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Potentials of Food Science and Technology to Foster a Sustainable Knowledge-Based Economy in a Developing Country: A Review

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Abstract

This paper reviews the potentials of food science and technology in fostering a sustainable knowledge-based economy in a developing country. Knowledge-based economy (KBE) is an economy based on the production, commercialization, and use of knowledge and information in order to achieve sustainable development by investing in human capital, technology resources, and innovation. Food Science and Technology has the potentials of contributing to economic development in a knowledge-based economy through innovation, efficiency, safety, sustainability, nutrition, economic growth, knowledge-sharing and digitization. The circular economy offers solutions to achieve global food sustainability by minimizing food loss and waste, promoting efficient use of natural resources and mitigating biodiversity loss, by retaining the resources within a loop. The constraints and challenges of achieving a knowledge-based economy in a developing country include limited knowledge readiness, brain drain, limited access to education, dependence on natural resources, limited innovation culture, limited infrastructure, limited funding for research and development, limited access to technology, limited skilled workforce, limited economic diversification and institutional corruption. The feasible strategies developing countries can adopt to achieve a sustainable knowledge-based economy are investing heavily in education, encouraging innovation, developing infrastructure, promoting research and development, encouraging foreign investment, fostering collaboration, developing a digital economy, supporting entrepreneurship, developing a skilled workforce, encouraging knowledge-sharing, developing clusters and encouraging open innovation. The paper concludes that a sustained government positive action is indispensable for a knowledge-economy, while suggesting that achievement of a sustainable knowledge economy requires a multi-stakeholder involvement.

Keywords: *Potentials, Food science, Technology, Knowledge economy*

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Background to the Study

Food science and technology involves the study of the physical, biological, and chemical makeup of food, as well as the development and application of innovative processes to improve food production, preservation, safety, and quality. It encompasses areas such as food chemistry, microbiology, engineering, and nutrition, aiming to create sustainable solutions for food supply and consumption. It is relevant to economic development in such areas as Improved Food Security, value addition: employment generation: innovation and knowledge economy and global competitiveness (FAO,2015).

Food Science and Technology is one the fields of science and technology that has potentials of contributing to economic development both in resource-based (factor-driven) economy and knowledge-based economy. It is the application of scientific principles to create and maintain a wholesome food supply (FAO,2017.). Food science is a multidisciplinary field that focuses on solving real-world problems around the production of food, involving the study of food composition, preparation, processing, preservation, and effects on human health (FAO, IFAD and WFP,2015). Food technology, on the other hand, is used to develop and manage the processes by which food is transformed from raw harvest to edible goods purchased by individual consumers (Mishra *et al*,2018). This review is structured along these sub-themes: constructs of food science and technology (FST) and knowledge-based economy (KBE), the importance of KBE in developing countries, pillars of KBE, contributions of FST to KBE, the place of innovation in FST and KBE, the circular economy, with a conclusion.

Liyanage, (2022) defines knowledge-based economy (KBE) as an economy based on the production, commercialization, and use of knowledge and information in order to achieve sustainable development by investing in human capital, technology resources, and innovation. A Knowledge-Based Economy (KBE) is "one where organizations and people acquire, create, disseminate and use knowledge more effectively for greater economic and social development (World Bank Institute,2004). There are perceived knowledge gaps in this topic. Such gaps are limited understanding of food science and technology's role in sustainable development, insufficient examination of the impact of food science and technology on local economies, gaps in understanding the social and cultural context of food science and technology adoption, and limited analysis of the policy and regulatory frameworks supporting food science and technology.

Importance of Knowledge-Based Economy in Developing Countries:

i. **Economic Growth**: By transitioning to a knowledge-based economy, developing countries can diversify and strengthen their economies, reducing dependence on traditional sectors such as agriculture and mining.
ii. **Innovation and Competitiveness**: Encouraging knowledge-driven industries fosters innovation, enabling countries to compete globally and attract investments in high-tech sectors.
iii. **Improved Education and Skills Development**: Building a knowledge economy emphasizes education and the development of a skilled workforce, addressing

unemployment and enhancing productivity.

iv. **Enhanced Resource Efficiency**: Knowledge-based economies focus on sustainable practices and technological solutions to maximize resource use, especially critical for developing nations facing resource constraints.
v. **Social Progress**: It bridges the gap between economic development and social wellbeing by promoting equal opportunities in education, technology access, and job creation.

Pillars of the Knowledge Economy

The World Bank Institute [2004] identifies four key aspects of an economy, which are regarded as the pillars of the knowledge economy. It is expected that these pillars would help countries articulate strategies for their transition to a knowledge economy. These pillars are: Economic and Institutional Regime (EIR), an educated and skilled population, a dynamic information infrastructure and an effective innovative system. Economic and Institutional Regime (EIR) comprises incentives that stimulate and promote enterprise development via knowledge creation, dissemination and use. The process of knowledge creation and diffusion in a knowledge-based economy heavily depends on appropriate government policies that are usually the outcome of economic incentives and institutional regimes [Debnath, 2011]. By implication, addressing tariff and non-tariff barriers, improving regulatory quality, and improving the rule of law will influence how quickly individuals can identify and exploit market opportunities to create wealth, jobs, and economic growth. In addition, improving the policy and business environments to create conditions favorable to trade is one of the most important ways for countries to obtain knowledge from abroad [World Bank, 1998].

An educated and skilled population: A highly-skilled and flexible human capital is essential to compete effectively in today's world and is a key building block of a knowledge-based economy [Radwan & Pellegrini, 2010.]. Access to basic education, number of years of schooling and exposure to tertiary level of education determine the proportion of the economy that is literate. A dynamic information infrastructure: Access to ICT infrastructure facilitates the effective communication, dissemination, and processing of information. The infrastructure strength and coverage of the telecommunications sector is revealed in the number of people with ability to use computers, with access to internet and the mobile telephony subscriber base. Number of internet users serves as an indication of how well a population has advanced to the level of adapting and using advanced communication channels to serve its priorities. An effective innovative system: This allows for close relations among knowledge institutions (research centres, universities) and firms with which they can tap into the growing stock of global knowledge, adapt it to local needs, and create new technological solutions.

Tchamyou 2017; Parcero and Ryan 2017; Vadra 2017) reported that it is a proven fact that in this contemporary époque, for nations to survive the challenges of globalization, they need knowledge-based economies (KBEs). Tchamyou 2017; Amavilah *et al*. 2017; Gama et al. 2018; Asongu 2017a; Asongu and Tchamyou 2019a) further stated that KBEs which are

essential for competition in the twenty-first century have been at the centre of key policy reports from the Organization for Economic Co-operation and Development (OECD) and the World Bank during the past decade. The relevance of KBE has been mastered by North America, Japan and Europe, and this has been determining the pattern of economic development in the international arena.Other developing countries in Latin America and Asia have been catching up with calculated moves that emphasize the importance of KBE in the pursuit of their regional and national goals (Tchamyou 2017; Chandra and Yokoyama 2011; Dahlman 2007; Shahabadi *et al.* 2017) 1.It is worthy of note and sad too that the overall index of knowledge economy (KE) in Africa has been decreasing since the beginning of the third millennium (Anyanwu, 2012).

Oluwadare, (2015) reported that as a factor-driven economy which is based on exploiting the abundance of crude-oil, Nigeria is highly sensitive to world economic cycles, commodity price trends and exchange rate fluctuations. This signifies a great need to diversify the economy, particularly away from crude oil and the need to begin to generate wealth and employment via knowledge creation, use and diffusion. In spite of Nigeria 's vast natural resources which range from crude oil, copper, gold and tin, to arable soil, abundant water resources and a large population, its Global Competitiveness Index Rank is 127th out of 144 countries [World Economic Forum (2014)]. This corroborates the assertion that a nation's competitiveness and prosperity depend on the capacity of its industries to innovate and upgrade and not just on its natural endowments [Porter, M.E. (1990)]. In transiting to a knowledge-based economy, Nigeria appears to have a long distance to cover. The 2012 Knowledge Economy Ranking places Nigeria in the 119th position out of 145 countries, with a Knowledge Economy Index of 2.2. (World Economic Forum,2014; World Bank,2012).

The economic incentives and regulations required for a dynamically functioning business environment in Nigeria are quite inadequate. The ease of doing business in Nigeria is ranked 170 out of 189 economies [World Bank (2014)]; this is lower than the 2013 ranking of 147 [World Bank (2013)]. Nigeria, according to the 2014-2015 Global Competitiveness Report, is still at the factor-driven stage of development. By implication, companies in Nigeria compete on the basis of price and are yet to compete by producing new and different goods using the most sophisticated production processes and by innovating new ones. Firm-level capacity to absorb technology in Nigeria is weak and this is a key area in which a knowledge economy can outperform a traditional economy [Radwan, & Pellegrini, (2010)].

There is ample evidence of interaction between universities and industry in developed and newly industrializing countries, developing countries are replete with universities that function, for the most part, independent of industry; and industry that depends on foreign sources of knowledge to sustain production and possibly meet competitive challenges [Adeoti, (2008)]. Several authors [Oyewale,2005], [Adeoti, Ayeyinka, & Odekunle (2008)], [Oyelaran-Oyeyinka & Adebowale, (2012)] have identified weak university-industry interaction as the most significant problem within the National Innovation System in Nigeria. Weak interactions among universities and firms have implications for the national system of

innovation and for the knowledge economy as it impedes the commercialization of new knowledge.

Contributions of Food Technology in a Knowledge-Based Economy

Food technology has made significant contributions to a knowledge-based economy in several ways: (Bhatt,Lee, Deutsch, Ayaz, Fulton, & Suri 2018).

i. **Innovation:** food technology has led to the development of new products (through product development), processes, and packaging materials, driving innovation and entrepreneurship.
ii. **Efficiency:** Food technology has improved food processing, preservation, and distribution, increased efficiency and reducing waste.
iii. **Safety:** Food technology has ensured a safer food supply through advances in food safety monitoring, testing and traceability.
iv. **Sustainability:** Food technology has enabled sustainable food production, processing and consumption practices, reducing environmental impact.
v. **Nutrition:** Food technology has enhanced nutrient retention, bio-availability, and fortification, improving public health and well-being.
vi. **Economic growth:** Food technology has created new business opportunities, employment, and revenue streams, contributing to economic growth
vii. **Knowledge sharing:** Food technology has facilitated collaboration, research, and knowledge sharing among industries, academia, and governments.
viii. **Digitization:** Food technology has embraced digital solutions, such as blockchain, internet of things (IoT), and data analytics, driving the knowledge-based economy.

The Place of Innovation in Food Science and Technology and Knowledge-Based Economy

Innovation plays a crucial role in food science and technology, driving progress and improvement in various areas such as: (Benfica, *et al.* (2023).

i. **Product development:** Creating new and improved food products, ingredients, and packaging materials.
ii. **Process optimization:** Enhancing food processing, preservation, and safety through novel technologies and methods.
iii. **Nutrition and health:** Developing functional foods, nutraceuticals, and personalized nutrition solutions.
iv. **Sustainability:** Reducing food waste, improving resource efficiency, and promoting environmentally friendly practices.
v. **Food security:** Ensuring global food availability, access, and utilization through innovative production, processing, and distribution approaches.

In a knowledge-based economy, innovation in food science and technology is fueled by:

i. Interdisciplinary research and collaboration.
ii. Investment in R&D and technology transfer.
iii. Encouraging entrepreneurship and start-ups.

iv. Fostering a culture of innovation and experimentation.
v. Leveraging digital technologies, such as analytics, IoT, and AI

With respect to feasible areas of interdisciplinary research and collaboration in food science and technology, aligned with a knowledge-based economy, the following areas are key: (Grace,S addiqui & Zaitchik,2020).

i. **Food Informatics:** Combining food science, computer science, and data analytics to develop innovative solutions for food safety, quality and traceability.
ii. **Nutriomics:** Integrating nutrition, genomics, and bio-informatics to personalize nutrition and develop targeted health-promoting foods.
iii. **Food Nanotechnology:** Collaborating on nanotechnology applications in food processing, packaging, and delivery systems.
iv. **Sustainable Food Systems:** Interdisciplinary approaches to reduce food waste, improve resource efficiency, and promote environmentally friendly practices.
v. **Food Biotechnology:** combining biotechnology, microbiology, and bioengineering to develop novel food products, ingredients, and processing technologies.
vi. **Digital Food Technologies:** Exploring AI, IoT, and blockchain applications in food production, processing, and distribution.
vii. **Food Materials Science:** Developing innovative packaging materials, edible films, and coatings through materials science and food engineering collaborations.
viii. **Food and Health:** Integrating nutrition, medicine, and food science to develop functional foods, nutraceuticals, and personalized health solutions.
ix. **Food Safety and Security:** Collaborative research on food-borne pathogen detection, predictive modeling, and risk assessment.
x. **Food and Environment:** Interdisciplinary studies on food production's environmental impact, climate change mitigation, and sustainable agricultural practices.

Investment in research and development (R&D) and technology transfer in food science and technology can drive innovation in a knowledge-based economy through the following ways: (Audretsch, Belitski & Chowdhury,2024).

i. Funding research grants and projects in areas like food safety, nutrition, and sustainability.
ii. Establishing innovation hubs, incubators, and accelerators for food tech start-ups.
iii. Collaborative research partnerships between industry, academia, and government.
iv. Technology transfer offices to commercialize research findings and IP development.
v. Investment in digital technologies like AI,blockchain, and IoT for food production and processing.
vi. Development of open innovation platforms for co-creation and knowledge sharing.
vii. Funding for proof-of-concept and pilot-scale projects to test new technologies.
viii. Human capital development through training and up-skilling programs for researchers and industry professionals.
ix. International collaboration and knowledge transfer through joint research projects

and scientific exchange programs.

x. Investment in food technology infrastructure, such as pilot plants, research facilities, and testing labs.
xi. Encouraging spin-off companies and start-ups from research institutions.

Development of innovation-focused policies and regulatory frameworks.
As it concerns entrepreneurship and start-ups, these can be encouraged in food science and technology innovation in a knowledge-based economy through: (Djellal, & Gallouj, 2013)

i. **Incubators and accelerators:** Providing resources, mentor-ship, and funding to early-stage companies.
ii. **Funding opportunities:** Offering grants, loans, and equity investments to support start-ups and scale-ups.
iii. **Networking events:** Facilitating connections between entrepreneurs, investors, and industry experts.
iv. **Mentor-ship programs:** Pairing experienced professionals with start-up founders for guidance and support.
v. **Food tech-specific funding initiatives:** Creating targeted programs like the USDA's Food Innovation Centre or the Food Technology Innovation Fund.
vi. **Tax incentives and breaks:** Offering benefits like R&D tax credits or reduced tax rates for start-ups.
vii. **Regulatory support:** Streamlining processes and providing guidance for start-ups navigating food regulations.
viii. **University spin-offs:** Encouraging researchers to commercialize their research and launch start-ups.
ix. **Corporate venturing:** Large companies investing in and partnering with start-ups to drive innovation.
x. **Food tech-focused co-working spaces:** Providing shared resources and a community for entrepreneurs.
xi. **Competitions and challenges:** Hosting hackatons, pitch competitions, and innovation challenges to spur ideas and innovation.
xii. **Education and training:** Offering courses, workshops, and conferences on food science and technology, and entrepreneurship.

It has been reported that a culture of innovation and experimentation in food science and technology can promote a knowledge-based economy in several ways such as: (Sagay, Silva & Cohen,2024).

i. **Encourages R&D:** Fostering a culture of innovation and experimentation drives investment in research and development, leading to new discoveries and applications.
ii. **Spurs Entrepreneurship:** Encourages start-ups and spin-offs, creating new businesses and job opportunities.
iii. **Develops Human Capital:** Attracts and retains top talent in food science and technology, building a skilled workforce.
iv. **Fosters Collaboration:** Promotes partnership between academia, industry, and

government, facilitating knowledge sharing and transfer.

v. **Drives Technology Transfer:** Encourages the adoption of new technologies and processes, improving productivity and efficiency.
vi. **Supports Sustainable Development:** Encourages innovative solutions for sustainable food production, processing and consumption.
vii. **Enhances Competitiveness:** Helps companies stay competitive in the global market, driving economic growth.
viii. **Encourages Risk-Taking:** Fosters a culture tha embraces experimentation and learns from failures.
ix. **Develops New Business Models:** Encourages innovative approaches to food production, processing, and distribution.
x. **Addresses Global Challenges:** Encourages innovative solutions for food security, safety, and nutrition.

Digital technologies in food science and technology promotes a knowledge-based economy in a number of ways, therefore; this can be leveraged upon in such ways as: (Xun et al.,2021).

i. **Data-Driven Decision Making:** Digital technologies provide real-time data and insights, enabling informed decisions in food production, processing and distribution.
ii. **Automation and Efficiency:** Digital technologies like AI, robotics,and IoT optimize processes, reducing costs,and improving productivity.
iii. **Food Safety and Traceability:** Digital technologies like block-chain and RFID enable end-to-end traceability, ensuring food safety and quality.
iv. **Personalized Nutrition:** Digital technologies like AI and machine learning enable personalized nutrition recommendations and tailored food products.
v. **E-commerce and Digital Marketplaces:** Digital platforms connect consumers with food producers and processors, creating new market opportunities.
vi. **Digital Education and Training:** Online resources and platforms provide access to knowledge and skills development in food science and technology.
vii. **Research and Collaboration:** Digital technologies facilitate global collaboration, data sharing, and research innovation in food science and technology.
viii. **Smart Agriculture:** Digital technologies like precision agriculture and vertical farming optimize crop yields, reduce waste, and promote sustainable agricultural practices.
ix. **Food Waste Reduction:** Digital technologies like predictive analytics and supply chain optimization help reduce food waste and improve resource efficiency.
x. **Consumer Engagement:** Digital technologies enable consumers to make informed choices, interact with food producers, and influence product development.

Artificial intelligence (AI) can advance the knowledge-based economy in food science and technology in such several novel ways as: (Mavani, Ali & Othman,2022).

i. **Predictive Modeling**: AI algorithms can analyze data to predict food trends, consumer behavior, and market demand.

ii. **Personalized Nutrition**: AI-powered nutrition counseling and personalized dietary recommendations.
iii. **Food Safety Monitoring**: AI-driven monitoring systems for real-time food safety surveillance and risk prediction.
iv. **Smart Agriculture**: AI-optimized crop yields, precision farming, and autonomous farming equipment.
v. **Food Fraud Detection**: AI-powered detection of food fraud and adulteration.
vi. **Recipe Development**: AI-generated recipes based on flavour profiles, nutritional content, and ingredient availability.
vii. **Food Processing Optimization**: AI-optimized food processing conditions for improved quality and safety.
viii. **Supply Chain Management**: AI-powered supply chain management for efficient food distribution and reduced waste.
ix. **Sensory Analysis:** AI-powered sensory analysis for objective evaluation of food taste, texture, and aroma.
x. **Scientific Discovery**: AI-assisted scientific discovery in food science, such as predicting protein structures and functional properties.
xi. **Digital Twins**: AI-powered digital twins for simulating food processing and predicting outcomes.
xii. **Consumer Insights**: AI-powered consumer insights for understanding food preferences and behavior.

The above novel applications of AI can drive innovation, efficiency, and sustainability in the food industry, advancing the knowledge-based economy in food science and technology.

The Circular Economy

The circular economy is based on closing the loop of materials and substances in the food supply chain. In this model, the value of products, materials, and resources is preserved in the economy for as long as possible (Merli *et al.*, 2018). Integrated into the food system, the circular economy offers solutions to achieve global food sustainability by minimizing food loss and waste, promoting efficient use of natural resources and mitigating biodiversity loss (Jurgilevich *et al.*, 2016), by retaining the resources within a loop, i.e., the resources are used in a cyclic process, reducing the demand for fresh raw materials in food production.

This sharply contrasts with the unsustainable practice of producing and consuming materials based on the linear (take-make-dispose) economic model. There is an urgent need for a shift toward innovative and sustainable approaches embodied in the principles of the circular economy (Jørgensen and Pedersen, 2018). This efficient use of natural resources in a circular economy, in turn, helps to rebuild biodiversity by preventing further conversion of natural habitats to agricultural land, which is one of the greatest contributors to biodiversity loss (Dudley and Alexander, 2017).

Food loss and waste accounts for 30% of the food produced for human consumption globally, translating into an estimated economic loss of USD 1 trillion annually (FAO, 2019). Food loss and waste also takes its toll on the environment in relation to the emission of greenhouse gases associated with disposal of food waste in landfills, as well as in activities associated with the production of food such as agriculture, processing, manufacturing, transportation, storage, refrigeration, distribution, and retail (Papargyropoulou *et al*., 2014). The various steps in the food supply chain have an embedded greenhouse gas impact, which is exacerbated when food is wasted and lost.

Constraints and Challenges towards realizing a knowledge-based economy in a developing country (Oluwadare, (2015):

i. **Limited knowledge readiness**: Many developing countries, including Nigeria, lack the infrastructure and resources needed to support a knowledge-based economy.
ii. **Brain-drain**: Developing countries often experience brain drain, as highly skilled workers emigrate to other countries in search of better opportunities.
iii. **Limited access to education**: Many developing countries have limited access to quality education, making it difficult for people to acquire the skills needed for a knowledge-based economy.
iv. **Dependence on natural resources**: Many developing countries rely heavily on natural resources, which can make it difficult to transition to a knowledge-based economy.
v. **Limited innovation culture**: Developing countries often lack a culture of innovation and entrepreneurship, which can make it difficult to drive economic growth.
vi. **Limited infrastructure**: Developing countries often lack the infrastructure needed to support a knowledge-based economy, such as high-speed internet and reliable transportation.
vii. **Limited funding for research and development**: Developing countries often have limited funding for research and development, which can make it difficult to drive innovation.
viii. **Limited access to technology**: Developing countries often have limited access to technology, which can make it difficult to drive economic growth.
ix. **Limited skilled workforce**: Developing countries often have a limited skilled workforce, which can make it difficult to drive economic growth.
x. **Limited economic diversification**: Developing countries often have limited economic diversification, which can make them vulnerable to economic shocks.
xi. **Institutional corruption**: One of the greatest challenges of developing countries toward achieving knowledge-based economy is corruption. Fund which might be budgeted for research and development tends to be either embezzled, siphoned or misappropriated. Nigeria developing country, is a typical example in this case.

Feasible Strategies for developing countries to achieve a knowledge-based economy are under-listed, therefore, implementing them, it is envisaged that developing countries, including Nigeria, can build a strong a strong knowledge-based economy, drive economic

growth, and improve the quality of life for their citizens.

i. **Invest in Education**: Focus on quality education, vocational training, and lifelong learning to build a skilled and adaptable workforce.
ii. **Encourage Innovation**: Foster a culture of innovation, entrepreneurship, and risk-taking, and provide resources for start-ups and SMEs.
iii. **Develop Infrastructure**: Build modern transportation, communication, and digital infrastructure to facilitate knowledge sharing and collaboration.
iv. **Promote Research and development**: increase funding for R&D, and encourage public-private partnerships to drive innovation and technology transfer.
v. **Encourage Foreign Investment**: Attract foreign investment in knowledge-intensive industries, and leverage technology transfer and skills upgrading.
vi. **Foster Collaboration**: Encourage collaboration between academia, industry, and government to drive innovation and knowledge sharing.
vii. **Develop a Digital Economy**: Leverage digital technologies to drive economic growth, improve efficiency, and enhance competitiveness.
viii. **Support Entrepreneurship**: Encourage entrepreneurship, particularly among youth and women, and provide resources for start-ups and SMEs.
ix. **Develop a Skilled Workforce**: Invest in training and up-skilling programmes to build a workforce with the skills needed for a knowledge-based economy.
x. **Encourage Knowledge Sharing**: Foster a culture of knowledge sharing, and provide incentives for collaboration and innovation.
xi. **Develop Clusters**: Encourage the development of industry clusters to drive innovation, collaboration, and knowledge sharing.
xii. **Encourage Open Innovation**: Encourage open innovation, and provide resources for co-creation, and collaborative problem-solving.

Conclusion

This review focused on the potentials of food science and technology to foster a knowledged-based economy in a developing country. It revealed a number of feasible ways through food science and technology can help to transition a resource-based economy to a knowledge-based economy in a developing country. The field of Food Science and Technology is promising with respect to contributing to achieve a knowledge-based economy in a developing country like Nigeria. The government active and sustained involvement and substantial investment in research, development and innovation through commercialization of outcome of functional research in tertiary educational institutions and research centers in addition to effective collaboration with existing industries are key to realize this goal.

Suggestions

i. Realizing a sustainable knowledge-based economy in any country should be a multi-stakeholder involvement.
ii. Developing economies should be resolute in dealing decisively with corruption in the system, more especially in government circles.
iii. The curriculum of any developing economy must reflect real and peculiar needs of the country, with intermittent reviews as the need arises.

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