Promoting Climate-Smart Education for Economic Sustainability

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Abstract. Climate change has emerged as a significant global challenge, with particularly devastating consequences for developing countries with rapidly emerging industries. Sustainable development is critical in these areas. As a result, Climate-Smart Education is critical for integrating climate change knowledge and sustainable practices to ensure the long-term viability of industries. As a result, this study examines strategies for advancing Climate-Smart Education to improve economic sustainability, with a focus on developing countries. To accomplish this, a commentary approach was used to review existing literature, policies, and current practices, and suggested actionable strategies. The findings suggest that strategies such as public-private partnerships, digital advisory services, and incorporating climate-smart principles into formal education can help to close knowledge gaps and boost resilience. Adapting initiatives to the socioeconomic realities of rural and peri-urban areas, along with coordinated policy efforts, is critical. However, challenges such as limited resources, inadequate teacher training, and cultural resistance, particularly in developing countries, may impede the successful implementation of climate change education. It was suggested that policymakers ensure the implementation of climate-smart principles in key sectors such as education, industry, agriculture, and the environment. This can promote a unified and coordinated approach to climate resilience and sustainability.

1. INTRODUCTION

International debates on global warming and climate change issues show that education has a key role to play in responding to the climate crisis. Policy interventions to support climate-smart education in industrial curricula and training can involve active government involvement in offering high-level support. This includes promoting cross-sectoral coordination and integrating efforts across education, environment, and industry sectors (Reid, 2019). Many developing countries are therefore not immune to the climate change crisis and its negative impact on the economy. Addressing climate change in a developing country like South Africa has become a key focus within the agenda of Education for Sustainable Development (ESD). ESD aims to use education to promote sustainable development and empower communities to respond to environmental challenges (Cordero et al., 2008). Climate action is the priority of the latest ESD for 2030 to step up the mainstreaming of sustainable development (UNESCO, 2020). Climate Change Education (CCE) is fundamentally part of ESD. In addition, economic and environmental sustainability is part of the 2030 Sustainable Development Goal agenda. Hence, this paper sought to discuss how to promote Climate-Smart Education. Mhlongo (2024) posits that the current national education policies in South Africa do not provide clear direction about what climate-smart education means for schools. This aligns with Usman et al. (2022), who emphasize that climate change is an environmental phenomenon capable of intensifying existing disaster risks. It can lead to significant human, economic, and environmental losses if not addressed effectively. For South Africa to improve social welfare, sustainable economic growth and development are required. It has been argued that environmental deterioration is a difficult issue in the process of economic growth (Burke et al., 2016).

It can be argued that climate change and its effects pose multiple threats to the profitability of businesses worldwide (Cho, 2019). The intensity of extreme weather in other countries could damage factories, supply chain operations and other infrastructure. The scholar further states that drought could result in water becoming expensive which would affect the cost of raw materials and production. Climate volatility may force companies to deal with uncertainty in the price of resources for production, energy transport and insurance. Furthermore, some products could lose their market due to weather uncertainty. It is against this background that this paper sought to determine ways of promoting climate-smart education for the economic sustainability of industries in South Africa.

1.1. Research Questions

i.   How can climate-smart education promote economic sustainability?
ii. What strategies can be adopted to promote climate-smart education in developing countries?

2. METHOD

In this study, a commentary approach was adopted to explore and address the research questions. According to Braun et al. (2023), the commentary approach is an analytical and reflective research method that draws insights from existing literature to critically examine a phenomenon. This method was used to review climate change education policies and practices, assess their effectiveness, and propose actionable strategies for improvement. The findings were drawn thematically from existing studies on climate change education. They were then organized to emphasize common patterns, key challenges, and innovative practices.

The thematic findings were presented in a narrative format, emphasizing the key themes that emerged from the literature. This approach was particularly useful in identifying gaps in aligning educational programs with real-world industry needs. The study also provided practical recommendations to improve policy development. Figure 1 is a flow chart was developed to visually present the major themes within the study.
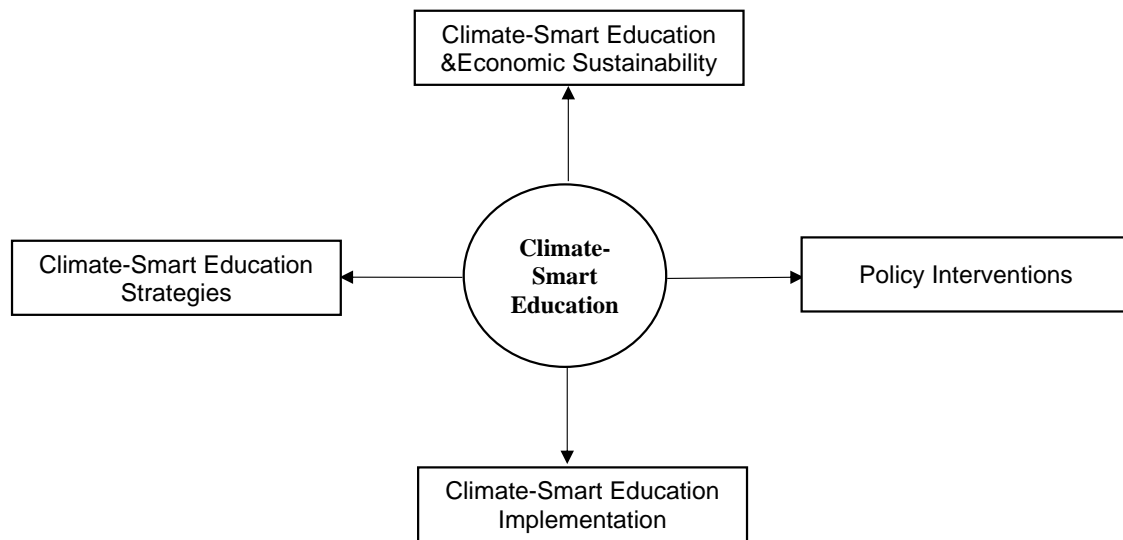
Figure 1: The major themes within the study.

2.1. Climate-Smart Education

In recent years, climate-smart education has emerged as a transformative approach that empowers learners with the knowledge, skills, values, and attitudes necessary to address the growing threat of climate change. Hügel and Davies (2024) argue that climate-smart education extends beyond mere awareness by incorporating climate mitigation, adaptation, and resilience strategies into the entire education system. This includes integrating these concepts into curriculum content, teaching methods, and education policy frameworks. In developing countries, the climate crisis often overlaps with poverty and weak infrastructure. Therefore, climate-smart education is essential for preparing young people to understand, manage, and respond effectively to these challenges.

Harper (2023) offers a comprehensive framework with seven dimensions that support the integration of climate resilience into education systems. This approach includes updating school curricula to reflect local climate issues and realities (Mpuangnan et al., 2025). It also involves training teachers and building partnerships with communities to make climate education more relevant and impactful. Practical examples, such as those found in Ghana, highlight how integrating climate-smart agricultural practices into learning not only boosts student understanding but also equips communities to respond to their own environmental vulnerabilities (Mpuangnan et al., 2023; Alidu et al., 2022; Davies et al., 2024). When learners see how theory connects with daily life whether on farms or in flood-prone areas education becomes a powerful tool for social transformation.

Moreover, climate-smart education is interdisciplinary and inclusive. Drawing inspiration from successful agricultural innovations in India and Africa (Ariom et al., 2022), educational strategies are being reshaped to include lessons on sustainable resource management. This inclusive model also emphasizes gender equity. Scholars such as Barooah et al. (2023) and Phiri et al. (2021) stress that women and girls, often most affected by climate-related stressors, must be at the center of educational interventions. Gender-sensitive curricula and community-based education initiatives ensure that climate-smart education addresses not only environmental challenges but also social inequalities making it a key tool for building long-term resilience across Africa and beyond. Figure 2 shows a model proposed by the authors for successful implementation of Climate-Smart Education.
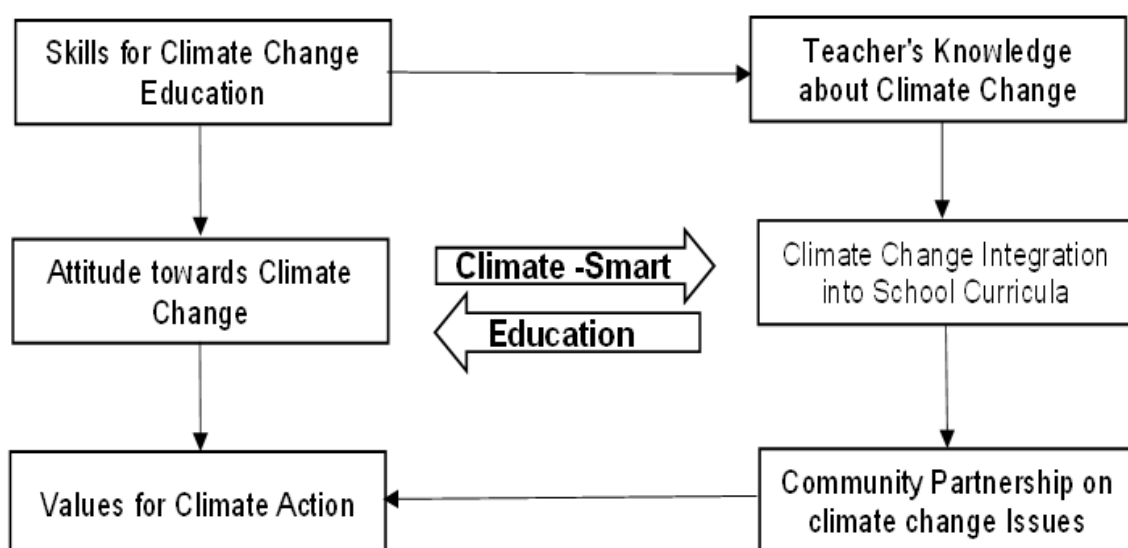

Figure 2: Authors' proposed Model for Climate Smart Education.

2.2. Promoting Economic Sustainability through Climate-Smart Education

Climate-smart education play an important role in promoting economic sustainability in local communities by providing individuals with the knowledge and skills necessary to adopt sustainable practices. Branca et al. (2021) argue that climate-smart agriculture (CSA) can boost productivity and economic stability by increasing crop yields and lowering greenhouse gas emissions. Educating communities about these practices allows them to make more informed decisions that improve both environmental and economic outcomes. However, the high initial costs of implementing CSA practices may limit adoption in resource-constrained communities, emphasizing the importance of financial support in addition to educational efforts.

Public-private partnerships can help to increase the reach and impact of climate-smart education in local communities. Senyolo, Long, and Omta (2021) highlight the success of initiatives such as the Water Efficient Maize for Africa (WEMA) program, which demonstrates the potential for collaboration to scale CSA adoption. Incorporating such examples into local education programs can demonstrate how collaboration can break down resource barriers and promote economic resilience. However, Chitakira and Ngcobo (2021) argue that peri-urban and rural communities require tailored approaches to address their unique socioeconomic contexts, emphasizing the need for context-specific education programs.

Community-driven and locally tailored approaches are critical to ensuring that climate-smart education meets the needs of South African communities. Angom and Viswanathan (2023) emphasize the importance of locally relevant education models, such as those focused on water conservation or sustainable farming techniques, in establishing long-term livelihoods. Education programs should prioritize community engagement to ensure that they are in line with local realities. However, as Molieleng, Fourie, and Nwafor (2021) point out, many smallholder farmers lack access to critical infrastructure, limiting their ability to implement CSA practices. Climate-smart education must therefore incorporate advocacy for systemic change to assist these communities.

Beyond agriculture, climate-smart education can address other critical industries, such as mining, which is both economically and environmentally important in South Africa. Nair (2024) focuses on the work of the Khuthala Environmental Care Group in Mpumalanga, which has implemented innovative practices to promote sustainable mining. Incorporating such examples into education programs can encourage local communities to investigate climate-smart innovations in a variety of fields. However, it is critical that these programs offer practical solutions for communities reliant on traditional livelihoods, fostering an equitable transition to sustainability.

Climate-smart education significantly advances several Sustainable Development Goals (SDGs). Notably SDG 4 (Quality Education), SDG 13 (Climate Action), and SDG 8 (Decent Work and Economic Growth). Climate-smart education gives people the knowledge and skills to use sustainable practices. This helps communities take action on climate change and supports economic growth that protects the environment. The integration of climate-smart agriculture and sustainable mining within educational frameworks aligns with SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production) by encouraging efficient resource management and resilient livelihoods. Furthermore, focusing on inclusive, community-centered strategies helps reduce inequalities (SDG 10). It ensures everyone can participate fairly in the move toward sustainable development.

2.3. Policy Interventions on Climate-Smart Education

Policy interventions are critical in advancing climate-smart education in developing countries. This serves as a goal of providing communities with the knowledge and skills they need to engage in sustainable practices. Acharyya (2022) emphasizes the importance of incorporating climate-smart agriculture (CSA) strategies into education systems. Notably strategy include providing a coherent policy to improve the dissemination of CSA knowledge and technologies. Policies aimed at strengthening institutional frameworks and creating enabling environments are critical for expanding these interventions. However, gaps in implementation and a lack of locally tailored approaches frequently undermine the effectiveness of these policies, necessitating more targeted and adaptable strategies.

Through institutional support, policy initiatives have demonstrated promise in advancing climate-smart practices in certain regions. According to Patra and Babu (2023), policy frameworks in Nagaland, India, have supported the adoption of climate-smart agriculture (CSA). They did this by aligning institutional processes with the specific needs of local farming communities. This integration demonstrates how education policies can help close the gap between community-level implementation and climate-smart initiatives. However, Defe and Matsa (2021) argue that many policies in developing countries are not effective. This is because they often overlook the unique social, economic, and cultural conditions of rural communities. In ensuring wider adoption, policies must be designed with a clear understanding of local needs and conditions. Tailoring strategies to fit specific community contexts increases their relevance and impact.

Moreover, to improve climate-smart education initiatives, community-based methods of policy formulation and execution are essential. Hanley et al. (2021) highlight that food security and livelihoods have improved through policies that prioritize community engagement and participatory methods, such as those used in Myanmar's climate-smart villages. These approaches ensure that policies are aligned with the needs and priorities of local communities. As a result, they enhance long-term sustainability and foster greater community acceptance and ownership. Acosta et al. (2021) warn that these interventions frequently ignore gender-specific issues, especially those pertaining to women's decision-making and resource access. Therefore, to address disparities and advance inclusive education, policies must embrace an intersectional perspective.

Another important element in promoting climate-smart education is policy coherence. According to Chevallier (2023), disjointed policies make it more difficult for CSA programs in Africa to scale and be effective. To align objectives and maximize impact, there needs to be more coordination between sectors, such as education, agriculture, and the environment. This viewpoint is supported by Rodríguez-Barillas et al. (2024), who point out that Costa Rica's CSA policy mix has been plagued by overlapping initiatives and inconsistencies, which have reduced efficacy and caused confusion. Developing nations should concentrate on developing cohesive policy frameworks that prevent duplication and expedite efforts at climate-smart education.

Allocating resources and providing financial incentives are also essential for promoting climate-smart education. According to van Asseldonk et al. (2023), smallholder farmers can be persuaded to embrace CSA practices by means of policy incentives like subsidies and training initiatives. To encourage widespread learning and application, these incentives can be incorporated into educational programs. Erekalo and Yadda (2023) caution that, especially in environments with limited resources, insufficient funding and resource limitations continue to be major obstacles. Policies that place a high priority on funding training initiatives and educational infrastructure are necessary to address these issues.

2.4. Factors Affecting Implementation of Climate-Smart Education in Developing Countries

Several factors including limited resources and poor infrastructure, make it difficult to implement climate-smart education in developing nations. The integration of climate-smart practices is hampered by limited access to digital resources, particularly in rural areas (Hebsale Mallappa &Pathak, 2023). This is consistent with Victory et al. (2022) indicating that Nigeria's lack of resources has slowed efforts to integrate climate education, especially in areas that are impoverished. These infrastructure deficiencies limit students' access to high-quality climate change education as well as teachers' capacity to instruct.

The absence of capacity building and training for teachers is another urgent problem. Some teachers lack the knowledge and abilities needed to effectively teach climate-smart education. in this light, Asante et al. (2024) emphasize how crucial it is to give teachers technical training in order to improve their capacity to present lessons that are both interesting and pertinent. Similarly, Senyolo et al. (2021) argue that offering focused resources and capacity-building initiatives, public-private partnerships is essential to promoting climate change education. However, these collaborations frequently encounter coordination issues and bureaucratic roadblocks, which restrict their efficacy and scalability. Another major barrier to climate-smart education is social and cultural factors. Some communities' traditional values and customs may be at odds with contemporary climate policies. This could lead to opposition to educational programs. According to Okoronkwo et al. (2024), incorporating local knowledge into climate-smart education could aid in bridging this gap. However, careful preparation is necessary to prevent alienation or misrepresentation. According to Shekmohammed et al. (2023), farmers' field schools and other participatory approaches are effective examples of fusing traditional knowledge with modern methods to increase community acceptance.

The difficulties in putting climate-smart education into practice are made worse by problems with governance and policy. To successfully incorporate climate education into their educational systems, many developing nations lack cogent policies or frameworks. According to Chevallier (2023), two major obstacles to scaling climate-smart interventions throughout Africa are policy fragmentation and a lack of institutional capacity. In addressing this these gaps, Karume et al. (2022) call for greater international cooperation and policy alignment. However, political will and conflicting national priorities frequently impede progress. Insufficient knowledge of climate change among students, teachers, and legislators compromises the efficacy of climate-smart education initiatives. Low engagement and support for such initiatives are frequently the result of this knowledge gap. According to Ali (2021), community participation is decreased in Togo when people are unaware of the advantages of climate-smart practices. Nonetheless, community-based initiatives and awareness campaigns have demonstrated the ability to promote increased comprehension and participation. It will take a coordinated strategy that combines capacity-building programs, policy reform, and active community engagement to overcome these obstacles.

2.5. Strategies for Promoting Climate-Smart Education

Targeted strategies that incorporate context-specific needs like addressing the effects of climate change on agriculture and livelihoods are necessary to promote climate-smart education in developing nations. Hebsale Mallappa and Pathak (2023) highlight the importance of using climate-smart agriculture technologies. These technologies help reduce risks caused by climate change. This approach is pertinent to South Africa's rural communities that rely on subsistence farming. Shekmohammed et al. (2023) highlight the Farmer Field School (FFS) approach, which uses community training to promote climate-smart farming. Using this approach in South Africa can help farmers learn new practices and become more prepared for climate challenges. Digital advisory services are a potent instrument for advancing climate-smart education, especially when it comes to expanding knowledge availability. Asante et al. (2024) show how these services help farmers adopt CSA in Ghana by giving them customized advice. This is an example that South Africa can use to spread climate-smart practices in both urban and rural areas by utilizing mobile platforms. Victory et al. (2022) note that problems with digital literacy and poor infrastructure are still common. To solve these issues, it is important to improve digital education and expand internet access in disadvantaged areas.

Another successful tactic for promoting climate-smart education in developing nations is public-private partnerships or PPPs. According to Senyolo et al. (2021), PPPs are essential for increasing the adoption of CSA, as demonstrated by the Water Efficient Maize for Africa (WEMA) program. These collaborations can offer funding, educational opportunities, and technical assistance to advance CSA practices. However, Okoronkwo et al. (2024) warn that striking a balance between business interests and community needs is essential to the success of such collaborations. Policymakers in South Africa must make sure that PPPs avoid exploitative practices and give sustainability and inclusivity a top priority. For long-term change, formal education systems must integrate CSA strategies. In order to prepare students to be change agents, Abdulai (2023) emphasizes the importance of universities in climate-smart education and the incorporation of CSA into curricula. This strategy can be implemented by South African universities, guaranteeing that agricultural, environmental, and technical education programs incorporate climate-smart concepts. Isiwu and Adejoh (2023) suggest that targeted workshops and extension services can help smallholder farmers. These programs are especially useful for South African farmers without formal education who need practical knowledge to apply climate-smart methods.

Lastly, the success of climate-smart education in developing nations depends on encouraging policy coherence and coordinated action. Chevallier (2023) highlights the need for integrated frameworks that connect education, agriculture, and environmental goals. He argues that fragmented policies slow down the adoption of climate-smart agriculture (CSA) across Africa. To ensure climate-smart education initiatives in South Africa are scalable and sustainable, strong collaboration among government agencies, academic institutions, and non-governmental organizations is essential. Such partnerships can help align resources, expertise, and policy efforts to support long-term impact. South Africa needs to concentrate on developing all-encompassing strategies that address both short-term and long-term issues, taking inspiration from other African countries like the Democratic Republic of the Congo (Karume et al., 2022).

3. RECOMMENDATION

Successive governments should institutionalize cross-sectoral collaboration, ensure adequate funding, and establish robust frameworks that link education to environmental sustainability.

Future researchers are encouraged to investigate context-specific models that connect industrial training, curriculum design, and sustainability goals.

Future studies should concentrate on adjusting Climate-Smart Education programs to meet local needs, especially in peri-urban and rural areas.

Policies must move beyond rhetoric to include measurable goals, teacher training strategies, and school-community partnerships that empower learners to act as change agents.

4. CONCLUSION

This research investigates methods for advancing Climate-Smart Education to improve industry economic sustainability. The purpose of climate-smart education is to equip local communities with the values, knowledge, and abilities needed to effectively address climate change issues. Adaptation, mitigation, and climate awareness are all part of these programs. However, issues like a lack of funding, inadequate training for teachers, and cultural resistance still exist particularly in a developing country like South Africa. These factors were found to hinder the implementation of Climate-Smart Education in the region. To address these issues, the research recommended strategies such as the use of digital advisory services, fostering public-private partnerships, and integrating climate-smart concepts into formal education to bridge knowledge gaps and reduce vulnerability. It was emphasized that programs should be tailored to the unique socioeconomic contexts of rural and peri-urban areas, with coordinated policy efforts. Furthermore, the study highlighted the importance of collaborative frameworks that align educational, agricultural, and environmental goals to support the scalability and long-term effectiveness of climate-smart education initiatives.

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