A Bibliometric Analysis of Engineering Research Productivity of Nigerian Universities from 2010 to 2022: Trends, Hotspots, and Future Outlook

Solomon O. Giwa[1], Adekunle A. Musa-Olokuta[2], Raymond T. Taziwa[1], Noluntu Dyantyi[3], Mohsen Sharifpur[4,5]

[1]Department of Applied Sciences, Faculty of Natural Science, Buffalo City Campus, Walter Sisulu University, South Africa
[2]Department of Mechanical Engineering, Olabisi Onabanjo University, 112104, Ibogun, Nigeria
[3]Faculty of Education, Butterworth, Walter Sisulu University, South Africa
[4]School of Mechanical, Industrial and Aeronautical Engineering, University of the Witwatersrand,
Private Bag 3, Wits 2050, South Africa
[5]Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan
[1]sgiwa@wsu.ac.za
[2]musa.adekunle@oouagoiwoye.edu.ng
[1]rtaziwa@wsu.ac.za
[3]ndyantyi@wsu.ac.za
[4,5]Mohsen.Sharifpur@wits.ac.za

Abstract—In this study, data of scholarly articles sourced from the Scopus® database were used to evaluate the performance of engineering-based research in Nigerian universities from 2010 to 2022. Analyses of the sourced data were carried out using VOSviewer®. These analyses via publication related to organization, country and author collaboration, citation counts of top scholarly articles and publication sources, and co-occurrence of author keyword were used to assess the engineering research productivity of the Universities. A total of 15083 scientific articles which translates to 1160 articles per year were published. Covenant University is the most productive University with 632 articles. Malaysia (1758 articles) and Tshwane University of Technology (South Africa) are the country and institution with the most research collaboration with Nigerian Universities. The most cited paper is the work of Alaneme K.K. (2015) with 170 citations. Engineering-based research publications are observed to be cited most in the Journal of Cleaner Production (5919 citations). Mechanical engineering is noticed to produce the highest number of publications followed by Civil Engineering. Hot topics are related to material development, renewable energy, machine learning, optimization techniques, modeling, and simulation studies. Future research (sustainable and novel materials, green building, machine learning, artificial intelligence, smart grid, COVID-19, renewable energy, etc.) is expected to agree with the fourth industrial revolution, circular economy, and sustainable development goals agenda. Conclusively, research funding and collaboration must be intensified, and local research outputs should be published in impactful journals to further improve the visibility and ranking of the researchers and the Universities.

Keywords—Bibliometric analysis; Engineering; Nigeria; Research; Universities.

1. Introduction

Bibliometric analysis utilizes both quantitative and statistical techniques to examine scholarly publications sourced from recognized databases such as Web of Science® and Scopus® (Alagumalai et al., 2021). Bibliometric analysis as a sub-division of information and library sciences has found application in numerous fields of study (such as medicine, veterinary, science, and engineering) and research areas. It deploys an orderly approach to

M. Sharifpur

School of Mechanical, Industrial and Aeronautical Engineering,
University of the Witwatersrand, Private Bag 3, Wits 2050,
South Africa.
Mohsen.Sharifpur@wits.ac.za

appraise the progress in various fields of study and research areas based on the scholarly publications associated with them. Also, bibliometric analysis can be explored to unveil the evolution related to new technology and innovation and to have a deep insight into research trends (past, present, and future) associated with a specific field of study or research area based on the related scholarly contributions (Giwa et al., 2022). Numerous studies have deployed the use of bibliometric analysis to have a better, logical, and in-depth understanding of the contributions of scholarly publications to the body of knowledge which include research performance of universities (Ani & Onyancha, 2011; Doulani, 2020), country (Boamah & Ho, 2017; Salisu & Salami, 2020), scientific journal outlets/publishers (Kappi & Biradar, 2019; Lei & Xu, 2020), continent (Confraria & Godinho, 2015; Cortés et al., 2021; Patra & Muchie, 2017), country-continent research collaboration (Eduan & Yuanqun, 2019), research areas (Adedayo et al., 2021; Giwa et al., 2022, 2023), fields of study (Okafor & Dike, 2010; Sooryamoorthy, 2018), etc.

Production of scholarly knowledge in Africa, especially sub-Saharan Africa is considered to be of huge importance and keen interest to policymakers, governments, and scholars. This is corroborated by the African Union's 10-year science, technology, and innovation strategic plan which prioritizes the deployment of scientific research for the social, technological, and economic development of Africa (Sooryamoorthy, 2018). From the 1980s to 2013, a progressive increase in scholarly publications stemming from Africa with a global share of 1.4% to 2.6% has been reported (Sooryamoorthy, 2018). This period witnessed a rise in the number of scholarly publications by African researchers from a global average of <1% to 2.3%. In addition, sub-Sahara Africa's scholarly contribution on a global scale was observed to increase (quality and quantity) from 0.44% to 0.72% and accompanied by a citation increase from 0.06% to 0.16%. However, in comparison to the African population, the African scholarly contribution is considerably lower than the world average (Confraria & Godinho, 2015). Subject to the importance of Science, Technology, Engineering, and Mathematics (STEM), South Africa, Nigeria, and Egypt are reported to have the highest scholarly contributions in Africa, thus, indicating the intense conduct of STEM research and its dissemination by these countries (Cortés et al., 2021). In addition, Nigeria was considered a leading country in West Africa when the China-Africa research collaboration was evaluated using a bibliometric approach (Eduan & Yuanqun, 2019).

The effect and performance of African science based on the scholarly publications of African researchers were evaluated using bibliometric analysis (Confraria & Godinho, 2015). Science-based publication data extracted from InCites® (by Thomson Reuters) from 1981 and 2011 were analyzed to monitor and evaluate science development and trends, research productivity, impact, output, collaboration, specialization, country participation, and performance using different performance metrics. Data of science-based publications (from Science Citation Index Expanded) contributed by all countries in Africa and African researchers from 2000 to 2015 were utilized by (Sooryamoorthy, 2018) to analyze the number of scholarly publications, and scientific research areas to evaluate the progress, development, and productivity of African countries in the field of science.

An evaluation of the research performance and productivity of scholars in Nigerian Universities was carried out (Ani & Onyancha, 2011). Data used were obtained from the Web of Science databases from 2000 to 2010. The publication number, subject, sources, and trend, citation counts and h-index impacts, and analysis of leading universities were carried out in their evaluation. Similarly, owing to limited bibliometric studies in Ghana concerning the evaluation of scholarly contributions related to Ghanaian universities, a bibliometric analysis using data from scientific publications contained in the Web of Science® (Science Citation Index Expanded) database was performed for scholarly publications credited to Ghana from 1936 to 2016 (Boamah & Ho, 2017). The data were analyzed for the article types, languages, subject classification, international collaboration, publication trend, article citation counts, leading articles, institutions, journals, and authors.

A bibliometric study to assess the research performance of scholars in Nigerian universities was carried out (Salisu & Salami, 2020). Scholarly data from the Scopus database covering a period of 117 years (1901 – 2016) were analyzed for publication output, trends, patterns, leading universities, and research and international collaboration to investigate research performance in the universities. Energy research publication data (1974 to 2019) for Nigerian universities obtained from the Scopus® database

were used to carry out a bibliometric analysis (Adedayo et al., 2021). Publication output, contribution by institution, region, energy subject, research area, journal, and energy sources, international collaboration by author and country, energy research keyword, and publication evolution were examined.

However, engineering research-based bibliometric analyses are observed to be scarcely reported in the literature, especially in the context of Africa and Nigeria. The engineering research performance of member countries of the African Union was studied by analyzing the engineering-based scholarly publications produced by these countries using a bibliometric approach (Patra & Muchie, 2017). The publication data which spanned 45 years (1970 – 2014) were sourced from the Scopus® database and analyzed using UCINET as a social networking analysis tool. African countries were evaluated for the publication number, trend, profile (activity and relative specialization index), research collaboration, and citations as performance metrics. In a relatively different study, the performance of academics based in the science and engineering fields in six federal universities in the southwestern part of Nigeria was examined (Okafor & Dike, 2010). He deployed a descriptive survey approach using stratified random sampling and considered only 291 academics (Professor to Lecturer II) in this work. Data of scientific publications and graduated postgraduate students sourced by questionnaire were used in this study.

Since Nigeria has been documented to be a leading country in scholarly contribution to Africa and West Africa in various fields of study, this work aimed to provide an insightful, thorough, and updated evaluation of the research productivity and performance in engineering-based research in Nigeria based on scholarly works published from 2010 to 2022. To achieve this, the number, distribution, and trend of scholarly publications in engineering-based research were studied along with the impact on author, institution, and country research collaborations using a social networking tool. In addition, through the author keywords linked with the publications garnered in the period under consideration, the most used author keywords were evaluated and used to identify the hotspot and emerging research and assess the evolution of engineering-based research in Nigeria using the social network analysis. As engineering is a pivotal component of STEM for

national, regional, and global development, this present study is expected to serve as a working tool for policymakers, non-governmental agencies, regulatory agencies, governments, researchers, universities, and other stakeholders to stimulate, educate, inform, and propel a new dawn in the development of engineering research in Nigeria, which will positively impact national and global development.

2. Research Design

A. Data extraction and filtering

Data from published works on engineering research in Nigeria employed in this study were extracted from Elsevier's Scopus® database since it is the largest database in the world (De La Cruz-Lovera et al., 2019). In the extraction of the data, a search query of "Affiliation" (under search within) and "Nigeria AND Engineering" (under search document) was initiated under the "Documents" pane in the Scopus® website. The raw extracted data were filtered for the years under consideration (2010 – 2022), document types (article, review, and conference proceedings), source type (journal and conference papers), and language (English), which were of interest and scope of this work. The flowchart of the procedure is presented in Fig. 1. Data
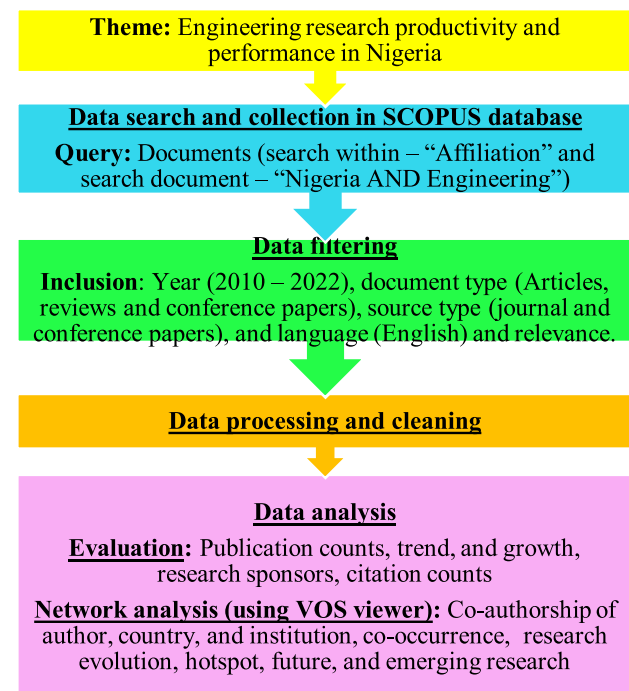

Theme: Engineering research productivity and performance in Nigeria

Data search and collection in SCOPUS database
Query: Documents (search within – "Affiliation" and search document – "Nigeria AND Engineering")

Data filtering
Inclusion: Year (2010 – 2022), document type (Articles, reviews and conference papers), source type (journal and conference papers), and language (English) and relevance.

Data processing and cleaning

Data analysis
Evaluation: Publication counts, trend, and growth, research sponsors, citation counts
Network analysis (using VOS viewer): Co-authorship of author, country, and institution, co-occurrence, research evolution, hotspot, future, and emerging research

Fig. 1 : Flowchart of the study procedure

extraction took place on January 23, 2023. It is worth mentioning that the coverage of African scientific literature is limited in Elsevier's Scopus® database, which is a limitation concerning this study.

B. Extracted data analysis

Importation of the filtered extracted data into a social networking software (VOS viewer®) was carried out. The software is a network-creating and analyzing tool that can be used for the evaluation of scholarly publications (He et al., 2019). Maps of the network of collaboration by institutions, countries, and authors, co-occurrence of author keywords, citation counts of scholarly documents, and publication sources were created using the VOS viewer® (Omoregbe et al., 2020; Su et al., 2020). The bubbles in the created maps are connected by lines called "links". An item on a map is represented by a label and bubble. The larger the bubble and the label, the more pronounced the item whereas the thicker the link the more the strength between the items which has a direct relationship with the associated value. In addition, the closer the items the more the relatedness of the items (David et al., 2020). The journal performance indicators (impact factor and Quartile) were employed to appraise the quality and impact of scholarly publications associated with engineering research in Nigeria.
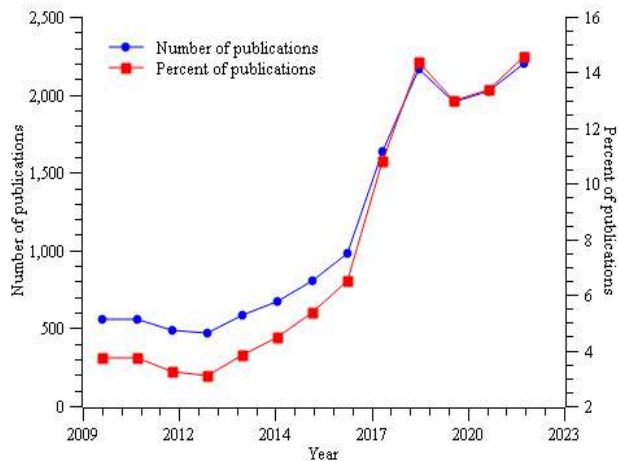

Fig. 2 : Trend of scholarly publications and percent from 2010 to 2022

3. Result And Discussion

A. Publication output and trend

Fig. 2 presents the number, percent, and growth of scholarly works published concerning engineering-based research in Nigerian universities for a period of 13 years (2010 to 2022). A total of 15083 scholarly papers were published in the field of Engineering in Nigeria. This is composed of 11554 journals, 2866 conference papers, and 663 review papers, accounting for 76.6%, 19.0%, and 4.4% of the total, respectively. An average of 1160 publications per year is recorded for the duration considered. As can be seen in Fig. 2, two marked trends are observed. Firstly, <600 articles were published from 2010 to 2014 followed by >600 articles from 2015 to 2022. The latter showed a progressive increase in engineering research publications from <1000 articles (from 2015 to 2017) to >1000 articles (from 2018 to 2022). Generally, a slight increase in the publication is observed from 2013 to 2017 after which a surge in 2018 and beyond is marked with a moderate rise. This demonstrates that in the early years, engineering research publications in top-notch journals and indexed by Scopus did not garner much attention from Nigerian researchers, as evidenced by the relatively consistent annual research publication output from 2010 to 2017. It is worth reporting as observed in Fig. 2 that a drop (10.69%) in the number of publications occurred from 2019 to 2020 as a result of the COVID-19 pandemic, which picked up gradually in 2021 and further increased in 2022. The COVID-19 pandemic can be said to have disrupted the increasing trend of engineering-based scholarly publications in Nigeria as research activities were disturbed. Publications in 2022 after the pandemic were observed to be slightly higher than those published in 2019 as scholars settle back into their laboratories and research activities which is an indicator that the pandemic affected the smooth rise in publication trend.

The highest number of publications was recorded in the year 2022 which corresponds to 14.58% of the entire publications (see Fig. 2). In 2021, 2021 papers (13.40%) were published while in 2020, 1955 (12.96%) articles were published. Maximum publication growth of 67.25% (from 2017 to 2018) is observed which accounts for the publication surge of 1638 articles in 2018 from 977 articles in 2017. From Fig. 2, the last three years reveal a progressive rise in scholarly papers with the possibility of an increase in the future. The publication contribution recorded in this work shows that till this point in time, most Nigerian researchers and Universities are not fully aware of the need and benefit associated with publishing their works in journals indexed by Scopus®. In this regard, either many don't know the names of these journals and tend not to bother, or some remain skeptical about such journals, or some

perceive such attempts as a tall order that is unattainable. The above is outside the fact that the research facilities (laboratory and instruments), research funding, and grants are relatively not available or inadequate. It is worth stating that where grants and research funds/seeds are available willingness to assess them, write good and successful proposals, and result delivery are issues to contend with.

B. Analysis of country collaboration

According to the analysis of country collaboration, a total of 133 countries contributed to engineering-based scholarly publications. With at least four papers and four citations, 94 countries are found to collaborate in the publication of engineering-based research. In terms of their scholarly publications, Table 1 shows the top 20 countries involved in the publication of engineering-based research. Nigerian authors published 13083 articles which attracted 108720 citations leading to an average of 8.31 citations. Table 1 shows that Malaysia, South Africa, the United Kingdom, the United States, China, and India were the leading six countries that collaborated with Nigerian authors. Malaysia and South Africa are ranked first and second as their collaboration with scholars in Nigeria yielded 1758 and 1655 publications, respectively. This highlighted their cross-national and international collaboration in this field. It further shows the strong research relationship between Nigeria researchers/Universities and the researchers/Universities in Malaysia and South Africa, which are both developing countries. In addition, the frequency and level of collaboration with these top leading countries can be connected to a large extent to the destination at which most scholars undertake their postgraduate degrees (most especially doctoral degrees) and postdoctoral research. These are through local and foreign scholarships or fellowships such as the Commonwealth Scholarships and Petroleum Trust Fund.

Continental distribution of the top 29 countries shows that Asia is the most dominant with 14 countries (48.3%), followed by Europe (6 countries; 20.7%), Africa (5 countries; 17.2%), North America (2 countries; 6.9%), South America (1 country; 3.4%) and Oceania (1 country; 3.4%). The United Kingdom remains the leading country in Europe with the most collaboration with Nigerian researchers. Collaboration with these different countries showed that Hong Kong, Iran, and Vietnam have the highest

average citations of 26.74, 22.66, and 21.81 respectively, making them the top three countries with impactful scholarly publications in engineering-based research. The average citation (8.09) of Nigerian scholars indicating the impact of their publications is observed to be lower than those of 24 out of the leading top collaborating countries. Only France, Iraq, Uganda, United Arab Emirates, and Russia have a lower value of average citation than Nigeria. A higher average citation value depicts higher citations coupled with lower scientific articles. The more citations the more impact the article has. By extension, it means that the publications from Nigerian authors are relatively less impactful while those published in collaboration with Hong Kong, Iran, and Vietnam researchers are very impactful as the scientific articles from these countries attracted more citations and were found more useful in engineering-based research globally. The quality of research and collaborators, country/institution of collaboration, visibility, and type of journal outlets in which Nigerian scholars publish their research output may have significantly contributed to the low average citation recorded.

Fig. 3 presents the map generated from the analysis of country collaboration. Due to the network connection, the participating countries were divided into 12 clusters and 94 items as represented by the color and number of bubbles, respectively. The number of scholarly papers published by each country is represented by the size and font size of the bubble. The thickness of the lines reflects the degree of the linkages between the countries, which correlates with the level of their research collaboration. Nigeria has the highest bubble size and label because it is studied in other countries. The country's network overall link strength is a valuable metric for indicating research collaborations. Table 1 shows that Nigerian scholars have research collaboration with other scholars in different institutions based in various countries of the world with a total connection strength of 9571. This metric/value reflects their collaboration link with these foreign scholars. In terms of the collaboration strength of Nigerian scholars with their counterparts globally as indicated by the total link strength, Malaysia came in first, followed by South Africa concerning engineering-based research. As observed in Fig. 3, the proximity of Malaysia, Germany, Hong Kong, Poland, Chile, Botswana, and Rwanda to Nigeria depicts substantial relatedness which, signifies strong research cooperation among authors from these countries and those from Nigeria. From the

Table 1 :
Leading Collaborating Countries in
Engineering-based Research

Country	Total Link Strength	Documents	Citations	Normalized Citations	Average Citations
Nigeria	9571	13083	108720	13682.00	8.31
Malaysia	2532	1758	21277	2686.53	12.10
South Africa	2222	1655	14954	1896.08	9.04
United Kingdom	1519	924	10454	1337.30	11.31
United States	1075	584	5464	674.65	9.36
China	928	524	6995	1069.30	13.35
India	898	443	6261	893.74	14.13
Saudi Arabia	767	306	3985	608.35	13.02
Turkey	572	264	4521	656.10	17.13
Canada	374	168	1986	272.61	11.82
Germany	363	166	1997	269.74	12.03
Pakistan	412	161	2075	354.51	12.89
Australia	355	143	2209	286.73	15.45
France	261	101	635	87.64	6.29
Ghana	221	99	1055	140.43	10.66
Egypt	280	98	1095	187.28	11.17
Japan	193	94	1505	172.55	16.01
Iran	236	86	1949	269.69	22.66
South Korea	212	86	955	148.11	11.10
Italy	206	77	879	106.19	11.42
Brazil	156	75	1473	158.21	19.64

obtained results, the need for more research collaboration between Nigerian researchers and their counterparts in top-ranked countries (developed and developing) with global pedigree and recognition in engineering-based research is of great essence for the development of engineering in Nigeria and for the country to compete at the highest level globally.
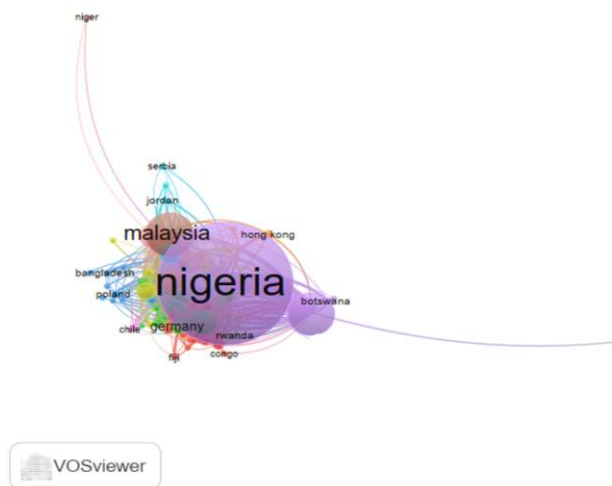

Fig. 3 : Network map of country collaboration

C. Analysis of institution collaboration

Table 2 provides the findings of the analysis of institution collaboration in the publication of Engineering-based articles in Nigeria. The table consists of the total link strength, documents, citations, and average citations for the top 20 institutions that have contributed to engineering-based publications. These leading institutions are composed of 2 international universities, 11 federal institutions (10 universities and 1 research institute), 2 state universities, and 5 private universities. From Table 2, Covenant University (Nigeria) is found to be the most productive university as it had the highest number of publications which equally attracted the most citations. This agrees with a previous work that reported the bibliometric analysis of energy research in Nigeria (Adedayo et al., 2021). Second is the University of Nigeria (Nsukka, Nigeria) with the highest number of publications after Covenant University and interestingly had the second highest citations. In terms of the number of scholarly articles and citations concerning engineering-based research, Covenant University appears to be the foremost institution in Nigeria. The mechanical engineering department followed by the Civil engineering department is observed to produce most of the scholarly publications credited to Covenant University. In addition, for most of the top productive institutions, the field of mechanical engineering is noticed to contribute most of the scholarly publications linked to them. However, the top five productive institutions that collaborated with Nigerian scholars are a mixture of private (1) and federal universities (2) in Nigeria and international universities (2). In the foreign domain, the Tshwane University of Technology (South Africa) and the University of Johannesburg (South Africa) are the top engineering-based research collaborating institutions. These findings demonstrate and establish the African research network concerning collaboration in engineering-based research which will further boost research and human capital development partnerships in Africa, especially between the leading countries of Africa.

Based on scholarly impact concerning engineering-based research, as evaluated using average citations, the top three institutions were the Federal University of Technology (Minna, Nigeria), the University of Nigeria (Nsukka, Nigeria), and the Nnamdi Azikiwe University (Awka, Nigeria) (see Table 2). It shows that the scholarly publications from

these institutions are of good quality leading to increased citation counts as these articles are cited in other articles and thus have higher average citations. For the top 30 productive institutions, it is observed that mechanical engineering as an engineering field had the highest average citation followed by civil engineering. This implies that the scholarly works from these top institutions are more impactful for civil engineering.

Fig. 4 shows the network map created due to the analysis of institution collaboration. The network has 39 clusters as shown by the bubble colors. The crowding of the bubbles indicates a well-connected network of institutions. This demonstrates that the bulk of these institutions were linked in terms of research partnerships. Apart from that, the institutions in Fig. 4 demonstrated substantial relatedness in terms of the bubbles with the distance between Covenant University – civil and mechanical engineering – and the other institutions being shorter. This demonstrates good research collaboration better among these institutions/departments. The civil and mechanical engineering department of Covenant University represented by ash bubbles are observed to be the leading department and university respectively in the publication of engineering-based scholarly articles. Covenant University, Tshwane University of Technology (South Africa), and the University of Nigeria were the top three institutions with the most research collaboration as indicated by values of their total link strengths (see Table 2).

D. Citation counts of publication sources

For this present study, a total of 13083 scholarly engineering-based research publications were published from different publication sources indexed by the Scopus database. The names of journals, number of citations and publications, and the total link strengths are listed in Table 3 for the top 20 performing journals as results of the analysis of publication source citation. The leading five journals based on citation counts were the Journal of Cleaner Production, Energy, IEEE Access, Alexandria Engineering Journal, and Construction and Building Material. It shows that the Journal of Cleaner Production is the most active journal outlet that cites engineering-based research in Nigeria. However, the Journal of IOP Conference Series: Material Science and Engineering is the leading publication source for Nigerian scholars in the context of this present study as it published the

highest number of articles, Agricultural Engineering International: CIGR Journal is the second most productive journal followed by the ARPN Journal of Engineering and Applied Science. It is surprising to observe that the Journal of IOP Conference Series: Material Science and Engineering publishes conference proceedings, and it is also observed to house the highest number of publications (engineering-based research) in Nigeria. In addition, the conferences wherein the proceedings were published in the Journal of IOP Conference Series: Material Science and Engineering were held by universities in Nigeria. Thus, the Journal of IOP

Table 2 :
List of Top Twenty Institutions

| Institutions	Total link strength	Documents	Citations	Average citations
Covenant University, Ota, Nigeria	482	632	4668	38.91
University of Nigeria, Nsukka, Nigeria	149	248	2092	41.83
Tshwane University of Technology, Pretoria, South Africa	158	128	887	27.44
Federal University of Technology, Akure, Nigeria	28	122	1506	34.75
University of Johannesburg, South Africa	141	120	546	32.35
Ahmadu Bello University, Zaria, Nigeria	52	103	903	37.07
University of Ibadan, Ibadan, Nigeria	37	103	821	14.33
University of Ilorin, Ilorin, Nigeria	67	93	666	28.41
University of Lagos, Lagos, Nigeria	67	90	631	16.96
Obafemi Awolowo University, Ile-Ife, Nigeria	54	67	306	11.39
Nnamdi Azikiwe University, Awka, Nigeria	27	50	483	39.66
Afe Babalola University, Ado Ekiti, Nigeria	40	47	194	16.36
Landmark University, Omu-Aran, Nigeria	30	44	389	30.02
Michael Okpara University of Agriculture, Umudike, Nigeria	29	25	145	38.75
Federal University of Technology, Minna, Nigeria	7	24	531	61.09
Pan African University, Ibadan, Nigeria	11	20	44	11.07
Cross River University of Technology, Calabar, Nigeria	9	19	169	20.91
African University of Science and Technology, Abuja, Nigeria	18	19	135	18.52
Kwara State University, Malete, Nigeria	24	19	158	15.28
National Agency for Science and Engineering Infrastructure, Nigeria	28	19	71	3.74
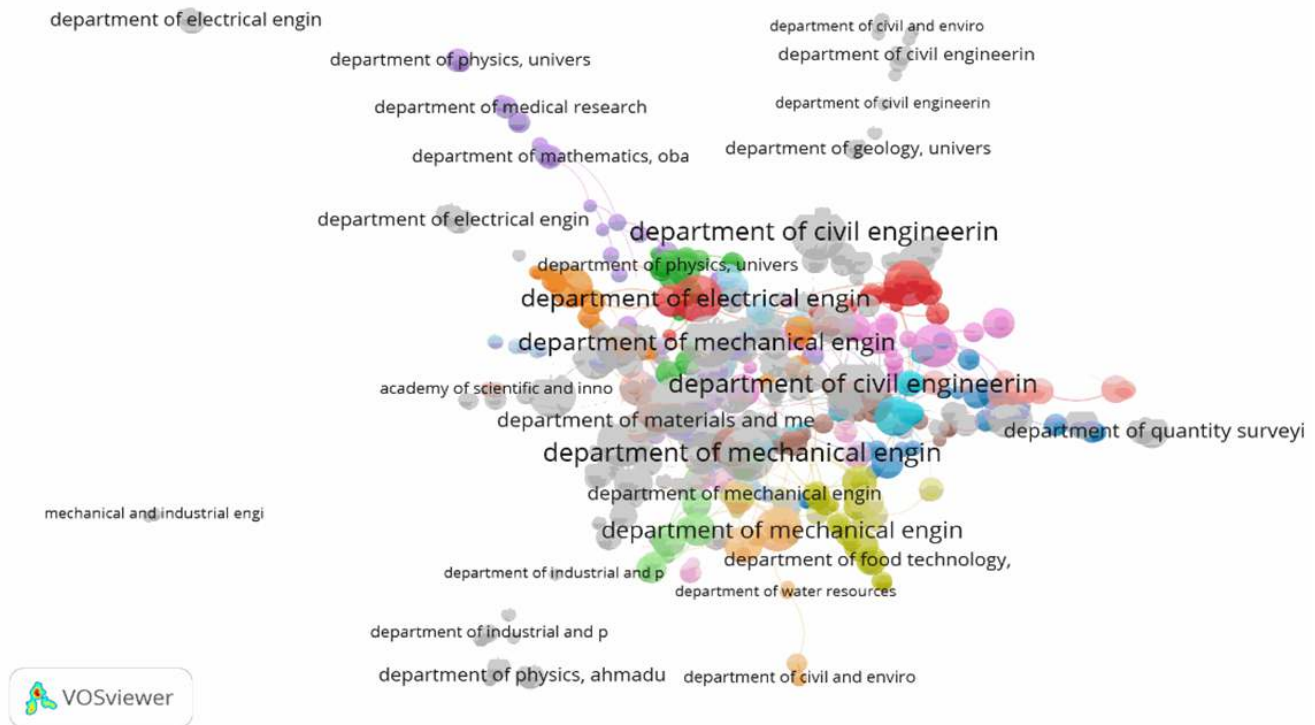
Fig. 4 : Network map of institution collaboration

Conference Series: Material Science and Engineering appears to be the main outlet where Nigerian researchers disseminate their research findings of which this trend needs to be addressed urgently.

The top three impacting publication sources based on the average citation for the dissemination of Nigerian scholars' research outputs were the Journal of Materials Processing Technology, Applied Energy, and Chemical Engineering Journal were the research disseminating outlets with the highest average citations. However, the least impactful publication sources (in the top 20 journal sources in Table 3) were the Agricultural Engineering International: CIGR Journal, Journal of IOP Conference Series: Material Science and Engineering, and ARPN Journal of Engineering and Applied Science.

Therefore, it can be deduced that the Journal of Materials Processing Technology is the most impactful journal outlet for engineering-based research in Nigeria while the Journal of IOP Conference Series: Material Science and Engineering with the most published articles about discussion is the second most less impactful after the Agricultural Engineering International: CIGR Journal. From Table 3, it can be observed that journal outlets with no impact factor produced most articles followed by

journals with relatively low impact factor and then journals with a high impact factor, except for the Journal of Cleaner Production and IEEE Access. Logical reasoning reveals that scholars in Nigeria publish their research findings in low-quality and less impactful journals and these findings are observed to be cited in high-quality and impactful journals. It shows that the research quality is not relatively in question but the outlets for findings dissemination. The reverse of the observed publication trend is good for the field of engineering, authors, and universities in Nigeria to keep abreast with international practices.

The performance of the various engineering-based research publication outlets is illustrated in Fig. 5 using the network map of the citation of publication source analysis. Based on the citation of source network linkages, the journals were divided into 31 clusters. Due to the sizes of the bubbles and labels, the first three top-cited journals were the Journal of Cleaner Production (ash bubble), Energy (sky-blue bubble), and IEEE Access (purple bubble). The citation network of the IOP Conference Series: Material Science and Engineering has the highest total link strength. This indicates that this journal has a strong relationship with others as evidenced by its high total link strength value.

Table 3 : Citations of The Top Leading Journals In Engineering-based Research

Publication source	Total link strength	Documents	Citations	Average citations	Q	IF
Journal of Cleaner Production	85	133	5919	44.50	1	11.092
Energy	72	75	3798	50.64	1	8.856
IEEE Access	46	134	2698	20.13	1	3.476
Alexandria Engineering Journal	125	93	2233	24.01	1	6.626
Construction and Building Materials	100	80	2201	27.51	1	7.693
Chemical Engineering Journal	26	28	2179	77.82	1	16.744
Applied Energy	42	24	2002	83.42	1	11.446
SN Applied Sciences	96	224	1713	7.65	2	-
Journal of King Saud University - Engineering Sciences	107	79	1577	19.96	-	-
International Journal of Advanced Manufacturing Technology	136	129	1525	11.82	1	3.77
Cogent Engineering	189	198	1452	7.33	2	-
IOP Conference Series: Materials Science and Engineering	265	428	1359	3.18	-	-
Journal of Alloys and Compounds	83	66	1193	18.08	1	6.371
Optik	67	65	1183	18.20	2	2.84
International Journal of Civil Engineering and Technology	214	196	988	5.04	-	-
Desalination and Water Treatment	56	88	974	11.07	3	1.273
Engineering Science and Technology, An International Journal	66	33	972	29.45	1	5.155
Advances in Space Research	41	111	954	8.59	2	2.611
Sustainable Cities and Society	40	25	938	37.52	1	10.696
Research Journal of Applied Sciences, Engineering and Technology	40	189	923	4.88	-	-
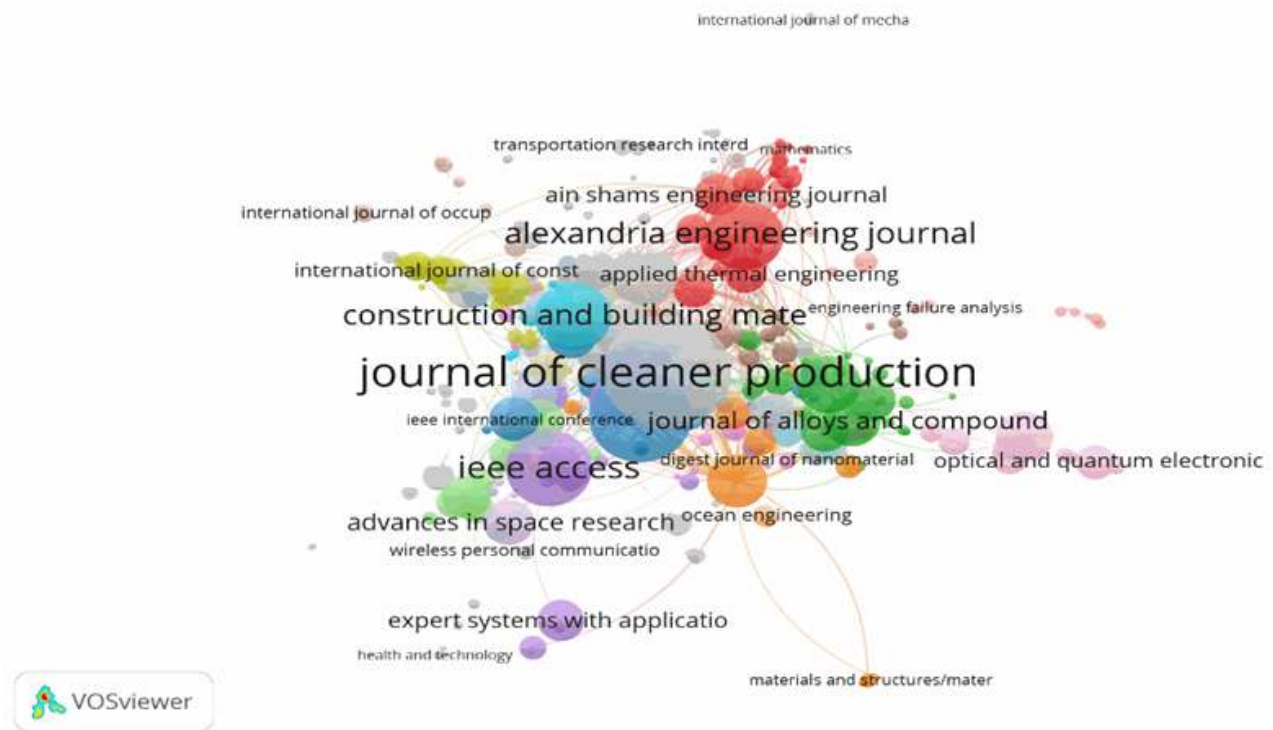
Fig. 5 : Network map of publication source citation

E. Citation counts of publications

The result of the analysis of citation counts of published articles for engineering-based research is presented in Table 4. The analysis showed that only 3177 scholarly articles of the 13083 articles had a minimum of 10 citations. Of the 20 most cited articles given in Table 4, the five top cited articles were the works of Alaneme K.K. (2015) followed by those of Alaneme K.K. (2012b), Chidiebere M.A. (2012), Hassan S.B. (2015), and Alaneme K.K. (2013). It can be observed that the work of Alaneme K.K. (2015) titled "Microstructural characteristics, mechanical and wear behavior of aluminum matrix hybrid composites reinforced with alumina, rice husk ash, and graphite" published in "Engineering Science and Technology, an International Journal" was the leading paper as it attracted the highest citation count. Also, the author is affiliated with the Department of Metallurgical and Materials Engineering, Federal University of Technology (Akure, Nigeria). Nineteen of the top 20 cited papers were original research papers while the rest was a review paper. They mainly reported the characterization of different materials (laterite, ceramic waste, stainless steel, hybrid composites, composite, green materials and wastes, alumina, etc.). The majority of these works stemmed from the Metallurgy and Materials engineering and civil engineering disciplines. The normalized citations of the most cited papers depict an evaluation of the impact of publication year, journal type, and field of study on the citation counts of the scholarly articles (see Table 4). Subject to the normalized citation, the five top-cited papers were Alaneme K.K. (2015), Alaneme K.K. (2012b), Chidiebere M.A. (2012), Sarki J. (2011) and Hassan S.B. (2015). The citation counts and publication year are observed to impact the numerical value of the normalized citations of papers.

Fig. 6 illustrates the network of the analysis of citations of published articles. The network was classified into 19 clusters as shown by the bubble colors. The red bubble named Alaneme K.K. (2015) was observed to be the largest bubble, and this indicates that the work of Alaneme K.K. (2015) was the most cited paper. Other leading papers were those of Idris U.D. (2015) – green bubble, Etim R.K. (2017) – purple bubble, and Awoyera P.O. (2018b) – yellow bubble. Strong relatedness was observed between Alaneme K.K. (2015) and Idris U.D. (2015) while no relatedness was noticed between Alaneme K.K. (2015) and Awoyera P.O. (2019b).

F. Co-occurrence of author keywords

Keyword analysis in bibliometric studies is a unique technique for assessing research trends. The analysis of co-occurrence of author keywords in engineering-based research revealed that 37167 keywords were used by the authors in this present study of which 1236 keywords occurred more than six times. Table 5 gives the overall link strength, occurrences, and average citation of the leading 20 keywords. Compressive strength, microstructure, optimization, mechanical properties, corrosion, modeling, and sustainability were the leading seven author keywords. "Compressive strength" as a keyword related to mechanical properties of materials is the most used keyword by authors of engineering-based research in Nigeria. With the leading 20 author keywords, the hot topics for the engineering-based research can be inferred which revolves around the characterization of different materials (concrete, lateritic soil, nanoparticles, adsorbents, green/eco

Table 4 :
Top Cited Papers In Engineering-based Research

Publication	Citations	Normalized citations	Publication year
Alaneme K.K. (2015)	170	16.83	2015
Alaneme K.K. (2012b)	163	16.67	2012
Chidiebere M.A. (2012)	139	14.22	2012
Hassan S.B. (2015)	130	12.87	2015
Alaneme K.K. (2013)	125	11.02	2013
Sarki J. (2011)	123	13.36	2011
Idris U.D. (2015)	120	11.88	2015
Nasri N.S. (2014)	112	9.15	2014
Ekanem U.F. (2010)	105	8.07	2010
Alaneme K.K. (2018c)	96	10.26	2018
Awoyera P.O. (2018b)	88	9.41	2018
Etim R.K. (2017)	84	6.24	2017
Awoyera P.O. (2016b)	84	5.83	2016
Ikpambese K.K. (2016)	83	5.76	2016
Ameh O.J. (2010b)	81	6.23	2010
Sen I. (2011)	81	8.80	2011
Hassan S.B. (2012a)	75	7.67	2012
Chidiebere M.A. (2014)	73	5.96	2014
Alaneme K.K. (2016a)	73	5.07	2016
Awoyera P.O. (2019b)	72	10.66	2019

materials, wastes, etc.), optimization, modeling and simulation, corrosion, energy (especially renewable energy (biodiesel)), construction, sustainability, adsorption, energy efficiency and system performance, and COVID-19. The emergence of the COVID-19 pandemic and the conduct and subsequent publication of studies on it as it relates to engineering-based research have been noticed to be state-of-the-art and hot topics due to the sudden and high frequency of its use as an author keyword.

The network map of author keyword co-occurrence analysis is provided in Fig. 7 and it is classified into 11 clusters as represented by the bubble colors. From Fig. 7, the three largest bubbles depicting the highest occurrence for the author keywords are compression strength (purple), microstructure (yellow), and optimization (orange). The purple bubble with the label compression strength is the biggest signifying that it is the most used keyword by the authors concerning engineering-based research publications. Also, the compression strength, corrosion, and microstructure as keywords had the top three high values of total link strength (with compression strength having the highest value), and these numerical values indicate their wide use as author keywords in connection to engineering-based research in Nigeria.

G. Leading research sponsors

The crucial and unique role of research funders is critical to the advancement of scientific and engineering-based research. It is heavily influenced by several connected policies on specific agendas at all levels such as regional, provincial, state, national, and international levels. The top 20 sponsors of

engineering-based research for the period under consideration (2010 to 2022) and the scholarly publications associated with it in this present work are presented in Table 6. An increase in publishing patterns from 2010 to 2022 earlier reported in this work could be linked to increased funding and funding availability. Covenant University, Tertiary Education Trust Fund, Ministry of Higher Education, Malaysia, Universiti Teknologi Malaysia, and National Natural Science Foundation of China were the top five research financing institutions in the context of this study. With a total of 595 scholarly publications (including the Covenant University Centre for Research, Innovation, and Discovery) being research funded by Covenant University, it is therefore adjudged as the leading research funding institution for Engineering-based research in Nigeria. For the top 30 research funding institutions, scholarly publications from Covenant University accounted for 20.08% of the total publications. This figure reflects a good laudable development in terms of university-based research funding which private, state, and federal universities in the country should emulate.

From Table 6, the top two funding institutions are based in Nigeria while three of the top five research sponsors are international institutions. In addition, only seven of the leading 30 research funding institutions are local institutions. It is observed that seven of the top 17 funding institutions are from Malaysia where they contributed 26.7% of the total scholarly publications for the top 30 funding institutions. Based on this, Malaysia can be ranked the leading funding country concerning engineering-based research. This result supported the earlier report in this work that Malaysia is the leading collaborating country in engineering-based research. It is strongly
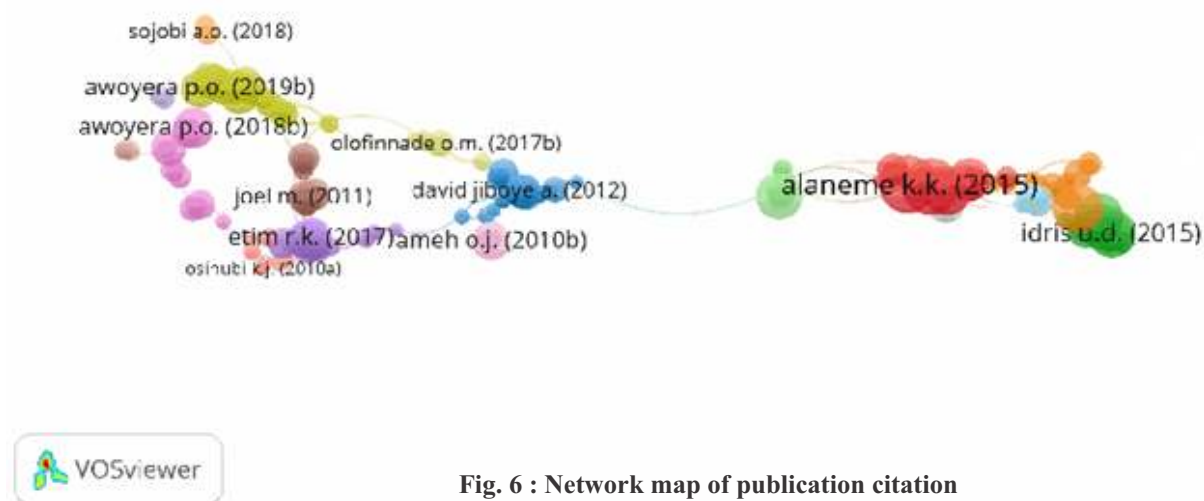

Fig. 6 : Network map of publication citation

recommended that funding for engineering-based research in Nigeria be considerably increased especially with the presence of local institutions/funders like the Tertiary Education Trust Fund, National Research Foundation, and Petroleum Technology Development Fund as the most research funders as reflected in the scholarly publications are majorly from international institutions. Therefore, there is a need to strongly drive engineering-based research funding locally (starting from individual universities and sourcing for grants by the universities and researchers) and to further encourage and intensify international research collaboration. This is because engineering education and research are extremely valuable to ensuring a better society and national development, as well as being firmly linked to and progressively in favor of the sustainable development goals and the fourth industrial revolution agendas.

H. Research evolution and future study

Evolution of engineering-based research from 2010 – 2022 as analyzed by the co-occurrence of author keyword based on the information provided via the extracted data for this study and displayed using the overlay visualization is presented in Fig. 8. The trend of scholarly publications via the author keywords is illustrated by the color legend which serves as an indicator for the publication year. Bubbles as items (keywords in this case) have different colors that depict publication years and by extension the research trend. The bubbles in Fig. 8 can be classified into four distinct colors (clusters), that is navy blue bubbles (cluster 1), teal green bubbles (cluster 2), lemon bubbles (cluster 3), and yellow bubbles (cluster 4). Navy blue, teal green, lemon, and yellow bubbles represent engineering-based research evolution for 2010 – 2016, 2017 – 2018, 2019, and 2020 – 2022 (see Fig. 8).

Items embedded in the navy-blue cluster (for research trend from 2010 – 2016) include moisture content, physical properties, characterization, density, chemical composition, leaching, stabilization, compaction, groundwater, water quality, solar dyer, cement kiln dust, natural gas, Niger Delta, fermentation, bentonite, aquifer, thin film, toxicity, particulate, porous medium, electric field, and injection. This implies that the research conducted during this period involved the characterization of different materials of which water, thin film, cement kiln dust, and bentonite are prominent. Also, the

Table 5 :
Top 20 Author Keywords in Engineering-based Research

Keywords	Total link strength	Occurrences	Average citations
Compressive Strength	519	235	9.00
Microstructure	396	215	13.24
Optimization	379	213	7.63
Mechanical Properties	388	206	13.00
Corrosion	462	205	8.13
Modelling	285	157	10.38
Sustainability	266	145	9.99
Adsorption	282	144	19.63
Concrete	318	132	12.50
Temperature	232	127	4.61
Machine Learning	194	125	5.82
Simulation	184	117	4.14
Renewable Energy	161	109	10.73
Artificial Neural Network	170	101	10.19
Construction Industry	158	101	7.25
Performance	146	97	8.11
Energy	176	92	7.21
Response Surface Methodology	168	87	13.78
Biodiesel	171	86	17.07
Efficiency	112	84	7.88

characterization includes mainly chemical and physical properties in which the latter is notable such as moisture content and density. Owing to keywords such as leaching, water quality, toxicity, particulate, aquifer, and groundwater, studies on water, air, and soil pollution with more emphasis on water pollution (groundwater) are well carried out during this period. Natural gas, bentonite, and Niger Delta are indicators of studies related to environmental pollution of the Niger Delta region of Nigeria via gas flaring and the use of bentonite as a drilling mud for crude oil prospecting. In addition, studies concerning the engineering of solar dryers, fermentation, porous mediums, fuel injection, and electric fields were conducted by Nigerian researchers and their collaborators from 2010 to 2016.

The teal green cluster contains items such as adsorption, corrosion, temperature, microstructure,
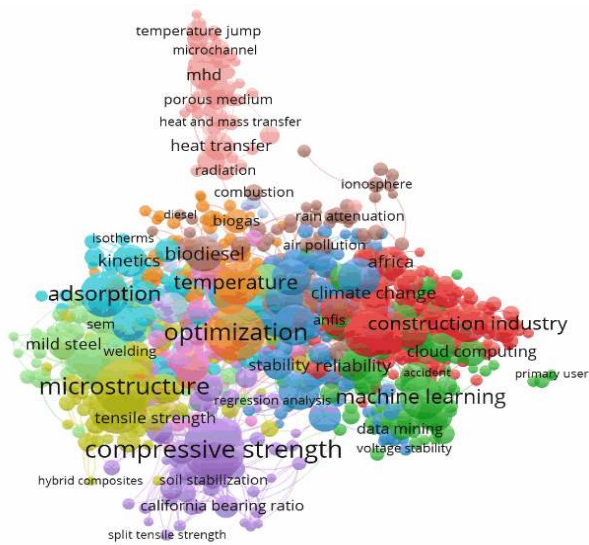
**Fig. 7 : Network map of co-occurrence
of author keywords**

kinetics, compressive strength, mechanical properties, simulation, solar energy, biodiesel, energy, biogas, transesterification, efficiency, performance, combustion, emission, concrete, mild steel, cement, lateritic soil, composites, climate change, sustainable development, heat and mass transfer, nanoparticles, characterization, activated carbon, rice husk ash, finite element analysis, and electricity, which represents research trend from 2017 – 2018. This period showcased an increase in studies concerning the characterization of various materials with concrete, mild steel, cement, lateritic soil, composites, nanoparticles, activated carbon, and rice husk ash being the most studied materials. Microstructure and mechanical properties (especially compressive strength) are the leading characterization tests carried out on materials. Temperature as a physical variable is observed to be dominant in most of these studies. Energy studies especially renewable energy (solar, biogas, and biodiesel) and electricity in addition to variables such as efficiency, performance, combustion, and emission came to prominence in this period. Corrosion, adsorption (with emphasis on kinetics), heat and mass transfer, climate change, sustainable development, and simulation (finite element analysis) studies are also research highlights of this period.

The research carried out in 2019 as captured within the lemon bubbles contained items such as optimization, biomass, sustainability, construction industry, artificial neural network, genetic algorithm, principal component analysis, particle swarm optimization, pattern recognition, heat transfer,

**Table 6 :
Top 20 Funding Institutions on
Engineering-based Publications**

Funding sponsors	Publications
Covenant University	465
Tertiary Education Trust Fund	282
Ministry of Higher Education, Malaysia	253
Universiti Teknologi Malaysia	210
National Natural Science Foundation of China	179
National Research Foundation	158
Petroleum Technology Development Fund	155
Covenant University Centre for Research, Innovation, and Discovery	130
University of Johannesburg	85
Tshwane University of Technology	81
Engineering and Physical Sciences Research Council	80
Universiti Sains Malaysia	79
Universiti Putra Malaysia	76
Universiti Teknologi Petronas	64
National Research Foundation of Korea	61
Universiti Malaya	56
Universiti Tun Hussein Onn Malaysia	53
University Of Nigeria Nsukka	51
World Bank Group	49
Deanship of Scientific Research, King Faisal University	42

natural convection, magnetohydrodynamics, entropy generation, microchannel, renewable energy, hydrogen, photovoltaic, thermal comfort, air pollution, power generation, corrosion inhibition, surface roughness, durability, silver nanoparticles, SEM, green synthesis, nanotechnology, pyrolysis, catalysts, nanofluids, construction projects, numerical simulation, automation, internet of things, and cloud computing. Research trends related to this period involved the deployment of various optimization (mainly genetic algorithm, principal component analysis, and particle swarm optimization) and machine learning (primarily artificial neural network and pattern recognition) techniques to engineering studies and the emergence of the internet of things, hydrogen, cloud computing, automation, nanotechnology (with nanofluids as advanced thermal fluids), catalyst development (using waste and green materials) and green synthesis of materials (especially eco-friendly and nanomaterials). Studies

on biomass (as energy source and pyrolysis as a key technique), sustainability, construction industry and projects, heat transfer and entropy generation (majorly natural convection and magnetohydrodynamics, and mainly with microchannel as thermal cooling device), air pollution, thermal comfort, power generation, corrosion inhibition (using bio-materials), and renewable energy (via photovoltaic as a major contributor), and catalysis is markedly investigated during this period.

The trend of research carried out in 2020 – 2022 was captured by the cluster containing yellow items such as machine learning, COVID-19, artificial intelligence, internet of things, deep learning, convolutional neural network, support vector machine, random forest, decision tree, adaptive neuro-fuzzy inference, response surface methodology, grey relational analysis, smart grid, stability analysis, sensitivity analysis, self-compacting concrete, electric vehicle, sustainable construction, green building, building projects, built environment, value management, energy harvesting, carbon footprint, CO2, densification, metakaolin, bio-oil, biochar, nanofluids, nanomaterials, nanotube, heterogeneous catalysts, sustainable materials, polystyrene, polymer composite, nanoindentation, friction welding, spark plasma sintering, additive manufacturing, water treatment, blockchain, cyber security, edge computing, robotics, waste recycling, and computer vision. This period is marked by the development of novel materials (biochar, metakaolin, bio-oil, nanofluids, nanomaterials, nanotube, heterogeneous catalysts, sustainable materials, polystyrene, and polymer composite) for different applications such as thermal management, energy, waste management, and water treatment. In addition, studies on machine learning algorithms (convolutional neural network, support vector machine, random forest, decision tree, adaptive neuro-fuzzy inference), COVID-19, artificial intelligence, internet of things, deep learning, optimization technique (novel grey relational analysis), smart grid, self-compacting concrete, sustainable construction, computer vision, additive manufacturing, nanoindentation, and green building are hot research while the electric vehicle, blockchain, edge computing, and robotics are emerging research during this timeframe. However, research relating to building projects, the built environment, value management, energy harvesting, carbon footprint, CO2 emission biomass densification, friction

welding, spark plasma sintering, cyber security, and waste recycling are prominent during this time. Owing to the outbreak of the COVID-19 pandemic during this research era (2020 – 2022), several studies have emerged in the engineering field in Nigeria relating to COVID-19 issues making it a topical subject. This has led to its being an emerging research area as well as a hot topic.

Future studies on engineering-based research are expected to be strongly connected to intense and further works on the hot and emerging research highlighted above. Understandably, future studies are to align with global best practices and trends which include the fourth industrial revolution, sustainable development goals, zero and low-carbon emissions and technologies, green and alternative energy, circular economy, smart cities and transportation, sustainable and green buildings and materials, blockchain technology application, artificial intelligence, machine, and deep learning techniques, etc. The future scope of this work is envisioned to entail deploying other notable databases and network mapping software to gain deep insights into specific subjects/fields of concern to the Nigerian, African, and global research community. Notable is the evolution of artificial intelligence and machine learning applications to science-, engineering-, and energy- (renewable and hydrogen) based research in Africa.

Conclusion

The bibliometric analysis of scholarly publications on engineering-based research in Nigeria has been carried out for a duration of 13 years (2010 – 2022). Publication data extracted from the Scopus® database were analyzed using VOSviewer®. A total of 15083 articles of which over 76% were journals have been published with a remarkable increase recorded from 2018. The analysis revealed that the most productive local institution was Covenant University (6323 articles) while the most performing international institution was the Tshwane University of Technology, South Africa (128 articles). Malaysia with the most publications (1758 articles) was the country with the highest research collaboration as well as the country with the most funding institutions. Results showed that the Journal of Cleaner Production, the work of Alaneme K.K. (2015) is the most cited journal, for engineering-based research in Nigeria. "Compressive strength" is the most used author keyword as mechanical engineering is the most

Fig. 8 : Overlay visualization map of co-occurrence of author keywords

productive engineering field of study. Hot research topics are related to materials (composite, nanoparticles, concrete, etc.), renewable energy, machine learning, optimization techniques, modeling, and simulation studies. Future research is focused on sustainable materials, and construction, green building, food security, COVID-19, and renewable energy which are in agreement with the fourth industrial revolution and sustainable development goals. The need to publish scholarly works in high-impact and quality journal outlets must be intensified for the inherent benefits with respect to researchers, universities, and regulating and funding agencies. Locally, poor engineering-based research funding is observed which requires urgent attention and increased funding.

References

Adedayo, H. B., Adio, S. A., & Oboirien, B. O. (2021). Energy research in Nigeria: A bibliometric analysis. Energy Strategy Reviews, 34(February), 100629. https://doi.org/10.1016/j.esr.2021.100629

Alagumalai, A., Mahian, O., Aghbashlo, M., Tabatabaei, M., Wongwises, S., & Wang, Z. L. (2021). Towards smart cities powered by nanogenerators: Bibliometric and machine learning–based analysis. In Nano Energy (Vol. 83, p. 105844). Elsevier Ltd. https://doi.org/10.1016/j.nanoen.2021.105844

Ani, O. E., & Onyancha, O. B. (2011). A measure of research productivity of Nigerian universities: A bibliometric analysis. Proceedings of ISSI 2011 - 13th Conference of the International Society for Scientometrics and Informetrics, 1, 54–65.

Boamah, P. O., & Ho, Y.-S. (2017). Bibliometric Analysis of Ghana Publications in the Science Citation Index Expanded. Revista de Biología Tropical, 66(1), 106. https://doi.org/10.15517/rbt.v66i1.29250

Confraria, H., & Godinho, M. M. (2015). The impact of African science: a bibliometric analysis. Scientometrics, 102(2), 1241–1268. https://doi.org/10.1007/s11192-014-1463-8

Cortés, J. D., Guix, M., & Carbonell, K. B. (2021). Innovation for sustainability in the Global South: bibliometric findings from management & business and STEM (science, technology, engineering and mathematics) fields in developing countries. Heliyon, 7(8).

https://doi.org/10.1016/j.heliyon.2021.e07809

David, T. M., Rizol, P. M. S. R., Machado, M. A., Guerreiro, & Buccieri, G. P. (2020). Future research tendencies for solar energy management using a bibliometric analysis, 2000–2019. Heliyon, 6(7), e04452. https://doi.org/10.1016/j.heliyon.2020.e04452

De La Cruz-Lovera, C., Perea-Moreno, A. J., De La Cruz-Fernandez, J. L., Montoya, F. G., Alcayde, A., & Manzano-Agugliaro, F. (2019). Analysis of research topics and scientific collaborations in energy saving using bibliometric techniques and community detection. Energies, 12(10). https://doi.org/10.3390/en12102030

Doulani, A. (2020). A bibliometric analysis and science mapping of scientific publications of Alzahra University during 1986–2019. Library Hi Tech, 39(4), 915–935. https://doi.org/10.1108/LHT-06-2020-0131

Eduan, W., & Yuanqun, J. (2019). Patterns of the China-Africa research collaborations from 2006 to 2016: a bibliometric analysis. Higher Education, 77(6), 979–994. https://doi.org/10.1007/s10734-018-0314-6

Giwa, S. O., Aasa, S. A., Shote, A. S., & Sharifpur, M. (2023). Nanoparticles-suspended biodiesel and its blends in compression ignition engines: a bibliometric analysis of research trend and future outlook. Biofuels, 0(0), 1–14. https://doi.org/10.1080/17597269.2023.2164958

Giwa, S. O., Adegoke, K. A., Sharifpur, M., & Meyer, J. P. (2022). Research trends in nanofluid and its applications: a bibliometric analysis. Journal of Nanoparticle Research, 24(3), 1–22. https://doi.org/10.1007/s11051-022-05453-z

He, M., Zhang, Y., Gong, L., Zhou, Y., Song, X., Zhu, W., Zhang, M., & Zhang, Z. (2019). Bibliometrical analysis of hydrogen storage. In International Journal of Hydrogen Energy (Vol. 44, Issue 52, pp. 28206–28226). https://doi.org/10.1016/j.ijhydene.2019.07.014

Kappi, M., & Biradar, D. B. S. (2019). Bibliometric Analysis of the Research Output of Kuvempu University's Publication in ISI Web of Science during 1990 - 2019. Library Philosophy and Practice, 2019, 1–13.

Lei, X. T., & Xu, Q. yuan. (2020). Evolution and thematic changes of Journal of King Saud University – Science between 2009 and 2019: A bibliometric and visualized review. Journal of King Saud University - Science, 32(3), 2074–2080. https://doi.org/10.1016/j.jksus.2020.02.006

Okafor, V. N., & Dike, V. W. (2010). Research output of academics in the science and engineering faculties of Federal universities in Southern Nigeria. African Journal of Library Archives and Information Science, 20(1), 41–51.

Omoregbe, O., Mustapha, A. N., Steinberger-Wilckens, R., El-Kharouf, A., & Onyeaka, H. (2020). Carbon capture technologies for climate change mitigation: A bibliometric analysis of the scientific discourse during 1998–2018. Energy Reports, 6, 1200–1212. https://doi.org/10.1016/j.egyr.2020.05.003

Patra, S. K., & Muchie, M. (2017). Engineering research profile of countries in the African Union. African Journal of Science, Technology, Innovation and Development, 9(4), 449–465. https://doi.org/10.1080/20421338.2017.1341732

Salisu, S. A., & Salami, M. O. (2020). A Bibliometric Analysis of Nigeria's Research Performance, 1901-2016. African Journal of Library, Archives & Information Science, 30(1), 23–36. http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=143392888&site=ehost-live

Sooryamoorthy, R. (2018). The production of science in Africa: an analysis of publications in the science disciplines, 2000–2015. Scientometrics, 115(1), 317–349. https://doi.org/10.1007/s11192-018-2675-0

Su, Y., Yu, Y., & Zhang, N. (2020). Carbon emissions and environmental management based on Big Data and Streaming Data: A bibliometric analysis. Science of the Total Environment, 733, 1–11. https://doi.org/10.1016/j.scitotenv.2020.138984 Computing Sciences in Colleges, 33(5), 115–123.