

Encouraging Scientific Entrepreneurship through Biotechnology Education in Nigerian Polytechnics as a Sustainable Economic Diversification Plan.

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ABSTRACT

In the last two decades, research and innovation in biotechnology have led to tremendous advances in agriculture, pharmaceutical production, healthcare, and food and beverage industries while introducing an efficient environmental remediation system through bioremediation as well as alternative and sustainable energy generation from biogas. The last few decades have witnessed an avalanche of science entrepreneurs, which are viable, innovative, sustainable, fast growing and highly profitable in a business world that was hitherto dominated by oil and gas, automobiles, media and banking. For Nigeria, which is in the midst of economic recession, there is no better time to include scientific entrepreneurship education in diversification plans, than now. About 49million of Nigeria's 170 million populations are unemployed, with youth population being the largest unemployed group. The national committee on job creation reported that 53% of youth within the 25-44 years age are unemployed. When this is juxtaposed with the National Bureau of Statistics data that about 1.3million Nigerians enter the job market yearly in a country where 52.88% of formal job sector are managerial/professional/technical jobs, we are left with a large unemployable youth within the formal job sector. This paper attempts to explore ways that Nigeria's 103 polytechnics can introduce biotechnology education with a comprehensive curriculum for hands-on training towards a more skill-based qualification. For medium term economic diversification plan, molecular biology skills that can create employable diploma graduates are considered while advanced biotechnology and genetic engineering technics that can create entrepreneurs are considered for PgD, MSc, and PhD level education as a long-term plan. Ethical issues and biosafety problems as they affect the public perception of genetically modified organisms (GMOs) have also been reviewed.

Keywords: Biotechnology, Education, Economic diversification, Polytechnics, Nigeria & Entrepreneurship.

Aims Research Journal Reference Format:

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1. INTRODUCTION

Biotechnology is a diverse scientific field that explores multidisplinary approach to advance basic and applied research in life sciences with the ultimate aim of improving life and enhancing industrial productivity. It combines basic and applied research in life sciences – biochemistry, molecular biology, microbiology, genetics, botany, and physiology - with other disciplines such as medicine, chemical engineering, physics, and computer science for industrial and healthcare benefits (Konde, 2009; Peacock, 2010). In the last two decades, research and innovation in biotech has led to a tremendous advances in agriculture, pharmaceutical production, healthcare, food and beverage industries as well as introducing an efficient environmental remediation system through bioremediation and and sustainable, alternative energy source through biogas production (Makinde et al. 2009; Visalkshi, 2009). Scientific entrepreneurship is now a major economic player in a business world that was hitherto mostly dominated by oil and gas, automobiles, media and banking businesses. The last few decades have witnessed an avalanche of science-based businesses, which are viable, innovative, sustainable, fast growing and highly profitable.

From software technology, championed by Silicon Valley to biotechnology industries, scientific 'start-ups' have proliferated the market and helped shape the economic landscape of developed nations from North America to Europe; and mid-income and emerging economies from China to Singapore; and from India to South Africa. Healthcare and education are important for economic development. Studies by Juma and Serageldin (2007) reported the dearth of effective diagnostic modern test kits, preventive vaccines and therapeutic drug and procedures in Africa. However, only 1.1 per cent of the total value of the global pharmaceuticals is consumed in Africa.

Africa is rich in natural resources and biodiversity such as land, wildlife, forests, fisheries and water, which require efficient development that can benefit from industrial and environmental biotechnology. In agriculture, biotechnology can provide farmers with disease-free seeds and crops that are resistant to local pests and disease, which decrease harmful chemicals. Biotechnology has the potentials to improve the nutritional value of food crops such as rice and cassava (FAO, 2002). Hands-on education is important in development of human capacities, which are central to sustainable economic growth. It is important for the new generations of African scientists and technicians to be at the center of any strategy aimed at building scientific and technological capacities. This exploratory study tries to look at how Nigerian polytechnics can include biotechnology course in their curriculum to facilitate entraprenuship among graduates. To achieve this, biosciences networks, such as training scholarships, fellowships and research grants, mentoring arrangements, and virtual outreach forum, can go a long way. However, as with every new technology, biotechnology ethical issues should be looked at by social scientists, philosophers, ethicists and the public (King and Webster, 2009).

1.1 Biotechnology Scope

Biotechnology has a very wide scope and compelling advantages, that virtually every industry is using this technology. Research and Developments(R &D) are ongoing in areas as diverse as pharmaceuticals, diagnostics, Agriculture, textiles, aquaculture, forestry, chemicals, household products, environmental cleanup, food processing and forensics among others. The impact of this field is helping these industries to make novel or better products, at a faster rate, efficiency and flexibility (Peacock, 2010; Konde, 2009). Experts believe it has the potential for being the key to world food supply, improved healthcare delivery, environmental remediation and renewable energy source if regulated properly. Many countries are initiating ways to strengthen the regulatory process and to create more effective awareness.

Biotechnology exploits cellular and bio-molecular processes to produce products or bring about processes that benefit humans and the environment. Applications in medicine include diagnoses of genetic diseases and diagnostic test kits (e.g, ELISA) for infectious diseases and Pharmaceutical drugs discovery (e.g., antibiotics) & synthesis of biopharmaceuticals (e.g insulin) (Peacock, 2010). In agriculture it helps improve breeds of crops or animals (e.g., GMOs). Industrial biotechnology involves the production of fine chemicals, enzymes for detergents and textile industries and biofuels generation from plant such as ethanol, and production of gas from biomass promotes sustainable energy Environmental biotechnology could help in environmental remediation: clean up soil, and water pollution, which help sustain biodiversity (Makinde *et al.*, 2009).

1.2 Biotechnology in Nigeria

Nigeria has had a thriving small-scale food processing industry which depends simple but effective use of traditional biotechnologies, such as the production of cassava-based foodstuffs, palm wine and various other wines from local fruits such as mango, pineapple and banana, and lager beer from malted sorghum and maize. In the early 1980s, researchers at the University of Ife identified a protein sweetener in the extremely sweet berry plant, *Thaumatococcus danielli*, later confirmed to be at least 1 600 times sweeter than sucrose. The gene for thaumatin was cloned, and the protein sweetener sold for more than US\$ 5 000 per kilo (Kassupa & Singh, 2007).

According to Kassapu & Singh (2007), about ten government research institutes out of 24 in 1993 were involved in some kind of biotechnology research, which are mostly food, and agriculture-based research. FAO, the United Nations Development Programme (UNDP) and the International Plant Genetic Resources Institute (IPGRI) are supporting the National Centre for Genetic Resources and Biotechnology (CGRB), Moor Plantation, Ibadan. It is charged with coordinating research in nine satellite laboratories, responsible for research in specific biotechnology areas. On the 23rd of April 2001, The Ministry of Science and Technology set up the National Biotechnology Development Agency (NABDA) and, with a view to pooling the scattered human resources in microbiology, genetics and molecular biology and to advising the Ministry and CGRB (NBDA, 2016).

Main research areas so far are:

- Longer shelf-life of palm wine and other foods and beverages
- Selection of wheat lines that could survive the humid conditions in the south.
- Two institutes and IITA in Ibadan (the Biotechnology Unit of the Institute for Agricultural Research and Training Ibadan), tried to improve maize, cowpea and peanut yield through tissue culture.
- The Biotechnology Centre of the Anambra State University of Technology deals with food fermentation and industrial enzyme production.
- The Nigerian Institute for Oil Palm Research, Benin, the Cocoa Research Institute of Nigeria, Ibadan, and the National Root Crop Research Institute, Umudike, all apply plant tissue culture and other basic molecular techniques.
- ICRIN has also been focusing on somatic embryogenesis, in vitro conservation of germplasm and the identification of microorganisms that could be used to improve the biochemical development of cocoa flavour during the fermentation process as well as those required for the digestion of pod husk for animal feed production.
- The research institutes involved in animal health were the National Livestock Research Institute, the National Animal Production and Research Institute (NAPRI), Shika, Zaria, and the National Veterinary Research Institute (NVRI), Vom, as well as the Nigerian universities at Sokoto, Ibadan, Maiduguri and Zaria, and recently Center for Biotechnology Research at Bayero University, Kano.
- The main research areas include the development of new breeds of cattle for beef and milk production, and of vaccines against a wide range of diseases.

However, the main problems facing biotechnology development in Nigeria include:

- Lack of fund from the government and private corporations,
- Lack of interest by multinational corporations.

2. STUDY BACKGROUND: TACKLING YOUTH UNEMPLOYMENT PROBLEM

According to one account by NBTE, about 49million of Nigeria's 140 million people are unemployed, with youth population, mostly 'SS3 leavers' being the largest unemployed group. This is even more so; as this group is the least skilled demographic among the educated populace. Nigeria is officially in financial recession as announced by the president recently. GDP growth comparison as at March 2016 is 6.3% (2014), 2.7% (2015e) compared to 0.8% (2016f), and projected as 3.5% (2017f). However, 40% of the economy is agricultural sector base and provides 75% jobs. (NBS, 2015; Wikipedia, 2016)

The national vocational qualification framework (NVQF) was introduced in 2013 to take care of the category of unskilled youths that are unemployed or under employed because they left school early without having the opportunity to acquire any post secondary education and with barely any special skill (NBTE, 2016). This novel development plan is aimed at transforming this demographic in to adequately skilled, employable citizens. However, Nigeria's youth unemployment problem transcends the 'secondary school-leavers' category. It is a problem that cuts across all youth group at all level of education. The national committee on job creation, as quoted by NBTE report on their website, that 53% of youth within the 25-44 years age bracket are unemployed.

When this is juxtaposed with the National Bureau of Statistics data that about 1.3million Nigerians enter the job market yearly in a country where 52.88% of formal job sector are managerial/professional/technical jobs, according to the federal ministry of finance, we are left with large unemployable youth within formal job sector alone. The diploma graduates who are usually the least qualified tend to be affected the most. Juma and Serageldin (2007) observed that there is a general problem of low absorption of labour in Africa's growth sectors. Most people of working age earn their living in agricultural sector, which remains, relatively labour-intensive when compared to what obtains elsewhere.

Nigeria needs to build up and concentrate its human resource capacities towards modern biotechnology. Various agencies and research institutions should be engaged in the mobilization, sharing and using existing scientific and technological capital-base, including human and financial resources as well as physical infrastructure for biotechnology research, innovation and development. Main focus should be primarily on local innovation areas, which have core research and business institutions. International collaborations are important for the realization of Nigeria's biotechnology policies and should be pursued accordingly (Juma and Serageldin, 2007).

3. BIOTECHNOLOGY ENTREPRENEURSHIP

Entrepreneurship is simply, designing, implementing and running a new business (product, service for sale or hire), mostly from small beginnings (start-ups). Main motivational driving forces for entrepreneurship include: perception of desirability & feasibility of starting a business; profitable business opportunity; technical Know-how and Entrepreneurial initiative (Mainoma and Aruwa, 2011). It is now a common knowledge that science and technological innovation is playing a great role in economic transformation and sustainable development. A lot of the economic advances in developed and emerging economies have roots in innovation. An important factor that promotes innovation is skills acquisition through learning and the knowledge received can be used for development by adding or improving on it (Kassuppa and Singh, 2007). Investment in research has helped advanced the economy of developed nations, such that national income rates have remained more or less the same since the Industrial Revolution. Combined OECD countries annual investment in research and development is around 1.5 times which is more than the entire economic output of sub-Saharan Africa.

Knowledge economy utilizes research and innovation for economic development through commercialization. What follows is translating research into products and processes and refining and tweaking them to conform to socioeconomic needs. Commercialization refers to the process by which new knowledge is transformed to finished products and services of commercial value. The model for commercialization of biotechnology is not a linear assembly like model. (Visalakshi, 2009). The biotechnology market is a mix of products from different industries. The current most important markets for biotechnology products are in pharmaceuticals, agrochemicals and seeds. Environmental remediation and the alternative large-scale chemical synthesis by biotechnological processes (e.g. vitamins) are smaller markets. With a market of about USD 17bn in 2000, biopharmaceuticals (minus diagnostics), come top as the largest market segment (EIB, 2002).

The relative market for gene-manipulated (GM) crops and related pesticides is rather small with less than USD 8bn. Biotechnology in the agrochemicals and seed markets mainly concerns GM seeds whereas related pesticides are purpose-built to increase efficiency of crop production in combination with GM seeds. Biotechnological applications in environmental remediation, targeting mainly water and soil regeneration but also biodegradable plastics, account for less than USD 1bn. overall, the market for biotechnology products is estimated at around USD 26bn in 2000(EIB, 2002).

Commercialization of biotech products & services is based on the hypothesis that successful commercialization in knowledge-intensive field with high rates of turn over like biotechnology depends on:

- (i) High levels of capabilities in R&D and strong network, to complement skills and facilities and
- (ii) Favourable environment which allows high levels of preparedness of the technology delivery system which, depend on favorable policies for regulation, access to fund, infrastructure and skills (Visalakshi, 2009)

4. INTRODUCING BIOTECHNOLOGY EDUCATION IN NIGERIAN POLYTECHNICS

According to Nigerian Board of Technical Education (NBTE), there are 103 accredited polytechnics in Nigeria as at July 2016. There are 25 federal and 40 state polytechnics that are responsible for running two-year diploma and three-year Higher National Diploma (HND) programmes (NBTE, 2016). To achieve a meaningful growth in the economy via biotechnology entrepreneurship, there is the need to expand human resources development base in biotechnology education and research. Some of the ways to achieve this are:

- By the creation of a comprehensive biotechnology curriculum that caters for both theory and hands-on student learning experiences
- Forming a consortium of clearly identified and designated polytechnics and universities with the requisite laboratory infrastructures to develop and provide biotechnology training courses
- Create partnership opportunity among polytechnics, research institutions and industries for students' internship and further field training.
- Create the link between entrepreneurship and innovation in the sciences and engineering
- And finally, form policies that regulate and guide the training in science and innovation development plan.

4.1 The Need for Reform Towards a More Research-Based Curriculum

To achieve some level of sustainable growth via biotech entrepreneurs, the polytechnic education needs some reforms because just like the universities they were not fashioned in the way modern learning institutions serve as the powerhouse of research, innovation and development. One of the main problems faced by both Staff and students in majority of Nigeria's higher learning institutions is the low or lack of indigenous non-state funding from sources that will complement TETFUND's efforts. Juma and Serageldin (2007) quoted a 2001 survey that reported that foreign sources account for nearly half of research funds in African universities. They also noted that gross expenditure on R&D in Africa is around 0.3%.

About a half of all scientific research published in Africa originates from Egypt and South Africa; a quarter from Kenya, Morocco, Nigeria and Tunisia while the rest of the 43 countries account for the last quarter. The number of articles published in global science journals from 1998-2001 saw a 40% increase, while Africa's publications recorded a 12% decrease over the same period. Africa's 10 larger countries: Nigeria, South Africa Kenya, Senegal and Zimbabwe have fewer articles in 2001 than in 1988. And what little success recorded in Africa at this period under study was less than a 100 publications a year each from some ten countries!

Main solution should focus on curriculum reformation, teacher training and welfare, reforming admin and management styles and finally injecting some funds in to R&D. This can be achieved via:

- i- Changing the way institutions are funded from mainly government intervention programs like TETFUND to encourage private sector partnership by indulging private entrepreneurs; Religious and charity funds as well as international donor partnership to compliment government efforts.
- ii- Some level of autonomy is also needed to allow the institutions some level of Innovative independence and utilize the little incentives from their efforts without government interference.
- iii- The various Universities of technology spread in all the country's geopolitical zones could form partnership with the polytechnics to help bolster their research strength in various faculties and support the courses offered, provide accreditation, and in the future they could also award degrees to qualified polytechnic graduates.

4.2 Short and Long-term Economic diversification plans

- In the case of short and long term plans, it is paramount to create a pool of talented and skilled citizens by introducing new specialized institutions and empowering existing institutions with hands-on learning materials.
- For short-term economic diversification with biotechnology entrepreneurship, Nigeria needs to evolve small and medium scale enterprises (SMEs).
- There should be a reform in the area of reviewing and adjusting federal and state policies and related legislation to create a sustainable and conducive environment for research and innovation in polytechnic education, such that students can undertake few months internship and proceed to the labour market or become entrepreneurs in their chosen fields after a two year diploma.
- As suggested by Juma and Serageldin (2007), the government can set biotechnology priority areas needed for accelerated development and proceed to identify the requirements (in terms of capacity building) for achieving such development.
- It is also important to put in place robust regulatory policies that can encourage biotechnology research while taking care of biosafety issues, commercialization and consumer protection.

4.3 Developing Human Capacities as a Long-Term Economic Diversification Plan

As observed by Juma & Serageldin (2007), Universities, research institutions, technical/vocational schools, private companies, and social institutions, are instrumental to developing human capital/capacity base. They shape and stimulate creativity, the effect of which is the impact of human innovative power in economic development.

African countries generally lag behind in terms of human resources investment in science, technology and innovation. According to Unesco Science Report (2005) findings, 92% of African researchers are not sufficiently paid. The highest number of researchers as at 1999, are in Egypt (10,000 full-time), South Africa (13,000), and all others have 3,200 or below (Juma & Serageldin, 2007).

Biotechnology-based economy requires huge skilled and experienced researchers in basic biotechnology disciplines such as molecular biology, biochemistry, microbiology and bioinformatics. Since research proficiency is mostly achieved through postgraduate studies, biotechnology disciplines derived from the applied research areas of those fields can be introduced in the various universities across all geopolitical zones to support the polytechnic trained biotechnologists with PgD, Msc, and PhD training.

5. FUTURE PROSPECTS

5.1 Agricultural biotechnology

Sub-Saharan Africa is facing a developmental challenge due to stagnant or slow growth in many developmental sectors including agricultural sector. It is estimated that population growth will pass food production capacities for a long time to come. If this continues there will be about 250 million tonne food shortage, or 20 times the current food gap, in the next 25 years (Kassapu & Singh, 2007).

There is also the problem of dwindling agricultural investment, especially for technology development and transfer.

Agricultural Biotechnology has the potential of improving plant breeding via selection, tissue culture and genetic modification (GM). In GM technology, genes are altered to introduce newer or improve desirable traits or even eliminate undesirable ones. Some of these traits include:

- Improved resistance to pest and disease
- Improved nutritive value, e.g., Beta-karotene introduction in to the 'Golden rice'
- Improved adaptation to extreme environmental stress such as drought condition & soil chemical regime.

In Animal Breeding: artificial insemination, cloning, genetic modification, etc. are employed to improve meat production; egg production; milk production etc.

Nigerian government can adopt measures to accelerate agricultural biotechnology since, as reported by Juma and Serageldin (2007), Scientists have unanimously agreed that, so far, there

is no compelling evidence of harm from the consumption of approved biotechnology foods and food products.

5.2 Biotechnology in Medicine and Pharmaceutical Industry

AU countries record some of the rapid spread of HIV/AIDS pandemic, which is at 7.3% compared to global rate of 1.1% in 2003. Life expectancy at about 46.1 years, compared to the North African average of 71.5. Poverty and poor health care systems are culprits as African countries spent a paltry US\$10, compared to the minimal US\$1000 in member states of the Organization for Economic Cooperation and Development (OECD) in 1999. Cost of healthcare is high for the poor, as a third of their monthly earning may be spent on malaria treatment alone (Juma and Serageldin, 200; Konde, 2009). Malaria burden means that one in six children dies before their fifth birthday and 1.5 million children die from vaccine-preventable diseases annually.

Anti- malaria drug precursor artemisinin is produced faster via biotech than via farming the chemical precursor from crops of *Artemisia absinthium* (wormwood). Though there are concerns about farmers losing their livelihood, but the benefits of producing artemisinin in an easy, faster, and cheaper manner outweighed the disadvantages. Biotech production would benefit poorer countries, as it would free lands that are previously devoted to wormwood, for growing food crops (Kassapu & Singh, 2007). In the future, within 25 years micro- organisms could be engineered or synthesized to permanently live in humans to detect a particular type of abnormality such as cancer (King & Webster, 2009).

Cloning: the replication of an exact copy of an organism, gene or biological system could be used for fertility problem, increased animal production, stem cell therapy, regenerative medicine, and gene therapy. Other applications of biotech in medicine include production of vaccine therapy (immunotherapy), DNA vaccine, gene therapy, molecular diagnoses of infectious & non- infectious diseases, nanomedicine and regenerative medicine. Pharmaceutical application is in the synthesis of biopharmaceuticals (insuline, single-cell protein), antibiotics, DNA/RNA vaccine, Pharmacogenomic (precision medicine) and biopharming. In future biotechnology can provide for Nigerians, reliable access to safer and more effective diagnostic tests (via molecular testing, monoclonal antibodies etc.); medicines (antibiotics, biotherapeutics, gene therapy, cell & regenerative medicine etc.); vaccines (attenuated vaccines, RNA/DNA vaccines, reverse vaccinology etc.) and reproductive health (stem cell embryogenesis, reproductive cloning etc).

5.3 Other areas of biotechnology application

- Africa's biodiversity is threatened by land and water degradation caused by drought and floods among others, which affect the people and economic development. Desertification leads to a reduction in arable and grazing land, pollution, and depletion of freshwater. Deforestation reduces wildlife, takes away important food source, fuel and medicines. Also reduces tourism potential and availability of medicinal plants.
In Africa, over 70 per cent depend on forests for their living, and 60 per cent of Africa's energy needs are met by wood. (Juma and Serageldin, 2007; Kassapu & Singh 2009)
- In the next ten years it is likely that microorganisms will be modified to be able to detect toxins and heavy metals. In the UK bacteria are now been engineered to detect arsenic in drinking water (King & Webster, 2009).
- Biotechnology companies are researching how to produce biofuels from bio-engineered organisms, expected on the market within 5 years (King & Webster, 2009).
- In bioremediation, bacteria engineered to take- up the pollutants in contaminated sites, break it down and thereby remove it from the environment are expected soon.

6. SUNDRY PROBLEMS/CHALLENGES ASSOCIATED WITH BIOTECHNOLOGY DEVELOPMENT

6.1 Finance/Funding source

Biotechnology funding involves various approaches to generate financial resources, including “innovation funds”. Other funding sources may include national, international and regional development banks all of which could also help in the commercialization of products from the biotechnology- related local innovation areas. The Start-ups dominate the market, they are small, early-stage, upcoming companies with a potential for rapid growth in labour force and annual income rate. Funding a start-up could be through public funds, if the government is interested; or Private: Venture capital firms, Private equity, & Angel investors provide the working capital to start-ups for growth and expansion (Wikipedia, 2016). Local Innovation Areas have the potential of creating competitive, biotechnology-driven African economies that will arise from homegrown innovators in local universities, biotech firms, and research institutes. (Juma and Serageldin, 2007). However, government should be involved in funding research and development in biotechnology as this can give some leverage and allow the Government to have some influence over developments.

6.2 Biosafety and Ethical Issues

These are issues concerning environmental releases of engineered organisms resulting from accidents from controlled environments as well as deliberate release as in bioremediation. Since research may lead to industrial scale production, there is the fear that any accidental release would correspondingly be huge, and widespread. For example, instances such as the 2007 escape of the foot and mouth virus from the Pirbright laboratory in Chernobyl are cited by people in a UK study (King & Webster, 2009).

- Another perceived threat is garage biology or bio hacking, the biotechnology activities of private individuals outside of controlled environments such as laboratories with access to materials such as equipment and DNA sequences (King & Webster, 2009).
- People differ on patents, some think it slows innovation, research and development, and others believe that investors are entitled to a return on their time and money.
- But there should be a balance between returns on investment and social responsibility so that it does not favour only the affluent people (King and Webster, 2009).

Nigeria needs to get regulatory bodies with transparent and high quality scientific capacity to assess biotechnology risks in a safe and timely fashion.

There should also be stakeholder collaborations and awareness campaigns to create public awareness and education on biotechnology.

- Regulatory agencies should ensure effective control and safety of biotechnology products and services.
- Research and development of various biotechnology products and services must follow strict controls and tests.
- Scientists should endeavour to create public awareness through open access seminars, workshops and conferences as well as social media engagements to neutralize undue media-induced paranoia.
- Creation and providing legal framework for research institutes and councils that can take the public concerns on biotechnology to regulators through discussions with the Chief Scientific Advisor as obtained in the UK for example.

6.3 Public Awareness and Public Engagement

As observed by King & Webster (2009), two key awareness problems likely to arise are the possibility of people rejecting something they did not understand and media sensationalism. About a half of the UK respondents (49%) in a survey, don't know what synthetic biology is. In contrast just 30% of the US respondents have no idea what it is. Respondents over the age of 65 were more likely to constitute this group compared with those in other age groups (60% compared to the average of 49%) King and Webster, 2009; Peter, 2008). However, there was a feeling that if the products and services derived from this technology were well presented, especially by highlighting the positive impacts on medicine, the media would favourably receive it. Ultimately, people feel that scientists and Government need to explain biotechnology to the public, indicating its purpose and the control measures in place.

6.4 Lessons from The UK & US awareness campaigns

Points raised:

- People appreciate huge potential benefits from synthetic biology but have some reservations about the release of synthetic or genetically modified organisms in to the environments.
- Not all believed that biotechnologists could have effective control on created and/or modified organisms, as there was some skepticism.
- There was relative acceptance for biotech processes involving microbial containment, over use of synthetic biology for bioremediation (King and Webster, 2009; Peter, 2008).

It is expected that if the public have additional knowledge of a science or technology, such as molecular biology, or immunology, then this would lead to easy acceptance of new technologies such as genetically modified foods, or synthetic biology.

Formation of active and continuous public engagement programme where scientists, policy makers, private companies and the public can share their views on both the potential benefits of biotechnology and their fears on the existing and evolving newer and emerging technologies.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Nigeria's 103 polytechnics can introduce biotechnology education with a comprehensive curriculum for hands-on training towards a more skill-based qualification. For medium term economic diversification plan, molecular biology skills that can create employable diploma graduates are looked at while advanced biotechnology and genetic engineering technics that can create entrepreneurs are considered for PgD, MSc, and PhD level education as a long-term plan. Ethical issues and biosafety problems as they affect the public perception of genetically modified organisms (GMOs) have also been reviewed. It is important that the Government is fully involved in the policy and regulatory framework of biotechnology R & D. This would give the government some leverage to act in the best interests of the people and allow for the strict enforcement of appropriate controls and regulations.

7.2 Recommendations

- (1) Human resources development strategies could be achieved by creating
 - National biotechnology educational curriculum for both universities and polytechnics that concentrate on job creation priority goals
 - Specialized and well-funded polytechnics, universities and research institutes that train youth in biotechnology courses across the six geopolitical zones with emphasis on entrepreneurship.
- (2) There is a need for creating conducive commercialization and business environment for biotechnology products and services through:
 - Educational and social Infrastructural development across the country
 - Enabling R&D cooperative partnerships at the local and regional levels as well as facilitating international partnership for high research-intensive biotechnology products
 - Introducing policy frameworks that support biotechnology business incubation and development around major cities such as Lagos-Ibadan, Enugu-Port Harcourt, Kano-Kaduna and Abuja-Jos axis.
 - Creating market infrastructure for biotechnology products and services that can accelerate economic development.
- (3) There is also the need to create schemes that facilitate funding for biotechnology R&D through:
 - National policy formulation on SMEs that are science and technology based with emphasis on biotechnology and other emerging technologies.
 - Increasing national budgetary allocation for R&D
 - Enabling other funding avenues that can include international development funds and partnerships,

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