Assessing the Entrepreneurial Ecosystem of Science Technology Engineering and Mathematics (STEM) Researchers in Nigeria

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Abstract

The external context plays a vital role for the promotion of entrepreneurship especially in entrepreneurial universities. The study therefore deploys a mixed methodology (quantitative and qualitative) approach to understand the role that innovation and entrepreneurship infrastructure plays in facilitating the development and commercialization of research outputs from the science, technology, engineering and mathematics (STEM) Faculties in a university in Nigeria. Questionnaire was administered on sixty lecturers/researchers across these six faculties (Science, Engineering, Basic Medical Sciences, Clinical Sciences, Pharmacy and Agriculture) which had 85% response rate. Eleven follow-up interviews were carried out in four Faculties. While field observation was carried out in four research and innovation facilities (the university's central science laboratory, central technical workshop and the intellectual property & technology transfer office). An Incubation Centre located outside but near the university was also visited. Based on the information collected, the study provided strategic implications for policymaking, practice and theory.

Keywords: Entrepreneurship Ecosystem, Entrepreneurial Innovation, STEM researchers, Research Outputs, Technology Transfer, Intellectual Property Rights.

Introductions

Over the years Nigeria continue to battle with issues of youth employment and poverty amid a growing population (Dauda, 2017). At present, Nigeria's population is conservatively estimated at 200 million with over 75% of the population falling within the labour force, aged between 15 to 65 years (Olurinola & Fadayomi, 2016; Chiazor & Udume, 2017). Entrepreneurship has become a very important alternative to increase employment and economic development in the Nigeria (Gamede & Uleanya, 2018; Figueiredo & Paiva, 2019). Especially since the different government interventions have failed. One of the greatest flips of government policies was the structural adjustment program (SAP) in the 1980s (Okoye, Nwakoby, Modebe & Okorie, 2016). The economic depression of the early 1980s which has lasted till date has led to the proliferation of entrepreneurial ventures. These were primarily by youths that couldn't find white collar jobs and have created different employment opportunities alternative to unemployment and poverty. The solutions provided by the entrepreneurs through entrepreneurship have now gained the attention of

policymakers and entrepreneurship is now seen as a pathway towards economic development (Roundy et al 2018; Fini et al., 2018; Morris et al, 2020; Horne et al., 2020).

Nigeria has since provided support to entrepreneurs through policies, programmes, creation of ministries, departments and agencies as well as other infrastructure that support entrepreneurship (Adebayo, 2016; Ayoade & Agwu, 2016; Afolabi et al 2017; Abioye et al., 2017). Asides important interventions such as provision of credit facilities, training and creation of institutions with the responsibility of developing the small and medium enterprises in Nigeria, one of the successful interventions by Nigerian government was the introduction of entrepreneurship as modules, courses and subjects in schools, universities and colleges in Nigeria. These interventions extended the mandate of universities, colleges and schools from just teaching and research to include entrepreneurship. Currently, the entrepreneurship and engagement mandate of tertiary institutions are as important to other mandates such as teaching and research. Though entrepreneurship education is still relatively new in Africa, it is fast diffusing through the fabric of tertiary institutions' curriculum. Most universities in Nigeria have now incorporated entrepreneurship education into both its undergraduate and postgraduate studies as supported by the Nigeria University Commission (Nwambam et al. 2018; Maxwell et al., 2018). Despite the policies, programmes and different policy instruments of government promoting entrepreneurship, students and researchers from the knowledge institutions still struggle to fulfil the new mandate on entrepreneurship and engagement. The main reason for this may be because the entrepreneurship ecosystem is still weak.

Literature Review

A conducive entrepreneurial ecosystem is essential for the development of successful entrepreneurial ventures by STEM researchers. These entrepreneurs have the education and potential to start, establish and grow high growth ventures that are conducive to wealth creation and economic development.

Academic Entrepreneurship, Intellectual Property Rights and Entrepreneurship

In developed countries, universities serve as knowledge parks and centres for entrepreneurship creation (Wonglimpiyarat, 2016); Fuster et al., 2019; Klofsten et al., 2019). Indeed, many companies in developed countries started off as ideas that generated from laboratories that were commercialized. Also, many other companies were as a result of spin-off or spin-out from research outputs from universities. Furthermore, knowledge on protection of intellectual property rights as a result of breakthrough in research by researchers in developed countries have promoted entrepreneurship activity in their universities; when a researcher has an invention and receives a patent or other forms of intellectual property rights (Etzkowitz, 2017; Dalmarco et al 2018; Urbano et al., 2019), he is free to commercialise it through different means such as outright sales, licensing, spin-off formation, joint venture, franchise and self-exploitation (Siyanbola et al., 2016)

Entrepreneurial universities such as the Massachusetts Institute of Technology, Harvard University, Stanford University, amongst others, are all known for the wealth they create through their scientific and technological research not just for themselves but also for the economy of the countries where they are domiciled (Massucci & Docampo, 2019). One thing common to these universities was the promotion of entrepreneurship from research outputs (Safón, 2019). The contribution of scientific and technological research to economic growth and development cannot be overemphasized. As such, science, technology, engineering and mathematics (STEM) education is important for economic growth and development. Around the world, science and technology (S&T) policies are being revised to include innovation – science, technology and innovation (STI) policies while some have even moved to the level of having Innovation policies. Between 2010 and 2012, Nigeria reviewed its previous (1986 & 2003) S&T policy documents to a STI policy stressing the need for commercialization of scientific and technological research outputs (Siyanbola et al 2016; Oyewale et al., 2017). The Nigeria's STI emphasized that while it's important to continue to strengthen the S&T systems of the countries, it may be more important to commercialize the S&T knowledge supplied.

STEM Education in Nigeria and Entrepreneurship

A good infrastructure for entrepreneurship for STEM researchers is necessary to convert the knowledge supply from the knowledge institutions to wealth (Datta, 2018). Often, the research output from STEM materializes in different forms such as: publication, prototype development, patents as well as other intellectual property rights, amongst others. These research outputs have great potential to be converted into wealth through entrepreneurship. A recent research by Abodunde, Jegede & Oyebisi (2020) shows that research outputs in the science, technology, engineering, arts and mathematics in Nigeria have been on the rise over the last decade. Another similar study by Abodunde & Jegede (2020) which examined the productivity of research output from STEM researchers in Nigeria showed that the quality of science and technology research outputs from Nigeria institutions were of high quality and represent useful resource materials for technology development and economic growth via entrepreneurship. Despite the quality and quantity of knowledge supply from researchers in Nigeria's S&T knowledge institutions, there is limited information on the quality of infrastructure for entrepreneurship available to these researchers. Good and readily available entrepreneurship infrastructure will promote the spin-off of businesses based on academic research from these institutions (Lockett et al., 2005; Dalmarco, Hulsink & Blois, 2018; Fuster et al., 2019)

Government Policies and Entrepreneurship

One of the vital roles government can play to promote entrepreneurship asides from policy instruments could be the creation and/or strengthening of entrepreneurship support infrastructure. Nigeria has a few agencies that promote innovation through commercialization of inventions from scientific and engineering research. They include: Federal Institute of Industrial Research (FIIR), SHEDA Science and Technology Complex (SHESTCO), Nigeria Agency for Science and Engineering Infrastructure (NASENI), National Office of Technology Acquisition and Promotion

(NOTAP), Project Development Institute (PRODA) and National Board for Technology Incubation (NBTI), Raw Materials Research and Development Council (RMRDC). All these agencies are funded by the Nigerian government and their roles are to ensure that scientific ideas become inventions through the development of prototypes and partnership with relevant private sector organizations and knowledge institutions for the development and commercialization of research outputs and prototypes. The National Board for Technology Incubation has several technology incubation centres located in different regions of the country with the responsibility of incubating science and technological researches into viable technology businesses. The incubators protect technology-based businesses from the harsh business environments during the start-up phase of the business. This period represents the roughest period in the business life cycle in which most businesses close. Incubators provide important facilities to help technology businesses grow. The National Office of Technology Acquisition and Promotion established several different Intellectual Property and Technology Transfer Offices (IPTTOs) in many universities with the aim to ensure that the research outputs from the knowledge institutions are protected for the purpose of commercialization. This initiative has been very effective in that university researchers are now aware of the importance of taking their researches further to the point of commercialization. The Sheda Science and Technology Complex (SHESTCO) was established as a multidisciplinary research and development centre. There are four National Advanced Laboratories at SHESTCO – a Biotechnology Laboratory, a Chemistry Laboratory, a Physics Laboratory and a Nuclear Technology Centre. The laboratories and centre are served by a workshop, where routine maintenance and fabrication of components take place. The National Agency for Science and Engineering Infrastructure (NASENI) was established to create an enabling knowledge-driven environment for local mass-production of standard parts, goods and services required for the Nation's Technology Advancement. The mandate of NASENI is specifically in the area of capital goods research, production, and reverse engineering with respect to industrial and analytical chemical materials, scientific equipment and components, engineering equipment, engineering designs and standardization as well as power equipment. Other efforts of government in promoting commercialization of research (entrepreneurship) include the creation of free trade zones, export processing centres, industrial parks, science parks, clusters and creations of agencies such as the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN) under the auspices of the Ministry of Trade and Industry that support the development activities of businesses in Nigeria. In addition to supervisory and advisory roles, the agencies assist small business to get credit facilities at low interest rates and long tenure from financial organizations such as the Bank of Industry, Development Banks, Commercial Banks, Venture Capitalist and Business Angels.

Though the support mechanism from government abounds for the commercialization of researchers' S&T outputs, there seems to be a big missing link as these supports have not been effective in Nigeria. There seems to be a big disconnect between the engagement among academia, industry and government. The three components seem to be working in independently. Each one of them doing what they know how to do best without any meaningful interaction with other components to ensure meaningful outputs that will create wealth for the country (Zanello, et al.,

2016; Egbetokun et al., 2017; Omobhude & Chen, 2019). Some literatures (Din et al., 2016; Fernández-Nogueira et al., 2018; Olofinyehun et al. 2018; Klofsten et al., 2019) posit that the academia must take the lead role in ensuring collaboration and engagement with other components of the innovation system while some think the government must use policy to foster interaction among the components of the innovation system. While others have indicated that the industry needs to rely on academia for the knowledge which they will deploy in production (Mejlgaard & Ryan, 2017; Garousi, Shepherd & Herkiloglu, 2019).

Owing to the fore going, one can imagine that the academia have been provided with the necessary support to leverage on for the commercialization of their research outputs. One major question is whether researchers in Nigeria are willing or have intentions to add commercialization of their researches and engagement with industry and society as part of their responsibilities in addition to teaching and research. The academia can only function successfully as potential entrepreneurs if there is a robust entrepreneurship ecosystem.

Entrepreneurial Innovation

The entrepreneurial innovation literature has always emphasized the importance of entrepreneurship for innovation. This scholarship draws its insights from the Schumpeterian tradition which talks about processes of creative destruction (Schumpeter, 1934), whether the entrepreneur introduces radical, new to the world innovation which continually threaten the industry's equilibrium and trigger further process of agglomeration, productivity and economic growth – Schumpeter's concept of creative destruction (Schumpeter, 1934; 1942). For Schumpeter, radical innovation outcomes have long been associated to entrepreneurship. Studies such as Stam (2015), Audretsch & Belitski (2017), Roundy, Brockman & Bradshaw (2017) and Spigel (2017) have pointed out the important role of the entrepreneur for innovation. This is slightly different from the knowledge advanced by the National System of Innovation literature (Fagerberg & Sapprasert, 2011; Nelson, 2013; Lundvall, 2016), which focus more on structure and institutions for innovation outcomes. In contrast to the NSI literature, the entrepreneurial innovation literature involves the disruption of industries and creation of new ones through multi-level processes and stakeholder's multiple context and multiple actors that constitute different entrepreneurial ecosystems.

Entrepreneurial Ecosystem

Several definitions of entrepreneurial ecosystems have been given in literature. For instance, Stam (2015:1765) defined Entrepreneurial ecosystem as "a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship." While Audretsch and Belitski (2017: 2) defined entrepreneurial ecosystem as "systems of entrepreneurship as institutional and organizational as well as other systemic factors that interact and influence identification and commercialization of entrepreneurial opportunities." Other notable descriptions of entrepreneurship ecosystem include those of Roundy, Brockman, and Bradshaw (2017: 99) where they defined entrepreneurship ecosystem as "communities of agents, social structures, institutions, and cultural values that produce entrepreneurial activity." And Spigel (2017: 49) where entrepreneurial

ecosystem was defined as "the union of localized cultural outlooks, social networks, investment capital, universities, and active economic policies that create environments supportive of innovation-based ventures."

The first component of the first term *entrepreneurial* refers to the entrepreneurship process by which individuals exploit opportunities for innovation (Stam, 2015) The second concept which is *ecosystems* refers to the interaction of living organisms with their environment. Moreover, the entrepreneurship ecosystem approaches the entrepreneur from the external environment context within which the entrepreneurship process takes place (Stam, 2015). The entrepreneurship literature therefore focuses on the individual characteristics of the entrepreneur and the context within which the entrepreneurial activity takes place. Entrepreneurial ecosystem literature builds on earlier scholarly works on entrepreneurship and literature on National Systems (NSI) approach to innovation. It recognises the shortcomings of the entrepreneurship literature, which tends to focus on the micro economic foundations and personal attributes of entrepreneurs and less on the contextual factors which might have a systematic bearing on entrepreneurial innovation outcomes. Moreover, the entrepreneurial innovation literature finds major fault with the NSI literature (Asheim, Grillitsch & Trippl, 2016; Binz & Truffer, 2017; Reischauer, 2018; Chaminade, Lundvall, & Haneef, 2018) due to its focus on structure and institutions and less on the micro foundations which are instrumental in determining entrepreneurial innovation outcomes. It can be argued that the literature on entrepreneurial innovation draws from these two focusing mechanisms by recognising both the role of the entrepreneur in driving entrepreneurial ecosystems but also highlights the strategic importance of contextual factors which regulate entrepreneurial innovation. Essentially entrepreneurial ecosystems are comprised of different contexts which, through their systematic interaction influence and regulate entrepreneurship innovation performance and outcome. Entrepreneurial innovation is the primary source of a country's competitive advantage (Distanont & Khongmalai, 2018; Anwar, Khan & Khan, 2018). It has long been argued within this tradition that positive economic outcomes are largely associated with radical, new to the world innovations. According to Autio et al (2014) an entrepreneurial ecosystem regulates the quality and quantity of entrepreneurial innovation by shaping the direction and potential rewards of entrepreneurial development and the type of organizational forms that would be deemed as necessary expands.

Entrepreneurial Ecosystem and Business Growth

The Entrepreneurship Ecosystem approach has arisen due to previous approaches being ineffective. Mason and Brown (2014) contend that the approach centres on creating and supporting a distinct environmental set-up in which high-growth firms (HGFs) thrive in. On the other hand, Stam and Spigel (2016) view the entrepreneur rather than the firm as the main focus of analysis in the approach but also place great importance on social and and economic cotext. Industrial policy in advanced countries now centres on increasing the number of HGFs (Mason and Brown, 2014), that is the quality of entrepreneurship, since empirical evidence suggests that a small group of entrepreneurs with high growth ambition, not new or small firms is vital for economic growth (Stam,

2015). Ambitious entrepreneurs are defined as those "who attach performing (more than well) with their business (Stam *2013).* Stam (2015) further notes that these type of entrepreneurs are innovative and inclined to ensure impressive growth of their ventures/businesses. In this sense policy focus has shifted away from increasing the number of SMMEs to encouraging growth and innovation-oriented entrepreneurship (Stam, 2015).

Entrepreneurial ecosystems range from being industry-specific; can arise from one industry to incorporate numerous industries and are "geographically bounded but not confined to a specific geographical scale" (Mason and Brown, 2014: 5). Economic activity generally gravitates and clusters towards specific geographical locations, Mason and Brown (2014) note that the entrepreneurial ecosystems approach gives new insights on the geographical clustering of economic activity. The entrepreneurial ecosystem approach explicitly targets entrepreneurial activity in HGFs and specifically emphasizes "local and regional environments and the conditions required to generate and support ambitious entrepreneurship" as well as "emphasizes the interactions between framework conditions and local/regional geographical conditions" (Mason and Brown, 2014: 8). Thus, certain types of environment, i.e. entrepreneurial ecosystems enable growth of HGFs. Feld's (2012) account on nine elements that make up a successful entrepreneurial ecosystem are leadership, intermediaries, network density, government, talent, support services, engagement, companies, capital. These elements of successful entrepreneurial ecosystems draw attention to the importance of interaction between key stakeholders in the ecosystem; access to appropriate resources with government playing a role at the background.
This paper contributes to the growing body of literature on entreprneurial ecosystems by assesing the entrepreneurial prowess of researchers in the science, technology, enginering and mathematics field through the quality of infrastructure for entrepreneurship made available to them.

Theoretical framework – Relationship of Entrepreneurship Ecosystem with other related Concepts
Entrepreneurial ecosystem approach represents an improvement over other established concepts - such as industrial districts, clusters, and innovation systems approach. The main difference it has with these other concepts – is that the focus of the entrepreneurial ecosystem approach is on the external business environment. In the industrial district approach, the emphasis is on the local division of labour of an industry (Marshall, 1920) and the interaction between the community of practice within a socio-territorial entity (Becattini, 1990) in order to be successful on international markets. The cluster approach focuses on physical concentrations of interrelated trade, specialized suppliers, service providers and firms in related industries, and allied institutions fields that compete but also co-operate' (Porter, 1998: 197). Regional innovation systems (RIS) refer to the networks and institutions linking knowledge producing hubs such as universities and public research labs within a region and innovative firms (Cooke et al., 1997). The entrepreneurial ecosystem approach diverges from industrial district, cluster, and innovation system approaches on the basis that the entrepreneur (or the start-up), not the firm, is the unit of analysis (Feldman, 2014).

The earliest work on entrepreneurial ecosystem gives a rather narrow view of the entrepreneurship (Schumpeter 1934). Other scholars (Zahra & Nambisan, 2012; Mason & Brown, 2014; Stam &

Spigel, 2016; Spigel, 2017; Acs, et al., 2017; Spigel & Harrison, 2018) have built on these by providing the social, political and economic perspective in which the entrepreneur functions. Their views represented a broader perspective where the external context, over which the entrepreneur has little or no control, matters. The entrepreneurial ecosystems approach places emphasis on the cultures, institutions, and networks that accumulate within a region over time rather than the emergence of order within global markets.

Entrepreneurial activity, as an *output* of the entrepreneurial ecosystem, is considered the process by which individuals create opportunities for innovation. This innovation will eventually lead to new value in society and this is therefore the ultimate *outcome* of an entrepreneurial ecosystem while entrepreneurial activity is a more intermediary *output* of the system. This entrepreneurial activity has many manifestations, such as innovative start-ups, high-growth start-ups, and entrepreneurial employees (Stam, 2014).

Based on this, Isenberg (2011) formulates six distinct domains of the ecosystem: policy, finance, culture, support, human capital and markets. This largely overlaps with the eight pillars distinguished by the World Economic Forum (2013: 6-7; Stam 2015) for a successful ecosystem, each with several components. These pillars also focus on the presence of key factors (resources) like human capital, finance, and services; the actors involved in this (talent, investors, mentors / advisors, entrepreneurial peers); the formal ('government & regulatory framework') and informal institutions ('cultural support') enabling entrepreneurship; and finally, access to customers in domestic and foreign markets.

The definition of entrepreneurial ecosystem adopted in this study is "combinations of social, political, economic, and cultural elements within a region that support the development and growth of innovative start-ups." (Spigel, 2015:2). He groups these attributes into three categories - cultural attributes (supportive culture and histories of entrepreneurship), social attributes (worker talent, investment capital, networks, mentors and role models), and material attributes (policy and governance, universities, support services, physical infrastructure, open markets) - that explain the level of entrepreneurial activity as the output of entrepreneurial ecosystems:

Methodology

This section discusses the methodology under two subcategories: research design and data collection.

Research Design

The study was based on the triangulation of two research methods – quantitative and qualitative techniques. The quantitative technique deployed the cross-sectional study which was done using a survey questionnaire to elicit information from the lecturers/researchers at a university in Nigeria. The qualitative technique was done using the case control method relying on information obtained from in-depth interviews conducted with lecturers/researchers in the relevant faculties and field observations made when facilities such as the incubator, technology transfer office, laboratories and workshops were visited. Data was collected at a university in southwestern Nigeria. The university

was selected based on research excellence and its exceptional outputs in terms of development of prototypes, filing of patents and spin-off activities. The university has always ranked among the top three in the country over the last few decades.

Data Collection

The first phase of the study was the quantitative technique. The questionnaire was designed to elicit information from lecturers, drawn from various faculties, schools and departments. Multistage sampling was used. The first stage involved the purposive selection of the highest-ranking university in Nigeria in terms of research outputs (publications and patents). The second stage involved the purposive selection of six Faculties relevant to the study. These were: (i) Science (ii) Technology, (iii) Basic Medical Sciences, (iv) Clinical Sciences, (v) Pharmacy, (vi) Agriculture. The rationale for this was to capture lecturers in the STEM field at the university. The third stage involved the purposive selection of lecturers across all levels. The fourth stage was the random selection of 60 lecturers across these six faculties with a 85% response rate, resulting in a total of 51 questionnaires used in the analysis.

The second phase of the study was qualitative. Lecturers with interesting stories were followed up for interviews. At least one interview was carried out in each of the four faculties selected for the interview phase (Science, Technology, Pharmacy, Agriculture). A total of 11 interviews were carried out in all. The interviews were recorded electronically and subjected to content analysis.

The third phase of the study was field observation. This involved visiting the infrastructure for entrepreneurship available to the researchers in the university. The facilities visited include: the central science laboratory, central technical workshop, the intellectual property and technology transfer office, and the technology incubation centre located 15 kilometres outside the university.

Results and Discussions

The discussion of the results is divided into two parts. The first part is the quantitative study that focuses mainly on the background of the STEM researchers and the nature of the entrepreneurship activities they are involved in. The second part is the qualitative study that focuses on how external factors shape the decision of the STEM researchers towards being entrepreneurial and towards becoming entrepreneurs.

Quantitative Study (Questionnaire Survey)

Though the study attempted to have equal representation from the six Faculties, the study had the most responses from researchers in the Faculty of Science, which represented about one-third of the response rate. This was closely followed by Faculty of Agriculture, then Faculty of Pharmacy. The lowest response rate was from the Faculties of Basic Medical Sciences, Clinical Sciences and Technology (Table 1). Of the researchers that participated in the survey, about half of them were still at their early stage of their academic career (Table 1). These are academics who have not or just received their PhDs (Lecturers) or medical doctors undergoing training (residency) to become

a consultant in a field. These young researchers represent academics that are actively involved in research. Other respondents include those that are more senior (22.2%), capable of independent research and that are involved in postgraduate supervision. Academics in the professorial cadre (24.2%) who have track records of research, postgraduate supervision, independent research projects and extensive community projects (Table 1) are the third group. Table 1 also shows that the researchers were more involved in applied research (46%) than basic research (16%). Though about one-third of the academics indicated they carry out more than one type of research. Only a few (4%) of the researchers engage in experimental development. This pattern is in line with extant literature (Reeves, 2000; Mathiassen & Nielsen, 2008; Perry, Chandler & Markova, 2012). Reeves (2000) reveals that to increase the amount of experimental/developmental research in the universities, it will require fundamental changes in a university's epistemology, attitude of researchers and university policies. OECD 2015 defines "experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes." It was also observed from Table 1 that about three quarter of the respondents have a Doctorate or are a Fellow of the West African College of Surgeons (fWACS) in the case of consultants (Medical Doctors who are actively involved in training medical students but still involved in treating patients in the hospitals). The length of experience of the researcher range from below 5 years (23.1%) to above 35 years (10.3%). But the bulk of the respondents have spent less than 25 years in the job (Table 1). Which implies that the respondents are very active in their academic career. Finally, Table 1 shows that the STEM field is a male dominated field with the size of the male researchers doubling that of the female researchers.

Table 1: Socio-Demographic characteristics of the STEM Researchers

Faculties	Percent
Physical & Life Sciences	33.3
Agriculture	27.5
Pharmacy	17.6
Basic Medical Sciences	11.8
Clinical Sciences	7.8
Engineering & Built Environment	2
Total	100
Current Job Position	**Percent**
Lecturer/Resident Doctor	53.4
Associate/Full Professor	24.4
Senior Lecturer	22.2
Total	100
Type of research	**Percent**
Applied Research	46

Mixed Research	34
Basic Research	16
Experimental Development	4
Total	100

Highest Educational Qualification	Percent
PhD/FWACS	76
Master	16
Honours /PGD	4
Graduate Degree	4
Total	100

Length of Work Experience (in Years)	Percent
Less than 5	23.1
5 to 10	15.4
11 to 15	15.4
21 to 25	12.8
16 to 20	10.3
Above 35	10.3
26 to 30	7.7
31 to 35	5.1
Total	100

Gender of the Researchers	Percent
Male	66
Female	34
Total	100

Table 2 shows that about 9 out 10 of the STEAM researchers have access to laboratories or workshops to carry out their research. Only those who don't have access to laboratories/workshops were those whose research could not be done within the university and had to be done either abroad or under specialised conditions in which the facilities are not available within the university but may be available elsewhere in the country. About half of the STEM researchers have prior entrepreneurial experience or are exposed to entrepreneurship either by having a spouse who is an entrepreneur or have parents who were entrepreneurs (Table 2). Indirect or unintended exposure to entrepreneurship could have a lot of influence on the entrepreneurship orientation or intention of a researcher. Table 2 also shows that about half of the STEM researchers have consciously taken steps to learn about entrepreneurship at some point in their career. Literature posits that entrepreneurship education may have strong influence on entrepreneurship intentions (Gerba, 2012; Hattab, 2014).

Table 2: Entrepreneurship Background of STEM Researchers

	Percent
Do you have access to a laboratory/workshop	88.2
Does your family run business?	45.1
Have you undergone any training in entrepreneurship	54

Table 3 shows the range of entrepreneurship activities the STEM researchers are involved in. About 7 out of every 10 of the STEM researchers engage in consultancy services. This happened to be the prevalent entrepreneurial orientation/entrepreneurship activities of STEM researchers. This is in line with previous studies by Perkmann & Walsh (2008), Gunter & Mills (2017), Fudickar, Hottenrott & Lawson (2018). Jewell, Jewell & Kaufman (2020) which all showed that consultancy as an entrepreneurship activity is popular in knowledge institutions. Another important entrepreneurship activity in which the STEM researchers engage was joint venture/ university-industry engagement. At least one out of every five of the STEM researchers are actively involved in participating in a joint venture, either by investing finances in a related business or investing knowledge, skills and competencies in a business not directly or solely owned by them. Literatures that support this view include those of Wright, Vohora & Lockett (2004), D'este & Perkmann (2011) and Perkmann et al (2013). Other entrepreneurship activities which were not so prevalent among the STEM researchers were academic spin-off and commercialization of an intellectual property (Table 3). This was in contrast with literature from developed countries. Extant literatures (Druilhe, & Garnsey, 2004; O'Shea, Chugh & Allen, 2008; Rasmussen, Mosey & Wright, 2011) posits that academic spin-of are part of the characteristics of entrepreneurial universities. Same position holds for commercialization of intellectual properties by the academic researchers as seen in developed economies (Goldfarb & Henrekson, 2003; Siegel, Veugelers & Wright, 2007; Oyedoyin et al 2013; Oyedoyin et al 2014). Though these holds for researchers in university in developed countries, the case is completely different among researchers in the developing and least developed countries.

Table 3: Entrepreneurship Activity Engaged in by the STEM Researchers

	Percent
Consultancy	66.7
Commercialization of an Intellectual Property	11.8
Spin off business from academic research	13.7
Joint venture (collaboration with other enterprises)	21.6

Qualitative Study (Interviews and Field Observations)

The study gathered that most if not all fields of research in the STEM field has the potential to be commercialised either on the local scale or regional scale or national scale or international scale. By default, the STEM researchers are always carrying out different researches that solve socio-economic problems which have the potential of being commercialised.

> *"My research is based on Artificial Intelligence, with application in agricultural technology where farmers can take pictures of leaves while the device I developed will diagnose the leaf and tell if it is diseased or not. If it is diseased it will also tell which kind of disease." (Tech/CSC/01/Male)*
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> "*One of them is the polyphenol research that I did together with other scientists here in Nigeria and in Canada that can be exploited to take over the supplements industry in Nigeria. The research can go into industry." (Agric/CPP/01/Male)*
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> "*My work deals with the testing of effects of some used materials on soil fertility, testing the effect when added to soil on the growth of plants. These materials are sourced from poultry manure, saw dust and some others biodegradable materials that improve the nutrients in the soil." (Agric/SSA/01/Male)*
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> *"The other aspect which later came as a result of my exposure at the National Biotechnology Development Agency and with by background as a Chemical Engineer was in the production of mushrooms, I floated a company and started producing mushrooms. I also got approval from the National Agency for Food and Drug Administration." (Tech/Chem Eng/01/Male)*
>
> *"Looking at my research, the policy aspect can be commercialised. Being in the innovation field, there are so many opportunities to generate income" (Tech/AISPI/01/Female)*
>
> *"I am working on some varieties of cowpea that are naturally resistant to pest and infection. This will help reduce the excessive use of insecticides which have hazardous effects on human health, animals even on the soil." (Agric/CPP/02/Male)*
>
> *"My colleague uses electrical and magnetic methods in prospecting for minerals and rocks, but I combine different aspects of geology and geophysics to solve some seemingly complex problems." (Sci/Geo/01/Male)*
>
> *"My research is about drug discovery from plants." (Pharm/Micro/01/Male)*

However, research has shown that the STEM researchers continue to fall short in the area of taking their research forward from just mere research outputs to tangible goods and services available on the market. Hence, there is need for the researchers in the STEM field to equip themselves with knowledge that will help them become entrepreneurial by undergoing entrepreneurship training and by making use of al the research enabling facilities available to them such as the Intellectual Properties and Technology Transfer Offices (IPTTOs), Incubators, Laboratories, etc.

"I am not even aware there is a Technology Transfer Office in the university." (Tech/CSC/01/Male)

"I have heard of the University Technology Transfer Office, but I haven't visited it before" (Agric/CPP/02/Male)

I have never thought of visiting the University's Intellectual Property and Technology Transfer Office." (Agric/ANS/0/Female)

"I have not visited the university's technology transfer office before though I have heard of it. I am willing to learn about entrepreneurship from research, the world is now tending to entrepreneurship." (Agric/CPP/03/Male)

"I have never visited the university technology Transfer office to learn about how to get a patent or on how to protect my research output. I am focussing on the research for now" (Pharm/Micro/01/Male).

"I have not visited the place, but they have conducted entrepreneurship seminars which I attended" (Sci/Geo/01/Male)

The researchers all indicated that they wish to take their research forward but are not clear on how to go about it. While some feared that an attempt to commercialise their research outputs might constitute a distraction to their mandate of teaching and research. The mandate of university researchers in Nigeria is limited to teaching, research and community engagement.

"I hope an established business will be interested so that we can team up to commercialise the product. I have taken my product of Department of Agricultural Engineering and they are interested in taking it forward." (Tech/CSC/01/Male)

"I believe the purpose of research is to bring your idea out to the marketplace so that the common man can benefit." (Agric/CPP/02/Male)

I am willing to invest time and money to take my research forward because it has proven to be quite productive." (Agric/ANS/0/Female)

"It depends on the acceptance…the knowledge of this new way of farming is still very limited." (Agric/CPP/03/Male)

"I know about entrepreneurship, but I need to know more." (Sci/Geo/01/Male)

"I ran the business for a while but there were too many distractions here and there. The business demanded for my attention, but I had to be in the classroom teaching. There was also issue of trust between me and my employees." (Tech/Chem Eng/01/Male)

The in-depth interviews also gathered that the external conditions for business in Nigeria are very harsh, characterised by incessant policy changes, cost of research materials, difficulty in sourcing raw materials, lack of modern equipment for research, funding to the educational institutions is poor, all these limitations prevents researchers from doing quality research and this have had grave

consequences on the quality and quantity of research outputs. However, the researchers remain motivated in the face of all these challenges.

> *"Different factors worked against my business then, coupled with ill-health, I had to shut down the business. I also wasn't making profit for a long period of time." (Tech/Chem Eng/01/Male)*
> *"There is no business that does not come with its own challenges. The entrepreneur needs to be prepared before going into business…a lot goes into starting and sustaining agribusiness." (Agric/ANS/01/Female)*
> *"The purpose of the research is not for self interest or for the profit of it but for the benefit of what it gives to people, if we can get this done, it will reduce the number of sickness from the use of these chemicals from insecticides, herbicides and pesticides. I am highly motivated to do this. Policy changes shouldn't be a problem." (Agric/CPP/02/Male)*
> *"I am not motivated, these value crops cultivation take a lot of time, you have to plant it, cultivate it for a long time before it can be deployed. This consumes a lot of resources and it's quite stressful but If I get all the resources that I need I will be happy to take the research forward (Agric/CPP/03/Male)"*

The researchers find taking research forward not to be an attractive choice. In addition, the university's position on researchers venturing into entrepreneurship is also not clear. Currently, the government does not support any of its workers (including university researchers) engaging in any other job or trade except subsistence farming which is not expected to be a distraction. The university on the other hand, allows researchers to be engaged in consultancy services. Government departments and agencies are the biggest clients of the university researchers for consultancy followed by the industry.

> *"We are under so many regulations, one of them is civil service rules which says civil servants in Nigeria cannot be engaged in any other business venture the only one allowed is farming. If anyone does anything outsides farming, he has contravened the law. As academics, we can do some consultancy, but there are regulations, (internal regulations) that guide consultancy. You must fulfil all the regulations. You can't take consultancy job directly you have to go through the university. The university will have a share. Many may not be aware of these regulations, but they are there." (Sci/Geo/02/Male)*

Our research also gathered that all researchers wish to make sure their research reaches a larger audience and eventually solves problems but the only method they know of, which the university recognises is publication, patents and consultancy but not entrepreneurship. In cases where there are spinoffs from research, the spinoffs usually become extension of the Department where it came

from and is managed by same. Hence, those spinoffs usually operate on a low scale serving the university and local communities.

> *"Mining is still at the infant level in Nigeria, only the organised private sector is doing something substantial while the only raw material mined and processed is cement. Artisanal mining is not an attractive choice. Hence, researchers focus more on publications and teaching students." (Sci/Geo/02/Male).*
>
> *"I am still working hard to ensure I get collaboration with those in the Agriculture industry but as of now there has not been any productive collaboration or engagement with industry." (Tech/CSC/01/Male).*

The interviewees also opined that their job involves generating new knowledge (finding answers to problems). Once these answers are gotten, the work of a typical researcher ends there. Typically, the professional network of a Nigerian STEM researcher are mostly researchers. Colleagues they can collaborate with to do quality research (research network). Hardly do they have business networks. This situation has also not been of help to the entrepreneurial development of researchers. Most researchers volunteer intellectual property freely in form of publication in top journals in developed countries. While those that have access to such information can easily exploit it for wealth.

> *"Researchers don't go into business as such. They develop an idea and give it to the next actors in the value chain." (Agric/CPP/02/Male)*
>
> *"My research is about drug discovery, if I find a drug company to partner with, we will be able to do some business." (Pharm/Micro/01/Male)*
>
> *"I do not have a business plan, but I have the intention on having one in future." (Agric/ANS/01/Female)*
>
> *"I have a network of researchers, colleagues in the industry as well as an array of the students that I have graduated." (Sci/Geo/01/Male).*

Conclusion

The study established that there exist many opportunities for entrepreneurship based on academic research. Every researcher in the STEM field can take their research forward to a point of generating income through different options of commercialization of their research. This can be done by first protecting their inventions through the different intellectual property rights such as patents, copyright, industrial design, trade secret, amongst other. And by commercialising same through the different means such as out sale of the intellectual property, creating of joint ventures with others, or licensing it to companies to receive royalties. Another channel of commercialization is by creating spin-off companies from the research output/intellectual property. The Researcher is at liberty to choose which options works best for him based on his interest in entrepreneurship or

depending on the extent he wants to be involved in entrepreneurial activities. The study shows that most of STEM researchers are interested in entrepreneurship but a re not clear on how to go about it since their mandate as researcher is teaching, research and community engagement. University's Intellectual Property and Technology Transfer Offices have a central role to play in building entrepreneurial interest in academics. The office needs to work closely with academics on their research to ensure that ideas and prototypes that result in inventions are protected and eventually translated to innovation by exploring the different channels of commercialization. This will keep the researchers undistracted from their main mandate of teaching and research while the commercialization of research outputs in being facilitated by the Intellectual Property and Technology Transfer Offices. To promote entrepreneurship in our universities in Nigeria and other developing countries, there is need for the researchers to focus more on developmental research/experimental development research as well as applied research over basic research. While it is important to increase knowledge based through basic research, application of already established knowledge is more important to solve sociological problems and create entrepreneurship opportunities for the researchers. The advantage developed countries have is that they focus at lot on applied research and experimental development. They focus on solving sociological problems locally and internationally. It is on this strength of this research activities that they are categories as entrepreneurial universities.

Strategic Implications of the Study

Patenting has not become part of Nigeria's STEM researcher's work routine. Whereas, there is an IPTTO office in the university that provide support service on how researchers can protect their inventions on hand and how they can commercialize same without distraction from their primary duties of teaching and research. Indeed, the options available include the outright sale of the patent, licensing, joint venture, self-exploitation, amongst others. An incubator has been situated close to the university, but it was observed that the STEM researchers have not been taking advantage of this incubator. University policies towards entrepreneurship and regulations on how IPTTOs, incubators operate with researchers needs to be revisited. The university's reward system needs to be revisited. Currently, there is no reward formula for patents unlike publications in Nigerian universities.

There needs to be an assessment of the infrastructure for entrepreneurship available to the researchers to that it can be strengthened accordingly. The visit to those facilities shows that even support facilities are not operating optimally as they are also affected by poor funding from government coupled with poor access to basic amenities (e.g. constant power supply) to function optimally. It is only when these support infrastructures are strengthened that the STEM researchers can benefit immensely from the presence of the facilities in and around the university premises.

The boundaries between disciplines are diminishing especially with the nature of researches that can be done currently. Hence, the university needs to revise some of its policies. The university needs to foster interdisciplinary research and collaborative team research among the researchers so that the quality of research output can be enhanced which will then increase the chances of more viable spinoffs.

Also, in line with Nigeria's New Science, Technology & Innovation (STI) Policy, the types of researches to be prioritized in knowledge institutions especially among the STEM researchers should be applied research & experimental development research not basic research. "Applied research is original investigation undertaken in order to acquire new knowledge" (OECD 2015). Applied research is a methodology used to solve a specific, practical issue affecting an individual or group. This scientific method of study and research is used in business, medicine, and education in order to find solutions that may improve health, solve scientific problems or develop new technology. Most of the researches carried out in most STEM faculties are still basic research with some applied research. "Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any application or use in view" (OECD 2015). Basic research is curiosity driven. Basic research does not have immediate commercial objectives and although it certainly could, it may not necessarily result in an invention or a solution to a practical problem. Applied research is designed to answer specific questions aimed at solving practical problems. It is not necessary to just increase the knowledge base nowadays but to apply the knowledge to solve sociological problems and take it forward to solving national problems thereby creating wealth from knowledge generated within the boundaries of the country. Also, an attempt might be made to export such knowledge

Above all, the study found out that the orientation of the STEM researchers needs to change. It is important to learn from universities in developed countries. See for instance a report by MIT in 2015 underscores the substantial economic impact of the Institute's alumni entrepreneurs, whose companies have created millions of jobs and generated annual revenues of nearly two trillion US Dollars – a value greater that the gross domestic product (GDP) of the world's 10^{th} largest economy. STEM researchers in Nigeria and other developing countries need to embrace academic entrepreneurship as well. This may be one of the ways to solve unemployment. Academic entrepreneurship is as important as the mandate of teaching and research. Also, the university and national policies must ensure that entrepreneurship and engagement become one of the mandates of university researchers such that every researcher will need to dedicate some of their time to innovation, entrepreneurship, engagement and consultancy. There is urgent need for entrepreneurship re-orientation through entrepreneurship education in the knowledge institutions in Nigeria.

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