations and gamified learning provides students with hands-on experiences that contextualize theoretical knowledge and it aligns with what was cited by (Chasokela, 2024). This active learning approach fosters deeper understanding, as students can experiment with and apply sustainability principles in a safe and controlled environment and this is supported by (Haque et al., 2024). Moreover, the collaborative nature of these technological tools promotes a communal learning atmosphere, allowing students to build relationships and share diverse insights on environmental issues.

The lecturers and students mentioned that the technologies facilitate diverse perspectives, and this aligns with what was discussed by (Kohler et al., 2019). Students and lecturers also shared that the ability to engage with peers and experts globally fosters a richer, multifaceted understanding of climate change and fulfills what was cited by (Dwivedi, 2022). The lecturers also said that interaction across diverse perspectives enhances students' 21st-century skills such as communication, and critical thinking skills, and nurtures a global citizenship mindset, preparing them to tackle climate challenges on an international scale.

The role of AI and ICT in having sustainable educational institutions is another crucial aspect highlighted by the findings from lecturers and this matches with (Maksimovic, 2018). The lecturers mentioned that by leveraging smart technologies and moving toward digital resources, institutions can significantly lower their environmental impact as noted by (Jia et al., 2019). This not only relates to energy consumption but also encompasses waste management practices, as digitalization minimizes the need for physical materials. The students' awareness of their carbon footprint, fostered by real-time data analytics, reflects a growing consciousness about sustainability that aligns with individual behavioral changes. Such conscious efforts by institutions to incorporate sustainability into their operations serve as a model for students, illustrating that academic organisations can lead by example.

Nevertheless, the lecturers noted that the integration of AI and ICT in promoting sustainability is not without challenges and is supported by various researchers (Bubou & Job, 2021; Chasokela & Moyo, 2024; Chasokela et al., 2024). While the unique opportunities these technologies present are vast, they also introduce complexities, such as the need for training faculty and ensuring equitable access for all students. Addressing the digital divide is essential for achieving inclusivity in educational environments; otherwise, marginalised students may miss out on the benefits that technology can offer. Furthermore, lecturers said that institutions must balance resource allocation between technology integration and the traditional aspects of education to ensure robust learning outcomes and this is supported by (Hmoud et al., 2023).

The discussion by lecturers underscores the pivotal role that AI and ICT play in shaping a new era of sustainability education. The collaborative, engaging, and data-driven approaches enabled by these technologies equip students with the skills and perspectives necessary to confront climate change proactively. Lecturers go on to say that consequently, as the educational landscape continues to evolve, it is imperative that educators and institutions fully embrace these innovations, ensuring they are accessible and effectively integrated to meet the pressing challenges posed by sustainability and climate action matches well with (West, 2012). There is a collective responsibility to capitalize on the potential of AI and ICT, not only to enhance learning but also to instill a culture of sustainability within the fabric of higher education.

### 5. CONCLUSION

In conclusion, the infusion of AI and ICT into higher education represents a powerful mechanism for promoting sustainability and climate action among students. As both students and lecturers have observed, these technologies facilitate dynamic and interactive learning experiences that deepen engagement with complex sustainability concepts. By enabling collaborative exchanges across diverse perspectives, they foster a richer understanding of global climate issues and prepare students to tackle these challenges in innovative ways. The role of AI and ICT extends beyond educational enhancement; they are also instrumental in reducing the carbon footprints of educational institutions. Through energy-efficient smart technologies and the move towards digital resources, universities can operate sustainably while inspiring students to adopt similar practices in their personal and professional lives. However, it is crucial to address the potential barriers to access and ensure that all students benefit from these advancements, thus fostering an inclusive environment for learning. Looking ahead, the continued integration of AI and ICT in education will be vital in shaping a generation that is not only informed about environmental issues but also empowered to take decisive action. As educational institutions embrace these technologies, they have the opportunity to lead by example, instilling a culture of sustainability that prepares students to navigate and address the pressing challenges posed by climate change. Ultimately, harnessing the potential of AI and ICT in this context serves as a pivotal step toward creating a more sustainable future for both the academic community and the world at large. To effectively harness the potential of AI and ICT in advancing sustainability and climate action within higher education, several key recommendations should be considered:

- Invest in Training: It is essential to provide educators with comprehensive training on the integration of AI and ICT into their teaching methodologies. This training should focus on best practices for utilizing these technologies to enhance student engagement and learning outcomes. By empowering educators with the necessary skills and knowledge, institutions can ensure that they effectively leverage technology to promote sustainability.
- Develop Interdisciplinary Curricula: Sustainability is a multifaceted challenge that spans various academic disciplines. Institutions should focus on developing interdisciplinary curricula that emphasize sustainability principles across different fields of study. By integrating sustainability topics into programs such as business, engineering, social sciences, and the arts, students can gain a holistic understanding of climate issues and are better prepared to propose innovative solutions.
- Upgrading infrastructure to enhance Internet of Things (IoT) systems is crucial for better energy
  management within educational institutions. Implementing smart technologies can optimise energy
  usage, reduce waste, and monitor environmental conditions in real-time. This not only contributes to
  the institution's sustainability goals but also serves as a practical case study for students to engage with
  cutting-edge technology in action.
- Encouraging collaboration between different departments and faculties on climate-related issues is vital for fostering a comprehensive approach to sustainability. By facilitating cross-department interactions, institutions can capitalise on diverse expertise and viewpoints, leading to innovative research initiatives, joint projects, and meaningful discussions around climate change. This collaborative spirit can help cultivate a sense of community and shared responsibility for addressing environmental challenges.
- Finally, fostering active student participation in sustainability research projects is essential for creating a culture of engagement and responsibility. Institutions should provide opportunities for students to get involved in research initiatives, internships, and community projects focused on sustainability. Engaging students in practical, hands-on experiences empowers them to apply their learning, develop problem-solving skills, and contribute to real-world solutions for climate issues. By implementing these recommendations, educational institutions can effectively harness the power of AI and ICT to promote a proactive approach to sustainability and climate action. This multifaceted strategy not only enhances the educational experience but also prepares students to become informed and engaged global citizens committed to making a difference in the world.

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