

# 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 in the promotion of entrepreneurship, especially in entrepreneurial universities. This study examines the role of innovation and entrepreneurship infrastructure in facilitating the development and commercialisation of research outputs from the science, technology, engineering and mathematics (STEM) faculties in a university in Nigeria. The study is based on a mixed quantitative and qualitative methodology. A questionnaire was administered to 60 lecturers/researchers across six faculties (Science, Engineering, Basic Medical Sciences, Clinical Sciences, Pharmacy and Agriculture), yielding an 85% response rate. Eleven follow-up interviews were conducted in four faculties and field observations were held at four research and innovation facilities. The study findings have strategic implications for policymaking, practice and theory.*

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

## INTRODUCTION

Nigeria has experienced persistent youth employment and poverty amidst a constantly growing population (Dauda, 2017). The country's population is conservatively estimated to be 200 million with over 75% of the population falling within the working age of 15 to 65 years (Chiazor & Udume, 2017; Olurinola & Fadayomi, 2016). Entrepreneurship has become an important alternative to increasing employment and economic development in Nigeria (Figueiredo & Paiva, 2019; Gamede & Uleanya, 2018), particularly since most government interventions have met with limited success. One of the greatest blunders of government policies was the structural adjustment programme (SAP) in the 1980s (Okoye, et al., 2016). The economic depression of the early 1980s-which is continuing to this date-has resulted in the establishment of numerous entrepreneurial ventures. These were primarily initiated by youths who were unable to find white collar jobs and therefore created alternative employment opportunities to counter unemployment and poverty. The solutions provided by these entrepreneurs have gained the attention of policymakers and entrepreneurship is now seen as a viable pathway towards economic development (Fini, et al., 2018; Horne, et al., 2020; Morris, et al., 2020; Roundy, Bradshaw & Brockman, 2018).

Nigeria has since provided support to entrepreneurs through policies and programmes, the creation of ministries, departments and agencies as well as other infrastructure to support entrepreneurship (Abioye, et al., 2017; Adebayo, 2016; Afolabi, Kareem, Okubanjo, et al., 2017;

Ayoade & Agwu, 2016). Alongside important interventions such as the provision of credit facilities, training and the creation of institutions responsible for the development of small and medium enterprises, one of the most successful interventions of the 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 educational institutions from just teaching and research to include entrepreneurship—which is now considered as important as the mandates of teaching and research. Consequently, most universities in Nigeria have now incorporated entrepreneurship education into both its undergraduate and postgraduate studies, as recommended by the Nigeria University Commission (Maxwell, et al., 2018; Nwambam, et al., 2018). However, despite the government's policies, programmes and instruments promoting entrepreneurship, students and researchers from knowledge institutions are struggling to fulfil the new mandate on entrepreneurship and engagement. The main reason for this may be that Nigeria's entrepreneurship ecosystem is still in its infancy.

## 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 establish and develop high-growth ventures that create wealth and economic development

### **Academic Entrepreneurship, Intellectual Property Rights and Entrepreneurship**

In developed countries, universities serve as knowledge centres for entrepreneurship creation (Fuster, et al., 2019; Klofsten et al., 2019; Wonglimpiyarat, 2016). Indeed, many companies in developed countries started off as ideas that were generated in laboratories and which were later commercialised. Many other companies arose as a spin-off or spin-out from research outputs from universities. Furthermore, knowledge on the protection of intellectual property rights as a result of research breakthroughs in developed countries has promoted entrepreneurship activity in universities. Thus, researchers who have come up with an invention and receive a patent or other intellectual property rights (Dalmarco, et al., 2018; Etzkowitz, 2017; Urbano, et al., 2019) are free to commercialise the product through different means such as outright sales, licensing, spin-off formation, joint venture, franchise or self-exploitation (Siyanbola, et al, 2016)

Entrepreneurial universities such as the Massachusetts Institute of Technology, Harvard University or Stanford University are all known for the wealth they create through their scientific and technological research—not just for themselves but also for the national economy (Massucci & Docampo, 2019). These universities share in common the promotion of entrepreneurship from research outputs (Safón, 2019).

The contribution of scientific and technological research to economic growth and development cannot be overemphasised. 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 science, technology and innovation (STI) policies while some have even moved to the level of having innovation policies. Between 2010 & 2012, Nigeria reviewed its previous S&T policy documents from 1986 and 2003 to include an STI policy, stressing the need to commercialise scientific and technological research outputs (Oyewale, et al., 2017; Siyanbola et al., 2016). Nigeria's STI

emphasises that while it is important to continue to strengthen S&T systems, it may be more important to commercialise the S&T knowledge supplied.

### **STEM Education in Nigeria and Entrepreneurship**

STEM researchers require good entrepreneurship infrastructure to convert innovative research outputs into wealth (Datta, 2018). The research output from STEM can materialise in different forms such as publications, prototype development, patents or other intellectual property rights. These research outputs have great potential to be converted into wealth through entrepreneurship. A recent study by Abodunde, Jegede and Oyebisi (2020) indicates that research outputs in science, technology, engineering, arts and mathematics (STEAM) in Nigeria have been on the rise over the last decade. A similar study by Abodunde and Jegede (2020) which examined the productivity of research output from STEM researchers in Nigerian universities showed that the science and technology outputs were of a high quality and represented useful resource materials for technology development and economic growth via entrepreneurship. Despite the quality and quantity of research 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 business spin-offs based on academic research from these institutions (Dalmarco et al., 2018; Fuster et al., 2019; Lockett, Siegel, Wright & Ensley, 2005).

### **Government Policies and Entrepreneurship**

One of the vital roles government can play to promote entrepreneurship, apart from policy instruments, could be through the creation or strengthening of entrepreneurship support infrastructure. Nigeria has several agencies promoting the commercialisation of inventions from scientific and engineering research. These include the 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 (PRODI), National Board for Technology Incubation (NBTI) and Raw Materials Research and Development Council (RMRDC). All these agencies are funded by the government and their roles are to ensure that scientific ideas become inventions through the development of prototypes. This is achieved through partnerships with relevant private sector organisations and knowledge institutions for the development and commercialisation of research outputs and prototypes.

NBTI has several technology incubation centres located in different regions of the country with the responsibility of incubating science and technological output into viable technology businesses. The incubators protect technology-based businesses from the harsh business environment during the start-up phase of the business. Most businesses close during this period, which is the most difficult in the business life cycle. Incubators provide important facilities to help technology businesses grow.

NOTAP established several different Intellectual Property and Technology Transfer Offices (IPTTOs) in many universities to ensure that research outputs are protected for the purpose of commercialisation. This initiative has been very effective in that university researchers are now aware of the importance of taking their research further, to the point of commercialisation.

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 production of components takes place.

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 standardisation as well as power equipment.

Other efforts of government to promote the commercialisation of research include the creation of free trade zones, export processing centres, industrial parks, science parks and clusters. These efforts include the establishment of agencies such as the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN) which was set up under the auspices of the Ministry of Trade and Industry to support the development of Nigerian businesses. 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 organisations such as the Bank of Industry, development banks, commercial banks, venture capitalists and business angels.

Though there is ample support provided by government for the commercialisation of S&T research outputs, there seems to be a missing link as this support has not proven effective in Nigeria. There is a disconnect between engagement from academia, industry and government as these three role-players seem to be working independently. There is little meaningful interaction between them to ensure viable outputs that will create wealth for the country (Egbetokun, et al., 2017; Omobhude & Chen, 2019; Zanello, Fu, Mohnen & Ventresca, 2016). Some researchers argue that academia must take the lead role in ensuring collaboration and engagement among the different role-players of the innovation system while others believe that the government should use policy to foster interaction (Din, et al., 2016; Fernández-Nogueira, et al., 2018; Klofsten et al., 2019; Olofinyehun, et al., 2018). Others still, have indicated that the industry needs to rely on academia for the knowledge which they will deploy in production (Garousi, et al., 2019; Mejlgaard & Ryan, 2017).

It is evident that academia has been provided with the necessary support to leverage the commercialisation of research outputs. A key question which arises is whether Nigerian researchers are willing or have the intention to commercialise their research and engage with industry and society, in addition to teaching and research. Academics can only function successfully as potential entrepreneurs if there is a robust entrepreneurship ecosystem.

### **Entrepreneurial Innovation**

Literature on entrepreneurial innovation has always emphasised the importance of entrepreneurship for innovation. This view is derived from the Schumpeterian tradition of the processes of creative destruction (Schumpeter, 1934). This refers to the entrepreneur introducing radical innovation that is new to the world, and which threatens the industry's equilibrium, triggering a process of agglomeration, productivity and economic development (Schumpeter, 1934; 1942). For Schumpeter, radical innovation outcomes have long been associated with entrepreneurship. Studies by Audretsch & Belitski (2017), Roundy, Brockman & Bradshaw (2017), Spigel (2017); Stam (2015) have pointed to the important role of the entrepreneur in innovation. This is slightly different, however, from the position of the National System of

Innovation (NSI) literature (Fagerberg & Sapprasert, 2011; Lundvall, 2016; Nelson, 2013) which focuses on structure and institutions for innovation outcomes. In contrast to the NSI literature, entrepreneurial innovation literature involves the disruption of industries and the creation of new ones through multi-level processes and stakeholders, in multiple contexts and with multiple actors—all of which constitute different entrepreneurial ecosystems.

### **Entrepreneurial Ecosystem**

Several definitions of entrepreneurial ecosystems have been provided in literature. For instance, Stam (2015) defines an entrepreneurial ecosystem as “a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship” while Audretsch & Belitski (2017) refer to “systems of entrepreneurship [which are] institutional and organizational as well as other systemic factors that interact and influence identification and commercialisation of entrepreneurial opportunities”. Other notable descriptions of the entrepreneurship ecosystem include those of Roundy et al. (2017) who view it as “communities of agents, social structures, institutions, and cultural values that produce entrepreneurial activity” and Spigel (2017), who sees it 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 word ‘entrepreneurial’ in the term ‘entrepreneurial’ refers to the entrepreneurship process by which individuals exploit opportunities for innovation (Stam, 2015). The second word, ‘ecosystem’, refers to the interaction of living organisms with their environment. The entrepreneurship ecosystem refers to the external environment context within which the entrepreneurship process takes place (Stam, 2015). 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 the NSI approach to innovation. It recognises the shortcomings of entrepreneurship literature, which tends to focus on the microeconomic foundations and personal attributes of entrepreneurs and less on the contextual factors which might have a bearing on entrepreneurial innovation outcomes. Entrepreneurial ecosystem literature also finds fault with the NSI approach (Asheim, Grillitsch & Trippl, 2016; Binz & Truffer, 2017; Chaminade, Lundvall & Haneef, 2018; Reischauer, 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 entrepreneurial ecosystem literature recognises the role of the entrepreneur in driving entrepreneurial ecosystems but also highlights the strategic importance of contextual factors which regulate entrepreneurial innovation. Entrepreneurial ecosystems comprise different contexts which, through their systematic interaction, influence and regulate entrepreneurship innovation performance and outcomes.

Entrepreneurial innovation is the primary source of a country’s competitive advantage (Anwar, et al., 2018; Distanont & Khongmalai, 2020). It has long been argued within this tradition that positive economic outcomes are largely associated with new and radical 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.

### **Entrepreneurial Ecosystem and Business Growth**

The entrepreneurial ecosystem approach has arisen due to the shortcomings of previous approaches. Mason & Brown (2014) contend that this approach centres on creating and supporting a distinct environment in which high-growth firms (HGFs) can thrive. In contrast, Stam & Spigel (2016) view the entrepreneur rather than the firm as the key role-player and they place great importance on the social and economic context. Industrial policy in advanced countries now centres on increasing the number of HGFs (Mason & Brown, 2014). This refers to the quality of entrepreneurship, since empirical evidence suggests that a small group of entrepreneurs with high growth ambition—and not new or small firms—are vital for economic growth (Stam, 2015). Ambitious entrepreneurs are defined as those who are performing well with their business (Stam, 2013). Stam (2015) further notes that these types of entrepreneurs are innovative and seek rapid growth of their ventures. 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 to incorporating numerous industries and are “geographically bounded but not confined to a specific geographical scale” (Mason & Brown, 2014). Economic activity thus generally gravitates towards specific geographical locations. The entrepreneurial ecosystem approach explicitly targets entrepreneurial activity in HGFs and emphasises “local and regional environments and the conditions required to generate and support ambitious entrepreneurship” as well as “interactions between framework conditions and local/regional geographical conditions” (Mason & Brown, 2014). Thus, certain types of environments, i.e. entrepreneurial ecosystems, enable the growth of HGFs. Feld (2012) proposes nine elements that make up a successful entrepreneurial ecosystem: leadership, intermediaries, network density, government, talent, support services, engagement, companies, capital. These elements of successful entrepreneurial ecosystems highlight the importance of interaction between key stakeholders in the ecosystem and access to appropriate resources, with government playing a role in the background.

This paper contributes to the growing body of literature on entrepreneurial ecosystems by assessing the entrepreneurial skills of researchers in the STEM field through the quality of entrepreneurship infrastructure available to them.

## **Theoretical Framework – Entrepreneurship Ecosystem and Related Concepts**

The entrepreneurial ecosystem approach represents an improvement over other established concepts such as industrial districts, clusters or the innovation systems approach. The main difference is that the focus of the entrepreneurial ecosystem 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, specialised suppliers, service providers and firms in related industries as well as allied institutions that compete but also co-operate (Porter, 1998). Regional innovation systems (RIS) refer to the networks and institutions linking innovative firms with knowledge-producing hubs such as universities and public research labs within a region (Cooke, et al., 1997). The entrepreneurial ecosystem approach diverges from the industrial district, cluster and innovation system approaches on the basis that the entrepreneur (or the start-up)—and not the firm—is the unit of analysis (Feldman, 2014).

The earliest work on entrepreneurial ecosystem gives a rather narrow view of entrepreneurship (Schumpeter, 1934). Other scholars (Acs, et al., 2017; Mason & Brown, 2014; Spigel, 2017; Spigel & Harrison, 2018; Stam & Spigel, 2016; Zahra & Nambisan, 2012) have built on this initial view by adding the social, political and economic environment in which the entrepreneur functions. Their views represent a broader perspective, prioritising the external context, over which the entrepreneur has little or no control. The entrepreneurial ecosystem approach also 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. In contrast, 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 view, Isenberg (2011) proposes six domains of the ecosystem: policy, finance, culture, support, human capital and markets. These largely overlap with the eight pillars identified by the World Economic Forum (2013; Stam, 2015) for a successful ecosystem, each with several components. These pillars include the presence of key factors such as (i) human capital, (ii) finance and services, (iii) talent, investors, mentors, advisors, entrepreneurial peers, (iv) the formal government and regulatory framework, (v) informal institutions enabling entrepreneurship, (vi) access to customers in domestic and foreign markets.

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

## METHODOLOGY

This section discusses the methodology used in the study.

### Research Design

The study was based on the triangulation of quantitative and qualitative techniques. As part of the quantitative approach, a cross-sectional study which was carried out using a questionnaire to elicit information from lecturers and researchers at a Nigerian university. The qualitative approach was applied through the case control method relying on information obtained from in-depth interviews conducted with lecturers and researchers in the relevant faculties. Field observations were also made during visits to laboratories and workshops as well as research support facilities such as an incubation center. Data was collected from a university in southwestern Nigeria. The university was selected based on research excellence and its exceptional outputs in terms of the development of prototypes, the filing of patents and spin-off activities. The university has ranked among the top three in the country over the past few decades.

## Data Collection

During the first, quantitative phase of the study, a questionnaire was designed to elicit information from lecturers and researchers 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 STEM faculties, namely, the Faculties of (i) Science, (ii) Technology, (iii) Basic Medical Sciences, (iv) Clinical Sciences, (v) Pharmacy, and (vi) Agriculture. 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. This yielded an 85% response rate, resulting in a total of 51 useable questionnaires.

The second, qualitative phase of the study, following analysis of the questionnaires, lecturers with relevant information 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 was carried out in all. The interviews were recorded electronically and subjected to content analysis.

The third phase of the study, which was also qualitative, was field observation. This involved visiting the entrepreneurship infrastructure available to the researchers in the university. The facilities visited included the Central Science Laboratory, the Central Technical Workshop, the Intellectual Property and the Technology Transfer Office as well as the Technology Incubation Centre, located 15 kilometers from the university.

## RESULTS AND DISCUSSION

The discussion of the results is divided into two parts. The first part describes the quantitative study, focusing on the background of the STEM researchers and the nature of the entrepreneurship activities they are involved in. The second part describes the qualitative study, focusing on how external factors shape the decisions of the STEM researchers to become entrepreneurs.

### Quantitative Study (Questionnaire)

Although it was intended to have equal representation from the six faculties, the most responses were gained from the Faculty of Science, representing about one-third of the response rate. This was closely followed by Faculty of Agriculture and then, the Faculty of Pharmacy. The lowest response rate was from the Faculties of Basic Medical Sciences, Clinical Sciences and Technology, as shown in Table 1 below.

As can be seen in Table 1, about half of researchers who participated in the survey were still at the early stage of their academic career. These academics were lecturers who had not yet completed their doctoral studies or had only recently done so. Alternatively, they were medical doctors undergoing training (residency) to become a consultant in a given field. These young academics were actively involved in research. Other respondents were more senior (22.2%), capable of independent research and involved in postgraduate supervision. Lastly, academics in the professorial cadre (24.2%) had well-established track records in research, postgraduate supervision, independent research projects and extensive community projects.

Table 1 also shows that the researchers were more involved in applied research (46%) than basic research (16%) although about one-third of the academics indicated they carried out



more than one type of research. Only a small number (4%) engaged in experimental development. This pattern is in line with extant literature (Mathiassen & Nielsen, 2008; Perry, Chandler & Markova, 2012; Reeves, 2000). Reeves (2000) maintains that increasing the amount of experimental/developmental research in universities will require fundamental changes in a university's epistemology, attitude of researchers and university policies. The Organisation for Economic Co-operation and Development (OECD) (2015) defines experimental development as 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 can also observe from Table 1 that about three-quarters of the respondents had a doctorate or they were Fellows of the West African College of Surgeons (FWACS) in the case of consultants (medical doctors who are actively involved in training medical students but who still treat patients in hospitals).

The length of experience of the researchers range from less than five years (23.1%) to more than 35 years (10.3%). However, the bulk of the respondents had spent less than 25 years in their role. This implies that the respondents are very active in their academic career. Finally, in terms of gender, the STEM field is male-dominated, with the size of the male researchers doubling that of the female researchers.

<b>Faculties</b>	<b>Percent</b>
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
<b>Current Job Position</b>	<b>Percent</b>
Lecturer/Resident Doctor	53.4
Associate/Full Professor	24.4
Senior Lecturer	22.2
Total	100
<b>Type of research</b>	<b>Percent</b>
Applied Research	46
Mixed Research	34
Basic Research	16
Experimental Development	4
Total	100
<b>Highest Educational Qualification</b>	<b>Percent</b>
PhD/FWACS	76
Master's	16
Honours / PGD	4
Graduate Degree	4

Total	100
<b>Length of Work Experience (in Years)</b>	<b>Percent</b>
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
<b>Gender</b>	<b>Percent</b>
Male	66
Female	34
Total	100

Table 2 shows that about nine out ten STEM researchers have access to laboratories or workshops to carry out their research.

<b>Table 2</b>	
<b>ENTREPRENEURSHIP BACKGROUND OF STEM RESEARCHERS</b>	
	<b>Percent</b>
Do you have access to a laboratory/workshop?	88.2
Does your family run a business?	45.1
Have you undergone any training in entrepreneurship?	54

Table 3 shows the range of entrepreneurship activities that the STEM researchers were involved in. As can be seen in Table 2, those researchers without access to laboratories or workshops had to carry out their research either abroad or under specialised conditions, at facilities available elsewhere in the country. About half of the STEM researchers had prior entrepreneurial experience or were exposed to entrepreneurship either by having a spouse who was an entrepreneur or parents who were entrepreneurs. Indirect or unintended exposure to entrepreneurship could have a significant influence on the entrepreneurship orientation or intention of a researcher. Table 2 also shows that about half of the STEM researchers had consciously taken steps to learn about entrepreneurship at some point in their career. Literature posits that entrepreneurship education may have strong influence on entrepreneurship intention (Gerba, 2012; Hattab, 2014).

<b>Table 3</b>	
<b>ENTREPRENEURSHIP ACTIVITY ENGAGED IN BY THE STEM RESEARCHERS</b>	
	<b>Percent</b>
Consultancy	66.7
Commercialisation of Intellectual Property	11.8
Spin -off business from academic research	13.7
Joint venture (collaboration with other enterprises)	21.6

As can be seen in Table 3, about seven out of every ten researchers provided consultancy services. This was the most prevalent entrepreneurial orientation/entrepreneurship activity of the researchers, in line with previous studies by Fudickar, Hottenrott and Lawson (2018), Gunter and Mills (2017) and Perkmann and Walsh (2008). According to Jewell, Jewell and Kaufman (2020), consultancy as an entrepreneurship activity is common in knowledge institutions.

Another important entrepreneurship activity was joint venture or university industry engagement. At least one of every five of the researchers was actively involved in a joint venture, either by investing finances into a related business or investing knowledge, skills and competencies into a business not directly or solely owned by them. This is supported by literature such as D'Este and Perkmann (2011), Perkmann et al. (2013) and Wright, Vohora & Lockett (2004).

Other entrepreneurship activities which were less prevalent among the researchers were academic spin-offs and the commercialisation of intellectual property. This finding is in contrast to literature from developed countries which indicates that academic spin-offs are typical of entrepreneurial universities (Druihe & Garnsey, 2004; Goldfarb & Henrekson, 2003; O'Shea, Chugh & Allen, 2008; Oyedoyin et al., 2013, 2014; Rasmussen, et al., 2011; Siegel, et al., 2007). Although such findings may hold for researchers in developed countries, the case is completely different for those in developing or undeveloped countries.

### **Qualitative Study Findings (Interviews and Field Observations)**

The qualitative study revealed that most if not all fields of STEM research have the potential to be commercialised, either on a local scale or regional scale or on a national or international scale. By default, the STEM research involves the search for solutions to socio-economic problems—which have the potential to be commercialised as explained by the researchers:

*“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)*

*“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/PPP/01/Male)*

*“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, sawdust and some others biodegradable materials that improve the nutrients in the soil.” (Agric/SSA/01/Male)*

*“The other aspect which later came as a result of my exposure at the National Biotechnology Development Agency and with my 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/PPP/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, studies have shown that STEM research is not being taken forward to the commercialisation stage. It remains as mere research output instead of becoming tangible goods and services available on the market. Hence, there is need for STEM researchers to equip themselves with knowledge that will help them become more entrepreneurial by undergoing entrepreneurship training and by making use of research-enabling facilities such as IPTTOs, incubators and laboratories. This came out clear from the researchers remarks:

*“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/PPP/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/PPP/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 focusing 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 respondents all indicated that they wished to take their research forward but were uncertain as to how to achieve this. Some also feared that commercialising their research might distract them from their core mandate of teaching, research and community engagement. This is evidenced in the comments below:

*“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/PPP/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/PPP/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 respondents also indicated that the external conditions in Nigeria are not conducive to business, characterised by incessant policy changes, high cost of research materials, difficulty in sourcing raw materials, lack of modern equipment, poor funding for educational institutions. These limitations have had negative consequences for the quality and quantity of research output in Nigeria. Nonetheless, the researchers remain motivated in the face of 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/PPP/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/PPP/03/Male)*

The respondents indicated that commercialising research was fraught with difficulties. In addition, the university's position on researchers venturing into entrepreneurship was unclear. Currently, the government does not support any of its workers (including university researchers) engaging in any other occupation or trade other than subsistence farming. The university on the other hand, does allow researchers to engage in consultancy services. Government departments and agencies are the biggest clients of university consultants, followed by industry. The concerns of the respondents are expressed below:

*“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 outside 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)*

The respondents revealed that they would like their research to reach a larger audience and eventually solve real-life problems. However, the only method they knew of to achieve this—as recognised by the university—was publication, patents or consultancy, but not entrepreneurship. In cases where there were spin-offs from research, these usually became an extension of the department where the idea originated from and were managed by the same.

Hence, spin-offs usually occurred on a low scale, serving only the university and local community. This is reflected in the comments below:

*“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 respondents also opined that their job involved generating new knowledge (finding answers to problems). Once a solution was arrived at, the work of a typical researcher ended there. The professional network of most of the researchers consisted of mostly other researchers and colleagues with whom they could collaborate to conduct quality research. Business networks appeared to be virtually non-existent, a situation which does little to promote the entrepreneurial development of researchers. Most researchers volunteered intellectual property freely in form of publications in top journals in developed countries. Those with access to such information could easily exploit it for their own gain. These concerns are expressed below.

## CONCLUSION

The study established that there are many opportunities for entrepreneurship stemming from academic research among Nigerian researchers in the STEM field. Such research could be taken forward to the point of generating income through different forms of commercialisation. This could be done by first protecting the innovations through intellectual property rights such as patents, copyright, industrial design or trade secrets. The innovations could then be commercialised through the sale of intellectual property, joint ventures or licensing to companies to receive royalties. Another channel of commercialisation would be to create spin-off companies from the innovations. Researchers would be at liberty to choose the options which suited them best depending on their interest in entrepreneurship or the extent to which they wished to be involved in entrepreneurial activities. The findings reveal that most of the researchers were interested in entrepreneurship but were uncertain how to go about this since their university mandate focused on teaching, research and community engagement. The university's IPTTO thus has a central role to play in building entrepreneurial interest in academics. The office should work closely with academics to ensure that ideas and prototypes are protected and eventually commercialised through different channels. If the IPTTO were to facilitate commercialisation in this way, researchers would be able to remain focused on their core mandate of teaching and research.

To promote entrepreneurship in Nigerian universities and other developing countries, there is a need for researchers to take on more developmental research, experimental development research or applied research as opposed to basic research. The OECD (2015) defines applied research as original investigation undertaken in order to acquire new knowledge. Applied research is used to solve a specific, practical issue affecting an individual or group. This scientific method of research is used in business, medicine and education in order to find solutions that may improve health, solve scientific problems or develop new technologies. Most of the STEM faculties still carry out basic research, with limited applied research. Basic research, according to the OECD (2015), 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. Basic research is curiosity-driven. It 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. While it is important to conduct basic research, the application of already established knowledge is more important to solve social problems and create entrepreneurship opportunities for researchers. Universities in developed countries focus more on applied research and experimental development to solve social problems, both locally and internationally. It is on the strength of this type of research that such universities are categorised as entrepreneurial universities.

### **STRATEGIC IMPLICATIONS OF THE STUDY**

Patenting occurs infrequently in Nigerian universities despite the presence of IPTTOs in most universities that provide support to researchers on protecting and commercialising their research ideas. An incubator is situated near the university under study, however, the findings revealed that the STEM researchers had not taken advantage of this facility. University policies on entrepreneurship and regulations on how IPTTOs and incubators operate should therefore be reviewed. The university's reward system should also be reviewed as currently, there is no reward for patents, unlike for publications.

Entrepreneurship infrastructure available to researchers also needs to be assessed and strengthened accordingly. The field visits to the support facilities showed that they were not operating optimally as they were underfunded and had poor access to basic amenities (e.g. constant power supply). It is only when such support infrastructure is strengthened that STEM researchers will be able to benefit from the presence of such facilities in and around the university campus.

The boundaries between disciplines are diminishing, especially with research that can be done currently. Hence, the university needs to revise its policies to foster interdisciplinary research and collaborative team research. This would enhance the quality of research and increase the chance of more viable spin-offs.

In line with Nigeria's new STI policy, the types of research to be prioritised, especially among the STEM researchers, should be applied research and experimental development research as opposed to basic research.

Lastly, the findings indicated that the orientation of STEM researchers needs to change as academic entrepreneurship is as important as the mandate of teaching and research. It is crucial to learn from universities in developed countries in this regard. A 2015 report by the Massachusetts Institute of Technology 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 than the gross domestic product of the world's tenth largest economy. STEM researchers in Nigeria and other developing countries need to embrace academic entrepreneurship as well which may be one of the ways to reduce unemployment. Both university policies as well as national policies must ensure that entrepreneurship and engagement become one of the mandates of university researchers so that every researcher will need to dedicate some of their time to innovation, entrepreneurship, engagement and consultancy. This urgent need for entrepreneurship re-orientation can be addressed through entrepreneurship education in the knowledge institutions in Nigeria.

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