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Communication and Perception of Emerging Science, Technology and Innovation in Nigeria: Implications for Development

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Abstract

There is a paucity of empirical research on emerging Science, Technology, and Innovation (STI) communication in Nigeria, and the impact on national development. This study sought answers to: what are the perceptions of emerging STI among Nigerian citizens and academics, and to what extent do emerging STIs contribute to national development? Based on the science-technology-society theory, the study conducted a survey of 2400 Nigerians in 12 states and an interview of select STI experts in 12 Nigerian universities. The study focused on synthetic biology, nanoscience and technology, robotics and artificial intelligence, drones, etc. The findings showed that a greater majority of the respondents perceived agricultural drones as the most necessary emerging STI in Nigeria while neuroparasitology was seen as the least necessary to the country's development. Respondents also agreed that emerging STI had the more impact on ICTs and the least on security, economy and the environment. Also, large segment of respondents perceived that the new/ mass media were the predominant sources of emerging STI information. Also, STI experts perceived emerging STIs to be in their infancy in Nigeria, communication of STIs was concentrated within the scientific community, and collaboration was lacking between the STI community and other stakeholders.

Keywords: Science communication; Technology/Science/Society Discourse; Survey research; Third world nation.

INTRODUCTION

Science, Technology and Innovation (STI) are occurring subjects in Nigeria, a populous and greatly endowed, but poor country. These subjects of scholarships and institutional research have found expressions in schools, universities, agencies, and research organisations. Often abbreviated as STEM – (science, technology, engineering and mathematics), many political decisions, and policy frameworks have been built around STEM or STI in order to boost scientific literacy in developing nations, stimulate economic growth, and foster social/cultural progress (Wycliffe & Ayuya, 2013; Jamme, 2015; Attah-Mensah 2015; Ndesauliwa & Kikula, 2016; Marsh, 2016; Juma, 2016; Kariuk & Kay, 2017; Chakravorti & Chaturvedi, 2019; Beumer, 2019; and Daniels & Gebhardt, 2020).

The problem is that while Nigeria is still struggling with funding and raising the tempo of activities in STI and STEM, the advanced world has done remarkable work in emerging STI/STEM meaning that the global south has to catch up or be left behind. What worsens matters is that, because emerging STI/STEM is nascent in third world nation such as Nigeria, there is a paucity of research on emerging STI/STEM information, the involvement and engagement of Nigerians in emerging STI, the extent of citizen's perception of emerging STI sources of information and how all of these are implicated in Nigeria's development.

This study therefore seeks answers to these questions: How do Nigerian scientists and citizens perceive emerging STI? What are the STI information sources for the public? What do these portend for Nigeria's development?

Emerging Science, Technology and Innovation

The concept of emerging science, technology and innovation is for grasping the essence of this study. Rotolo, Hicks, and Martin (2015) define an emerging technology as follows:

> A radically novel and relatively fast growing technology characterised by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socioeconomic domain(s) which is observed in terms of the composition of actors, institutions, and patterns of interactions among those along with the associated knowledge production processes. Its most prominent impact, however lies in the future and so in the emergence phase, is still somewhat uncertain and ambiguous (p. 1827).

Examples of emerging technologies include biotechnology, nanotechnology, artificial intelligence/ robotics, drone technology, etc. The impact of these technologies on development in the global south cannot be taken lightly. This realisation predicts our interest in these subjects.

Innovation involves scientific, technical, or technological stages, applied in managerial, organisational, social, industrial, agricultural, etc. settings operates at transcontinental, transnational, regional, large, medium, and small scales. Innovation makes economic, social, ecological, and integrated processes efficient. Kogabayer and Mariliauskas (2017) cite Twiss as defining innovation as, "a process that combines science, technology, economics, and management, as it is to achieve novelty and extends from the emergence of the idea to its commercialisation in the form of production, exchange, consumption (p. 60). The characteristics, according to Rudd and Simonds (2022) that make innovations adoptable include lower social or economic costs, provision of a good fit with values and current practices, and low complexity. Innovations in science and technology are needed for development purposes.

An emerging science is, nascent, epistemic, and methodological approach to the systematic study of the sciences in interdisciplinary and multidisciplinary contexts. Some examples are gastrophysics which combines the physical, chemical, nutritional, psychological, gastronomic, entrepreneurship/ innovation sciences (Mouritensen & Risbo, 2013; Van der Linden, 2013). Another emerging science is nutrigenomics which enables, "a molecular (genetic) understanding for how common dietary chemicals (i.e. nutrition) affect health by altering the expression and or structure of an individual's genetic make-up" (Kaput & Rodriquez, 2004, p.1). Nutrigenomics Neeha and Kinth's (2013) provides new technical lexicon, innovative experimental techniques, and drastically fresh nutrition studies into genetic expression at cellular or organic structures. Neuroparasitology deals with the manner in which parasites control the nervous systems of the host. It studies how human or animal behaviour is altered by parasitic organisms (Libersat, Kaiser, & Emmanuel (2018).

Other emerging sciences include synthetic biology – which uses advancements in DNA synthesis and sequencing to engineer (manufacture) organisms from discrete chemical parts and designed to specifically perform novel functions (Powels, 2013); and epigenomics which studies how exposures and experiences can switch genes back and forth without altering DNA sequence examining how environmental factors such as food, toxic substances, injury, nutrients, and stress impact on gene behaviour. It makes molecular connections between the physio-social milieu and human genetics.

Emerging sciences, technologies, and innovations are fundamental to the development needs of developing countries. They help solve health, environmental, educational, security and agricultural problems if attention is paid to them. This study interrogates the extent to which the Nigerian public and scientists perceives STIs, how it obtains and or communicate information related to these matters, and how it connects these matters to national development.

Research Questions

This study sought answers to four questions.

a. What is the perception of emerging STI among university specialists and educated Nigerian citizens?
b. What are the communication and collaboration efforts on emerging STI among Nigerian university scientists?
c. From what sources do educated Nigerian citizens obtain information on emerging STI?
d. To what extent is emerging STI perceived to contribute to Nigeria's national development?

Communication and Public Perception of Emerging STI

The perception of emerging STI by the public is linked to communication. Aminu (2018), states that no nation aspires to greatness without making STI as the pivot because advances and applications in STI determine national wealth and livelihood of citizens. Nigeria's National STI Roadmap 2030, a follow up of the National Policy on STI revised in 2012 was envisioned as the country's strategy to institute long-term sustainable development. About this vision, the African Capacity Building Foundation (2017) notes that though Africa is reworking its development policies to embrace STI at several levels, the capacity is dismal.

Beyond STI's low capacity in Africa, communication within and beyond the science community is critical for awareness creation, knowledge acquisition, and public understanding of STI. Entradas, Bauer, O'muircheattaigh, Marcinkowski,

Okamura, Pellegrini, *et al*. (2020) note that whereas public communication has altered from an ideal to an obligation for scientists covering countries and fields, knowledge of what research institutions are about, and what factors propel public communication are restricted. In their study, the authors found out that science institutes embrace communication with non-scientists. Using public arenas, old and new media, they do a lot less using new media channels. The importance of science communication to public attitude formation as Cormick (2019) points out requires the need to better understand the social and media environments and how they affect new technologies in the world. This is more so, where ideas about truth, trust, and expertise are frequently debated, Cormick stresses the need therefore for scientists and science communicators to frame new technologies on the bases of solutions to social problems such as equity of access, unintended effects, health and safety.

Mormina (2019) sees STI as key to economic development, regretting that the capacity for scientific innovation is unevenly distributed globally. Take nanotechnology for instance, Besley's (2010) research on public perception of the field shows that while the expectation is that a reasonable connection exists between awareness of nanotechnology and positive views about it; multivariate studies emphasise the valid roles of trust, diffused views about science, and general world views. Additionally, Tartaruga, Peyre, Cazarotto, Martins, and Fukui (2016) point to other indicators for the analysis of public attitudes to STI to include efficiency, creativity, uncertainty, tolerance, and cooperation. Hetland (2016) weighs in the role of journalists as they popularise topical new technologies within technological expectations while researchers do so within both a retrospective and prospective understanding of technological change.

Generally, Peters, Dunwoody, Allgaier, Lo, and Brossard (2014) note as follows about the public communication of science: (a) the communication between scientists and the public is changing driven mainly by the Internet, (b) the (new) media fundamentally transform the interface between science and society, (c) increased interactivity and participation do not necessarily lead to improved public dialogue, (d) both the motivation and the ability of non-scientists to engage in communication vary by field of research and its possible applications, (e) most scientists continue to use "classic" media and consider them more influential in public communication than the new media, (f) almost all researchers considered "national newspapers in print" to have a strong influence on public opinion and political decision-making, (g) online media offer scientists more opportunities to communicate directly with the general public rather than rely on journalists as mediators, and (i) leading scientists nowadays accept public communication as part of their role whereas for most, the main tasks are research, publishing, teaching, and grant proposal writing.

In Nigeria where public communication of emerging STIs is perhaps low, scientists and communicators need to deeply examine the above listed observations and consider public engagement seriously for as Todd, Haupt, Kollmann, and Pfeifle (2018) who studied synthetic biology suggested, public engagement with science builds trust between scientists and audiences. Bidirectional communication and educational/informational interfaces involve science matters and social imperatives. The same is true for highly innovative fields such as robotics and artificial intelligence as covering their adoption and attitude towards them (Horowitz & Kahn, 2021).

Communication influences perception and vice versa. For emerging STI, Llorente, Revuelta, Carrio, and Porta (2019) affirm that the growing feeling that public communication significantly produces a knowledge society produces more public engagement efforts. Weingart, Joubert, and Connoway (2021) agree that, communication and engagement with cognate stakeholders on particular scientific issues bring more successes. To McFadden (2016), science is a significant factor in innovation and technology and hardly operates in a vacuum. This explains the use of new/mass media apart from interpersonal, group, institutional and organisational channels to communicate STI. For Mede (2022), this frequently helps to temper the global prevalence of resentment towards science by alleviating anti-science attitudes, cultivating positive views of science, connecting publics to scientific discourse, and educating citizens.

A generally aware citizenry, a knowledgeable public, and stakeholders who are perceptive of the role and contributions of STI to society are a boon to the scientific community. For Li and Guo (2021) science literacy in society assists in resolving socio-scientific puzzles by turning citizens into smart and responsible global persons. Howell and Brossard (2021) add that science literacy is germane to jettisoning science-related misinformation and fostering personal, collective, and informed decision systems. Beyond this, interest in STI among the people encouraged by the science community increases the use of digital science media, confidence in the mass media, and positive perception of scientists (Takahashi & Tandor Jr., 2016). To make the science community more inclined to success, Cooper (2011) suggested discourse approaches that produce trust, emphasised empowerment with reasoning skills, and an embrace of media literacy education. This helps to achieve the goals of helping citizens separate science and evidence-based information from entertainment content, misinformation, disinformation, and pseudoscience (Gerges, 2021).

Truly, STIs depend on communication to reach the public. A positive attitude and perception of science by the public is also a critical component of the science-technology-society triad if national development is to be achieved. Emerging STIs are therefore important to the development process with great benefits to health, agriculture, education, security, environment, etc. These imperatives are steeped in social aspects, policy choices, self-management, and deployment of resources (ACBF, 2016; Llorente, Revuelta, Carrio & Porta, 2019).

National Development

National development encourages all facets of national life and reflects the numerical measure of the national quality of life (Osakpa, 2021). The notion captures the reformation and varied sectoral development involving people, institutions and communities in a nation (Nweke & Nweke, 2020). It encapsulates growth and expansion of education, agriculture, industries, socio-cultural institutions and fields STI in their totality. Likewise, Bhawna (2016) conceptualises national development as an integrated and deliberate building of diverse parts of national political, economic, scientific, technological, innovative, material, and socio-cultural life using strategies that result in advancements.

Furthermore, the United Nations (2018) describes national development as qualitative and quantitative growth and changes for social, economic, and cultural wellbeing of a nation. National development seeks to alleviate poverty, improve national and per-capita incomes, raise the quality of education, revolutionise agriculture, develop efficient transport and communication, and improve healthcare and medical services. Development checks pollution and environmental hazards, preserves and protects the environment, and promotes the concept of sustainability. It improves the economic or living condition of the people, their social welfare, the democratic and political system, and preserves, enriches, and promotes culture.

National development uses and depends largely on STI to realise, maintain, and sustain all aspects of progress. Beyond STI policy and roadmaps which Nigeria has formulated since 1986 and revised in 2012; Nigeria has had series of development plans since 1960 (Ogbonnaya, 2020). This study focuses on the emerging STIs, how they are communicated by Nigerian experts, the perception of Nigerians, and how these impinge on development.

METHODOLOGY

The qualitative and qualitative survey designs proved useful to elicit answers to the research questions. In the quantitative segment, the questionnaire survey technique was adopted. Nigeria and its six geopolitical zones comprising the 36 states of the country was the study area. A sample of 384 respondents per state and a total of 4608 subjects were selected from the adult population of 84,004,084 registered voters in Nigeria. This sample was determined using the sample size online calculator.

However, because of the movement restrictions due to the spates of insecurity occasioned by insurgencies, banditry, kidnapping, and robberies in several parts of Nigeria, the sample was purposively limited to 200 respondents per state and state capitals which ensured availability of people from all parts of the state as well as those with the education required for participation in the survey. The eventual sample was 2,400. The following twelve states spread across Nigeria's six geopolitical zones were selected thus: Lagos, Oyo (south west), Rivers, Cross River (south-south), Enugu, Ebonyi (south east), Plateau, Niger (north central); Sokoto, Kano (north west) and Adamawa, Bauchi (north east).

The Likert scale-based questionnaire sought answers to what the perception of the respondents were regarding the necessity of emerging STIs. It also sought to obtain information on media and human sources of emerging STI information as well as the likely contributions of emerging STI to economy, and water/sanitation.

In the qualitative aspect of the study, prominent scientists in 12 universities spread across Nigeria's six geopolitical zones were selected as follows: conventional federal universities (3), federal universities of technology (3), conventional state universities (2), state universities of science and technology and private universities (2). In-depth interviews which recorded and transcribed were conducted mostly in-person. The interview schedules were designed to find out university scientists' engagement in emerging STI, how they communicated emerging STI with other stakeholders, their collaboration activities and how emerging STI contributed to national development.

Data are presented in calculated frequency and percentage scores, presented in tables and analysed descriptively using the Statistical Package for Social Sciences. The qualitative data were analysed through the use of explanation building.

Theoretical Framework

This discourse on communication and perception of emerging STI sits fittingly under the science, technology and society theory especially when viewed in the context of the implications of STIs for development. According to Cutcliffe (2022) this is captured in basic themes such as constructivism, contextualism, problematisation, and democratisation.

Constructivism conceptualises cognition of STI as socially mediated processes. Contextualism recognises STI as embodiment of history, politics, and culture; meaning that STI products and solutions are brought about in the context of specific political, social, and economic circumstances emanating therefrom. Problematisation envisions science knowledge and technological development as value-inherent phenomena with both positive and sometimes negative societal consequences. Thus STIs have ethical implications. Lastly, democratisation encapsulates the tendency to regulate techno-science in view of its value orientation as well as being socially constructed or mediated.

When considering the critical role of communication in the democratisation of techno-science using all the forms available from interpersonal communication to virtual media, and social networking platforms, it enables greater explication of the social, moral, cultural and ethical consequences of STIs. Communication also, by regulating opinions, perceptions and attitudes, fosters wider public participation in moulding and regulating STI. It engenders active involvement in decision making for all stakeholders.

Data Presentation, Analysis of Findings and Discussion

Table 1: Perceived necessity of Emerging STIs

Statements	SA	A	U	D	SD
Synthetic Biology is necessary for national development	774 (32.2%)	765 (31.9%)	291 (12.1%)	299 (12.5%)	271 (11.3%)
Nutrigenomics is necessary for national development	758 (31.6%)	728 (30.3%)	394 (16.4%)	287 (12.%)	233 (9.7%)
Gstrophysics is necessary for national development	762 (31.8%)	768 (32%)	349 (14.5%)	289 (12%)	232 (9.7%)
Neuroparasitology is necessary for national development	666 (27.8%)	696 (29%)	460 (19.1%)	329 (13.7%)	249 (10.4%)
Agricultural Drones are necessary for national development	808 (33.7%)	804 (33.5%)	270 (11.3%)	241 (10%)	277 (11.5%)
High Speed Transportation is necessary for national development	648 (27%)	767 (32%)	434 (18%)	281 (11.7%)	270 (11.3%)
Proteotronics is necessary for national development	674 (28%)	707 (29.5%)	436 (18.2%)	302 (12.6%)	281 (11.7%)
Epigenomics is necessary for national development	694 (28.9%)	722 (30.1%)	384 (16%)	323 (13.4%)	277 (11.5%)
Nanotechnology is necessary for national development	654 (27.2%)	755 (31.5%)	393 (16.4%)	322 (13.4%)	276 (11.5%)
Artificial Intelligence/Robotics is necessary for national development	710 (30%)	766 (32%)	385 (16%)	298 (12%)	241 (10%)

The result in Table 1 shows that 1539(64.1%) out of 2400(100%) of the respondents agreed that Synthetic Biology was necessary for national development while only 570(23.8%) of the respondents disagreed. Out of the 2400 respondents, 1486(61.9%) agreed that nutrigenomics was necessary for national development. A greater percent of the respondents 1530(63.8%) also agreed that Gastrophysics was necessary for national development. The majority of the respondents 1362(56.8%) agreed that Neuroparasitology was necessary for national development. 1612(67.2%) out of 2400(100%) of the respondents agreed that Agricultural Drones were necessary for national development. A good number of the respondents 1415(59%) agreed that High Speed Transportation was necessary for national development. Also, 1381(57.5%) of the respondents representing agreed that Proteotronics was necessary for national development. Likewise, 1416(59%) of the respondents agreed that Epigenomics was necessary for national development while 1409(58.7%) of the respondents agreed that Nanotechnology was necessary for national development and 1476(62%) respondents agreed that Artificial Intelligence/Robotics was necessary for national development.

The Pearson chi square statistical tests of significance measuring the relationships between perceived necessity of emerging STIs in 12 states of Nigeria and national development were computed at degrees of freedom 44 and probability value (P-value) of 0.000. Results of significant relationships were obtained as follows: synthetic biology (173.0760, nutrigenomics (199.826), gastrophysics (213.512), neuroparasitology (287.202), agricultural drones (221.452), and high speed transport technology (214.781). Others are: proteotronics (220.652) epigenomics (196.649), nanotechnology (144.125) and artificial intelligence/robotics (184.387).

Table 2: Perceived contributions of Emerging STIs to National development

Statements	SA	A	U	D	SD
Emerging STI contributes to Education	722 (30.1%)	694 (28.9%)	365 (15.2%)	303 (12.6%)	316 (13.2%)
Emerging STI contributes to Health	696 (29%)	685 (28.5%)	412 (17.2%)	295 (12.3%)	312 (13%)
Emerging STI contributes to Agriculture	740 (30.8%)	669 (27.8%)	350 (14.6%)	317 (13.2%)	324 (13.5%)
Emerging STI contributes to Environment	648 (27%)	676 (28.2%)	427 (17.8%)	357 (14.9%)	292 (12.1%)
Emerging STI contributes to Water/Sanitation	649 (27%)	704 (29%)	416 (17%)	348 (15%)	283 (12%)
Emerging STI contributes to ICTs	751 (31.2%)	753 (31.4%)	378 (15.8%)	271 (11.3%)	247 (10.3%)
Emerging STI contributes to the Economy	637 (26.5%)	644 (26.8%)	403 (16.8%)	381 (15.9%)	335 (14%)
Emerging STI contributes to Security	597 (24.9%)	651 (27.1%)	434 (18.1%)	370 (15.4%)	348 (14.5%)

The result in Table 2 shows that 1416(59%) out of 2400(100%) respondents agreed that Emerging STI would contribute to Education. Also, 381 respondents (57.5%) agreed that Emerging STI can contribute to Health while 1409(58.6%) respondents agreed that Emerging STI may contribute to Agriculture. Also, 1324(55.2) agreed that Emerging STI contribute can to Environment whereas 1353(56%) respondents agreed that Emerging STI can contribute to Water/Sanitation; and 1504(62.6%) of the respondents agreed that Emerging STI can contribute to ICTs. Out of 2400 respondents, 1281(53.3%) agreed that Emerging STI would contribute to the Economy while 1248(52%) respondents agreed that Emerging STI can contribute to Security.

The computation of the chi square statistics for the perceived contributions of emerging STIs produced the following scores calibrated on the bases of degree of freedom 44, and probability value (0.000). The Pearson chi square scores of significant relationship to national development were as follows: education (207:998), health (172.636), agriculture (265.888), environment (210.848), water and sanitation (194.625), ICTs (208.077), economy (272,492) and security (300.415).

Table 3: Sourcing of Emerging STI information

Statements	SA	A	U	D	SD
I source from Emerging STI Information from the Print Media	718 (29.9%)	729 (30.4%)	374 (15.6%)	316 (13.2%)	263 (10.9%)
I source Emerging STI Information from Electronic Media	730 (30.4%)	716 (29.8%)	358 (14.9%)	326 (13.6%)	270 (11.3%)
I source Emerging STI Information from the Internet	729 (30.4%)	741 (30.9%)	345 (14.4%)	319 (13.3%)	266 (11.0%)
I source Emerging STI Information from the Social Media	724 (30.1%)	731 (30.5%)	363 (15.1%)	331 (13.8%)	251 (10.5%)
I source Emerging STI Information from Interpersonal Communication	611 (25.4%)	553 (23%)	503 (21%)	374 (15.65)	359 (15%)

The result in Table 3 shows that 1447(60.3%) out of 2400(100%) respondents said they sourced Emerging STI Information from the Print Media while only 579(24.1%) of the respondents said they didn't source Emerging STI Information from the Print Media. Out of the 2400 respondents, 1446(60.2%) agreed that they sourced Emerging STI Information from Electronic Media. 1470(60.9%) agreed that they sourced Emerging STI Information from the Internet while 1945 (60.96%) of the respondents agreed that they sourced Emerging STI Information from the Social Media. Out of the 2400 respondents, 1236(51.65%) didn't source Emerging STI Information from Interpersonal Communication.

The Pearson chi square test of significance calculated at degrees of freedom 44 and probability value of 0.000 produced the following scores for the print media (175.394), electronic media (247.230), the Internet (229.289), social media (170.314), and interpersonal communication (141.730). This test shows that the greatest sources of emerging STI information in the sample are the electronic media, the Internet, and the print media; while interpersonal communication sources were the weakest.

Experts' Perception of Emerging STIs

In the area of artificial intelligence and robotics, respondent A at the Akwa Ibom State University said many specialists in the area though qualified through training; do not work in environments that permit them to excel in their specialities. He said, "I trained in artificial intelligence and robotics abroad, but teach in the Department of Physics where there are no equipment for further research in my field."

At the Sokoto State University, respondent B, a specialist in agricultural drones spoke of the application of drones that are deployed in agricultural programmes to monitor crops, spray insecticides and ensure the health of crops for greater food sufficiency. He reported that, "the uses of drones which are not only for agricultural purposes are becoming more common in Nigeria for healthcare, security, and information gathering."

Regarding the emerging science of nutrigenomics, a senior lecturer in Nutrition and Dietetics, University of Lagos: respondent C, explained that nutrigenomics determines, "the effect of food – nutrients, on gene expression, i.e. the relationship between diet and health and how nutritive intake impinges on health, reducing or increasing the risk of diet-related diseases." Also, connecting the effects of environmental factors on human health, a chemical pathologist at the University of Ibadan, respondent D stated that, "nutritional principles which apply the mechanism of molecular processes and driven by micronutrients and by antioxidants, are used to mitigate harmful environmental effects of chemicals, toxins, etc. on human health." He said the emerging sciences help in the examination of the causes, diagnosis, and management of such chronic non-communicable diseases such as diabetics, heart diseases, endocrine diseases, and other metabolic diseases affecting the liver and kidneys.

At the Abubakar Tafewa Belewa University in Bauchi, respondent E explained the emerging science of neuroparasitology. He said it deals with the study of parasites and how they affect the nervous system to alter behaviour. The importance of this emerging science he said is situated within the context of behavioural impacts of parasitic organisms and their implications. Similarly, another specialist at the Ladoke Akintola University of Technology, Ogbomoso, Oyo State, added that, parasite that affect human nervous systems and behaviour produce human symptoms such as aggressiveness, weakness, fever, headache, fatigue and make them exhibit unimaginable behaviour. Respondent F admitted that this area of research is still at its infant stage.

Another aspect of emerging science covered in this study is synthetic biology. Respondent G at Legacy University, Okija in Anambra State who specialises in synthetic biology, genomics, and transcriptomics stated:

> *Synthetic biology is an interdisciplinary field that has developed rapidly in the last two decades though it seems to be new in Nigeria. It deals with the design and manufacturing or construction of new biological systems from standard biological components. Its major aim is to construct logical forms of cellular control. It involves the re-design of biological systems and their parts to perform completely new functions and responsibilities. This creates opportunities for agro economies of Africa with the potentials to revoluntionise biofuels, healthcare, chemical production, energy, security, environmental remediation, and agriculture.*

The respondent added that genomics as a related field of study facilitates an in-depth understanding of diseases through the investigation of specific genetic changes associated with the disease. He explained transcriptomics as the study of the techniques that provides information on the abundance of genetic transcripts within a biological sample simultaneously. Providing an understanding of the emerging fields of nano-science and nanotechnology, respondent H explained that the fields:

> *Cut across chemistry, biology, physics, material science, and engineering and deals with the adaptation of and application of extremely small matter measured in say a billionth of a meter permitting the production of lubricants, parts, colours, temperature regulators, etc. Nanoscience and technology have wide applications in medicine, environmental management, health/sanitation, etc.*

Respondent I, a director and professor at the Centre for Genetic Engineering and Biotechnology, Federal University of Technology, Minna explained the emerging science of proteotronics to be the study of genetic engineering in protein sequencing and working with molecules necessary for bioprocessing that can be useful in the production of fuels, medicines, as well as electronics operations.

These findings confirm the extant literature on the nature of emerging STI. Bauer and Bogner (2020) explain that synthetic biology is, "an emerging research and technology area focusing on the design and construction of new biological parts, devices, and systems and the redesign of existing natural biological systems for useful purposes," (p. 493) citing Endy (2005). On the useful purposes of synbio, Mudziwapasi, Mufandaedza, Janane and ten others (2022) add that synbio hugely impacts on human health, the environment; biofuels, and chemical production with

huge economic advantages. Concerning public attitudes to the field, Akin, Rose, Scheufele, Simis-Wilkinson, Brossard, Zenos and Corley (2017) found in their study that the American public did not widely feel informed about synthetic biology although it was individually important. They also found out that, respect for scientific authority, religion, and trusts in scientists were important values and predispositions for supporting synthetic biology.

This study has shown in the survey of the Nigerian public that synthetic biology one STI perceived to be necessary. However, academic scientists in their responses generally agreed that the field was still in its infancy though it possessed the potential to contribute greatly to Nigeria's development in the areas of health, environment, manufacturing, and economic growth.

The literature also corroborates the responses offered by respondents on nano-science and nanotechnology. Olaniyi (2020) affirms that nanotechnology is an emerging field capable of radically altering the manufacturing and technological processes that make products lighter, smaller, stronger, cleaner, more precise with tremendous effects on agriculture, health/medicine, and chemical industries in order to improve human lives. This stresses the call by Nigeria's STI Ministry to the national community to embrace, domesticate, and further the research in the field if the country must achieve food security, revamp its health sector, develop space technology, secure its citizens, and defend its borders.

Similarly, Ejeta, Dolor, Ndubuka, Udah, Azeez, and Odogwu (2017) have added that the impact of nanotechnology in Nigeria would cover products such as medicines, electrical parts, lubricants, chemicals, cancer therapies, imaging agents, optoelectronics, clothing/textiles, reinforcement substances, energy fuels, and telecommunications. However, how do these impacts affect the perception of nanoscience and technology? Salleh (2006) reported a survey result that perceived nanotechnology as less risky and more beneficial than technologies such as genetically modified organisms and human genetic engineering. The explanation for this to Lee, Scheufele and Lewentein (2005) is that emotional variables regulate the weight of knowledge of nanotechnology on people's attitudes to it.

In this study, the Nigerian literate public generally perceived nanotechnology as a necessity along with other emerging technologies, and innovations by scientists hold a consensus that inspite of the huge contributions nano-science and technology could make towards national development in Nigeria; the field was stymied by lack of funding, minimal research, and poor synergies between government and industry; and researchers. The then Nigerian Minister of STI is reported to have advised scientists to source for additional funding of their researches, and partner with universities, and research institutes to attract government funding (Olaniyi, 2020).

Also, Nigerians surveyed agreed to large extent that drones are necessary emerging technologies for national development especially for agricultural purposes. The respondents interviewed in the universities equally agreed that drones were a key requirement for a number of development areas covering communication, health/medicine, agriculture, defence, etc.

These positions are in tandem with the literature. Ayranci (2017) writes about the use of drones in journalism and broadcasting to capture views of incredible videography and photography from aspects earlier possible by use of aircraft at great costs. Interestingly, drones can impact society in more than thirty ways to include defense, emergency response, disaster management, conservation, disease control, healthcare, agriculture, weather forecasting, maritime, and waste management. Other areas of impacts are in mining, construction planning, infrastructure development, insurance, urban planning, transportation and communications, leisure/tourism, crime prevention, space management, education, security etc. (www.cbinsights,com). Drones contribute in many areas of development. For reasons bordering on cost, local content, technology transfer, patents, and manpower, Nigeria is yet to deploy drones to solve many of its development problems. As respondents have stated, drones, are used mainly in agriculture in Nigeria whereas they could be deployed to Nigeria's health, security, education and environmental problems too.

This study shows that respondents generally agreed in the majority, that information and communication technologies as well as artificial intelligence and robotics are necessary and have the capacity to improve Nigeria's national development. The respondents also reached a consensus that the use of these technologies and innovation was stymied by factors such as low capacity building, digital inequality, poor funding/research/investment in the area, and reliance on foreign alternatives. This affects Nigeria's development adversely. *The Guardian* (2020) quoting Nigeria's Minister of Communication and Digital Economy while launching the National Centre for Artificial Intelligence and Robotics affirmed that Artificial Intelligence and Robotics would have great impact on healthcare, automotive, financial services, retail and consumer technology, energy, transport, etc.

Other emerging STIs focused on in this study namely proteotronics, nutrigenomics, and epigenomics;

the survey has shown are in their budding stages in Nigeria. These areas howbeit have large impact on several areas of development. Nutrigenomics for example according to Akogwu (2016) impacts society in ways ranging from healthcare to food security, and nutritional practices to socio-demographic policies and their applications.

Communication of Emerging Science, Technology and Innovation by Nigerian Specialists in the Tertiary Institutions

Science, technology and innovation specialists in tertiary institutions and research institutes cannot do without communicating their endeavours. They do so within their peers groups, with governments, the media, with the scientific community and the public. They are critical to deepening and spreading knowledge about emerging state of affairs in their fields and how they impact society. They are also key drivers for the dissemination of informing through the media to the public, a responsibility that is relevant to how the public utilises STI information.

From the interviews with a section of emerging science, technology, and innovation experts in some Nigerian universities, the following facts emerged:

a. University-based specialists in emerging science, technology and innovation mainly communicate their research efforts through peer-reviewed publications restricted to the scientific/technology community. To buttress this point a few sampled opinions would suffice:

- *The model of dissemination of my work has largely been through didactic, scientific means of communication namely scientific conferences, symposia, workshops, seminars, inaugural lectures, publication of journal articles, and book publishing.*
- *Occasionally, we engage in radio, television, or newspaper interviews, and present public lectures. We often do not present our scientific findings to national science agencies though we serve as consultants to government agencies.* (John I. Aretor, Professor of Chemical Pathology at the University of Ibadan).

b. Emerging Science, Technology and Innovation specialists in Nigerian Universities only sometimes utilise the media for public dissemination of science information. Some of the respondents stated:

- *The mass media are a veritable tool in communicating scientific guiding and ongoing researchers to the public but we do so, on radio and television only if invited.* (Prof. Fabian Ezema, specialist in nanotechnology, University of Nigeria, Nsukka).
- *The social media platforms present a robust opportunity for STI specialists to communicate with the public in this digital age, but we are yet to use these novel areas to publicise our emerging fields* (Shodiya E. Oluwatoyin, Nutrigenomics specialist, University of Lagos Teaching Hospital).
- *Sadly, we do not make direct contact with the media to communicate our researches except through our publications in open access journals (Prof. Godzama Ibrahim Madu, synthetic biology specialist, Ahmadu Bello University, Zaria).*

c. Communication and collaboration between emerging STI specialists and government along with its agencies are poor. The following responses illustrate the point:

- *Sadly, there is a gross lack of synergy between the scientific community and government or its agencies. The communication is dismal, the interest is low.* (Leo N. Ozurumba – Dwight; specialist in synthetic biology, genomics and transcriptomics, Legacy University, Okija, Anambra State).
- *Collaboration initiatives are often rebuffed by government and its agencies. It is frustrating because access to international grants depends on past access to local and national research grants* (Nsikan Ekpenyong, Al/Robotics specialist, Akwa Ibom State University).
- *Communication and collaboration involving neuroparasitology hinge on funding. The field is yet to be deeply explored and researched in Nigerian universities. That is certainly because the government, institutions, and organisation are yet to provide research grants in the area. Grants facilitate collaborations for research; researches bring results which can be communicated.* (Abel Adetunde, Research fellow at Ladoke Akiintola University of Technology, Ogbonoso, Oyo State).

Communication is the key to the dissemination of emerging STIs not only because they are novel but because public understanding and utilisation rely on communication. This study indicates that a greater majority of respondents sourced their emerging STI information from the mass media principally the Internet, followed by the print and the electronic media, with fact-to-face communication trailing behind. This reflects the fascination with hand-held devices for information acquisition.

Information acquisition about STI connects visibly with knowledge and both have relationships with perception and attitudes. Llorente, Reuvelta, Carrio and Porta (2019) agree that the more people perceive that public communication of STI is big in hiking knowledge; the more encouraging it is to engage in STI communication. When the public is well informed in STI matters, knowledge grows and science is emboldened to engage with the public the more. Weingart, Joubert, and Connoway (2021) add that the more successful method of engaging the public, is to communicate and involve clearly defined stakeholder groups about specific, pertinent scientific problems and knowledge. Metadden (2016) notes: when public perception is disparate from that of the science community, the efficacy of scientific quest and innovation as tools for solving challenges reduces.

Likewise, Droog, Burgers and Kee (2020) agree that experts and communicators contribute to the creation of frames of innovation although much needs to be researched about how specific contributions of different societal actors affect frame building of emerging information technologies. Therefore, the effect of media on the perception of STI is not in doubt but Hmielowski, Feldman, Myers, Leiserowitz and Malebach (2014) stress that conservative media use reduces trust in scientists while use of non-conservative media increases trust in scientists. Also, Drummond and Fischhoff (2017) found that that science literate people possess greater extreme beliefs on contentious science matters. This discourse has therefore shown from both this study and the literature the prime place of communication and the media in the dissemination, perception, and use of emerging STI.

Contributions of Emerging Science, Technology and Innovation to Nigeria's National Development

Undoubtedly, science, technology and innovation make tremendous contributions to national development in Nigeria. However, because emerging STIs are only coming into being of recent, the respondents do agree that the extent of contributions may low. The following responses from interviewees underscore the point:

- *Emerging sciences have helped to conserve national resources when Nigerian scientists, are able to domesticate researches, tests, diagnosis, and treatments; funds that would have been used to procure offshore services are used nationally for other pressing needs* (Prof. A. B. Ismaila, Neuroparasitologist at Abubakar Tafewa Belewa University, Bauchi).
- *Agricultural biotechnology research in Nigeria has contributed immensely to national development in the area of food security. Researchers rarely used biotechnology techniques to develop improved crop varieties, economically viable breed of animal species, as well as pest and drought resistant crops. Through GMO research, Nigeria has been able to develop improved cowpeas, cassava, cotton plants, etc. with commendable effects on agricultural production* (Dr. Mustapah Isah, Biotechnologists, Sokoto State University).
- *Nigerian academics are using biotechnology to solve environmental problems. There is technology that transforms sewage to electricity, and organic fertilizers and other means of clearing the environment of plastics, oil spills etc. with enzymes. Sadly, industry, commercial interests, funding agencies and government are not showing interest in these innovations perhaps because there are imported but more expensive alternatives*. (Prof Egwin Evans, centre for Genetic Engineering and Biotechnology, Federal University of Technology, Minna).
- *STIs are contributing to Nigeria development although well below their full potentials. This applies to education, health, environment, etc. Poorly regulated industrialization impacts negatively on health sometimes causing career. It also leads to environmental degradation, loss of biodiversity, migration, poverty, social strife and insecurity. Effective communication and proper utilisation of scientific, technological and innovative knowledge will largely contribute to realistic national development* (Prof. John I. Anetor, Chemical Pathologist; University of Ibadan).
- *Robotics and AI have tremendous offerings in healthcare, intelligence gathering/security, defence, education, agriculture, manufacturing, environmental protection, communication etc. However national investments in training, funding, research are very low in Nigeria* (Dr. Nsikak Ekpenyong, Akwa Ibom State University).
- *Nano-science and nanotechnology are not contributing significantly to Nigeria's development. However, if properly harnessed (through sustained research, knowledge transfer, funding, product investment, training), they would contribute to the manufacturing industry, paint production, battery making, medicine, environmental remediation etc. For now, they are in their infancy stages, and stakeholders need to invest deliberately in the STIs to reap the full benefits* (Prof. Fabian Ezema, University of Nigeria, Nsukka).
- *Contemplate the contributions of synthetic biology and genomic technology to food sufficiency, health care, and environmental protection. They are vast but in Nigeria, lack of investment in STI research/education,*

pathetic funding and low synergies involving the academia, industry and government are the major setbacks (Leo-Nnamdi Ozurumbe-Dwight, Legacy University, Okija, Anambra State).

As these responses from Nigerian university experts in emerging sciences have shown, emerging STIs particularly biotechnology, nanoscience and nanotechnology, synthetic biology as well as drone technology and artificial intelligence/robotics have the potential of impacting significantly in Nigeria development in various sectors including health, education, environment, security, food sufficiency etc. However, the depth of these fields in Nigeria is unsatisfactory.

The problem identified in Nigeria is worrisome. The African Capacity Building Foundation (2017) states that it was in recognition of this parlous state of STI in Africa that the African Union adopted the Agenda 2030 which specified STIs as major catalysts to achieving development objectives, and instituted the decade long STI Strategy (STISA - 2024). The problems highlighted include, "poor STI infrastructure, a small cache of researchers, low patronage of science and engineering professionals, weak intellectual property frameworks, and low scientific output relative to the world"(ACBF Policy Brief, 2017, (p.1).

Summary of Findings

This study has shown that:

a. Nigerians surveyed in twelve states representing the six geopolitical zones of the country were significantly perceived emerging sciences, technologies, and innovation identified in the study as being necessary for national development. Respondents in Cross Rivers State showed the strongest perception while those of Sokoto respondents indicated weaker perception
b. Respondents surveyed across the country perceived agricultural drones as the most necessary emerging STI in the country (67%) while neuroparasitology was seen as the lesser necessary emerging science (57%) to the development of Nigeria.
c. Concerning the contributions of emerging STIs to national development in Nigeria, the majority of surveyed respondents agreed that emerging STIs would have the greatest impact on Information and Communication Technology development(63%), education (59%), Agriculture (59%), followed by water/sanitation (56%) and the lesser impacts on security, the economy and the environment.
d. Regarding the communication and sourcing of emerging STI information, the greater majority of respondents agreed that the internet, the legacy media: print, electronic, and the social media in that order were the principal means through which STI information was communicated and obtained. Communication by interpersonal or face-to-face means trailed far behind.
e. Respondents in the depth interviews agreed that the emerging STIs were critical to development in Nigeria but were mostly in the infancy stages of research and development due principally to poor STI culture and infrastructure, pathetic funding and slack synergies involving government, funders, industry, academia and other stakeholders.
f. Communication of emerging STIs by University-based experts was principally within the peer community to the near neglect of other critical stakeholders such as the media, the public, the government, the industry.
g. As far as collaboration was concerned, the synergistic relationship involving emerging STI experts in the Universities, their counterparts in the industry and research institutes, as well as funding agencies, government and international agencies was far below expectations.

CONCLUSION

There is no doubting the potentials of emerging STIs to the development of Nigeria particularly in the areas of literacy and education, water/sanitation, environmental protection, defense/security, information dissemination and communication, healthcare, food security and economy. However, in spite of the appreciable level of positive perception of emerging STIs for national development among the Nigerian literate population, and the consensus among STI experts; many factors are responsible for the failure of STIs to contribute to national development. These factors include poor STI culture and infrastructure, low funding of STI research and development, lack of synergistic relationship and collaboration involving key STI stakeholders; and lopsided STI communication that is skewed in favour of the academic/scientific community.

The urgency needed to invest in science, technology, and innovation which cannot be overemphasised in a country such as Nigeria which is beset with development challenges. The literature supports this position. Wilkinson, Bultitude, and Dawnson (2008) for instance stressed the potency of the emerging technologies of nanotechnology, robotics, and genetic engineering to steer development in this Century. Similarly, Mardin, Darling and Hardt (2019) have underscored the importance of drone technology, satellite technology as well as artificial intelligence to

solving major environmental problems. Likewise, Juma (2016) affirms the relevance of genetics, synthetic biology, and other emerging STIs to addressing agricultural, health, and ecological issues. The import of these is not lost on a developing country such as Nigeria with several development difficulties.

RECOMMENDATIONS

In view of the findings of this study and then conclusion drawn there from, the following suggestions are made:

1. There is ample need to expand communication efforts in Nigeria to create more knowledge and awareness as well as interest beyond agricultural drones, biotechnology and ICTs inspired by artificial intelligence and machine learning. Since the study has demonstrated that synthetic biology, nano-science and nanotechnology, nutrigenomics, epigenomics, etc. impact development in tremendous ways, attention should be focused on these too using all media platforms.
2. Beyond communication, major stakeholders such as government, industry, agencies and multilateral organisations should invest significantly in the research and development of STI infrastructure through teaching and funding if they must contribute meaningfully to Nigeria's development.
3. The promotion of STI culture in Nigeria through an aggressive generation of interest in the sciences, technology, engineering, mathematics and innovation in all levels of schooling, serious encouragement of science literacy through citizen and media science initiatives are necessary to engender national development.
4. Communication of emerging STIs and their implications for national development should permeate all media forms. Though this is the digital age, STI information should be placed in printed, electronic, digital and interpersonal platforms in order not to alienate groups that still face digital and energy inequalities.
5. Collaboration involving key stakes namely: academics, researchers, scientists, government, funding bodies, donor agencies, and multilateral interests should be taken more seriously in meaningful, synergistic manner if the national development objectives of emerging STIs are to be realised.

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