Enhancing Sustainable Engineering Education and Practice in the Developing Countries Through University-Industry Collaboration: A Nigeria Perspective

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Abstract

The demand for skilled engineers due to dynamics of technology and socio-technological challenges could only be met in all countries through sustainable engineering education and practice. Enhancing sustainable engineering education and practice is a global concern especially in developing countries. Over the years, many economies have grappled with obsolete, inefficient traditional methods of technology transformation and lack of practical implementation of distributed problem-solving techniques, which can be traced to paucity of sustainable engineering education. Good efforts had been made in this paper to explore university-industry collaborations as one of the robust means to enhancing sustainable engineering education and practice in Nigeria. The identified areas of collaboration include establishment of institutional factories and industries, revamping students industrial work experience scheme, establishment of engineering schools for further quality practical training after graduation, collaboration in utilising efforts made by institutions in research and development, joint conferences and workshops for cascading effects, and sustaining periodic industrial visits, funding of researches by industries through the universities.

Keywords
Technology, Sustainability, Engineering Education, University-Industry Collaboration, Developing Countries.

1. Introduction

Global demands for skilled engineers over the years had been sustained by constant need to address the dynamics of technology and socio-technological challenges. While the rigours of transformation of society have been lessened by technology and innovation proven in developed countries by training and availability of skilled engineer, most of developing countries of the world grapple with obsolete, inefficient traditional methods of technology transformation, lack of practical implementation of distributed problem-solving techniques which could be traced to lack of sustainable engineering education. Engineering education in the developing countries should be designed to enhance analytical skills, exhibition of practical ingenuity and creativity in socio-technical and operational context, maintenance of high standards and professionalism, leadership, business and management skills. Graduate engineer equipped with these abilities would never be a mismatch, but contributes adequately to sustainable development. The education and training of engineers begin with knowledge of elementary science through to high school education and to echelons of acquiring the required academic background in the institutions of higher learnings to be able to solve real world problems through professional and management trainings. How well the curricular content of engineering schools in the developing world are designed to accommodate the theory-based learning with complementary adequate practical trainings of professional standards is still in doubt, otherwise there should be appreciable key performance indicators for engineering education administration, engineering education resources and training, positioning engineering graduates for self-dependence or employment. Researchers have proposed good solutions, but yet there should be a specific look at enhancing sustainable engineering education for the developing countries through university-industry collaboration. Such undertaking is imperative especially when we view university education as the last strata that prepares a graduate engineer to solve and manage the global dynamic technological changes. In this paper Nigeria will be used as a reference point since enhancing the sustainable education for developing countries through university-industry collaboration cannot be adequately understood on a global scale.

Nigeria is a developing country with a total number of 193 Universities in 2021. There are 43 federal universities, 48 state universities and 99 private universities. In addition to the number of universities, there are 17 federal polytechnic colleges and 26 state owned polytechnic colleges. By these statistics, there are 236 faculties of engineering in Nigeria. By demonstrating significant readiness after secondary school education to cope with advance courses through any of West African Examination Council (WAEC), National Examination Council (NECO), National Business and Technical Examination Board and Unified Tertiary Matriculation Examination (UTME), candidate can gain admission into these universities and polytechnics. Engineering education in Nigeria is designed for 5 years-university programme leading to the award of Bachelor of Engineering(B.Eng,), Bachelor of Science (B.Sc) and Bachelor of Technology (B.Tech) in respective discipline, while polytechnic programmes are designed for 2 or 4 years leading to award of National Diplma (ND) or Higher National Diploma (HND) respectively. Postgraduate engineering programmes include Postgraduate Diploma of up to 2 years for graduates with HND, Masters programme of up to 2 years leading to award of Master of Engineering (M.Eng), Master of Science (M.Sc) and Master of Technology (M.Tech). Doctoral degree programme runs for minimum of 3years leading to Doctor of Philosophy (PhD). Universities and polytechnics in Nigeria face periodic accreditation by the National University Commission (NUC), National Board for Technical Education. Council for the Regulation of Engineering in Nigeria (COREN) is the statutory regulatory body for engineering regulation and practice in Nigeria. COREN is analogous to Accreditation Board for Engineering and Technology (ABET) in the United States, European Accredited Engineering Programmes (EURACE) and Engineering Council of South Africa (ECSA).

1.1. Research Objectives

The objectives of this paper are to identify and recommend areas of collaboration between the universities and industries in the developing countries for enhancing sustainable engineering education and practice.

2. Literature Review

The challenges imposed by the dynamics of engineering and technology especially in developing countries cannot be contained without sustainable engineering education and practice. According to Cristina(2016), technological entrepreneurship can be promoted through sustainable engineering education. Korhonen et al. (2017) corroborated the above position and rightly observed that new challenges to engineering education could be adequately tackled through university-industry co-operation. Rosen (2009) also noted that future trends and advances in engineering education could be enhanced by refocusing priorities, enhancing professionalism, advancing teaching and learning methods and increasing diversity in engineering profession. For the sustainability of engineering education and practice, Vijayan et al. (2018) suggested engineering knowledge creation through learning factory. They described learning factory as a platform for the interaction and exchange of knowledge and ideas between students, academics, and industrial participants. Beyond the learning factory, Trevelyan (2010) opined that understanding engineering practice beyond design and technical problem-solving would be a boost to engineering education and practice. Contemporary engineering education curriculum examined revealed that practically all of the formal instruction effort is devoted to engineering science, with little attention to business aspects and social culture. Ozor and Mbohwa (2019) noted the environment and training path of engineers in Nigeria can be re-engineered to provide room for the graduation of quality world class engineers that will transform the country technologically and economically. In an analysis inspired by Lewinian field theory, Bjursel and Engstrom(2019) identified six categories of barriers to university-industry collaboration which among others included system-related, value related and resource related barriers. Suggested solutions include trust and openness between the parties, resources allocation and reward system. Gillen et al. (2021) applauded interorganisational collaboration but feared the complex relationships for the implementation in terms of partnership and how to integrate engineering into middle school science curriculum. It was their opinion that macro-level look at the collaborative processes involved can help to develop implications for collaborative stakeholders to be intentional about designing for future success. Survey carried by Obanor and Kwasi-Effah (2013) to assess university-industry collaboration and technology transfer in schools of science and engineering in Nigeria revealed a very low level of technology transfer and collaboration between most industries and universities in north central, south-south and western regions of Nigeria. Recommended solutions include adequate funding to the SMEs, establishment of industries based on local content development, research collaboration between schools and industries. Comacho and Alexandra (2019) observed that design of engineering education in the developing world often happens in hypothetical contexts indifferent to reality or the surrounding context, disregarding articulation between academy and industry and with no attention to approaches that might enable the academy and the business world to get closer and share knowledge and dynamics reflecting the cultural, technological and social realities of present day society. The paper advised that design of academic curriculum should be based on a plural contact with art, science, technology and the business world for real innovation, sustainability and social responsibility. Similarly, Staniškis and Katiliute (2016) advised that engineering education should be extended to social responsibility and sustainable development through a change of fundamental epistemology in culture and educational thinking and practise. From a developing country perspective, a study in Sri Lanka by Wickramasinghe and Malik (2018) recommended sustainable engineering education and practice through university-industry collaboration and such could be strengthened by national innovation system to be funded by the government. Looking at university-industry collaboration in Turkish SMEs, Temel et al(2013) noted that innovation-based strategy is important in competitive markets in emerging countries, and that university-collaboration needs to be taken more seriously and must involve higher levels of effort and commitment if benefits are to emerge; otherwise, companies may decide against working with universities. From the perspective of Egyptian industry, El Hadidi and Kirby (2017) found a low level of university-industry collaboration due to firms' perception that academic research is not relevant to them. Authors recommended that such misconception should be addressed through robust campaign for university-industry collaboration by the government. Tener(1996) strongly canvassed for industry-university partnership for construction engineering education to enhance the performance of engineering graduates in practice. A paper by Khorsheed and Al-Fawzan (2014) proposed a new model for university–industry collaboration which targets combining academic and industrial resources to conduct research and development focused on industry-oriented problems and innovation. The research led to the establishment of technology innovation centres program at King Abdulaziz City of Saudi Arabia for science and technology. Salleh and Omar (2013) also recommended the establishment of research laboratory in university by large companies, and provide funding for research activities. With these approaches, the university-industry will have a tremendous effect on successful collaboration. Similarly, Othman and Omar (2012) described university-industry collaboration as symbiotic which is to generate successful and sustainable partnership in ensuring highly skilled and competent manpower is supplied to satisfy the industrial needs and the industry in turn assist in engineering practice. Iskanius and Pohjola (2016) suggested a community of practice through open innovation strategy to enhance university-industry collaboration. Apart from university- industry partnership, Wang et al. (2015) recommended project based learning and design-centric engineering education, vertically integrated practical teaching and industry best-practice oriented laboratories as key elements of simulating industry.

University-industry collaboration has been exposed by literature as a means of enhancing sustainable engineering education and practice. But because it is generic, approaches and models to be adopted in developing countries are to be discussed in perspectives. Nigeria is a representative case in this paper.

3. Research Method

Qualitative research approach was adopted through review of extant literature to explore experience and opinions of researchers. The merits of university-industry collaboration in enhancing sustainable engineering education and practice in developing countries were extracted and solutions to how it could be adequately implemented in Nigeria perspectives as developing country were identified and presented.

4. Data Collection

Data for the paper was collected through public records, historical and statistical documents, government publications and technical journals on engineering education and practice, status of university-industry collaboration in the developed and developing countries.

5.Results and Discussion

Data collected from developed countries was used as a standard to enhancing sustainable engineering education and practice in the developing countries through university -industry collaboration. Some commonly held characteristics of developing countries include low education and literacy level, less developed industrially, lower human development index (HDI).

5.1. Numerical Results

From the United Nations Development Programme (UNDP) Report (2022), table 1 shows Human Development Index (HDI of developed and developing countries. Human development index considers a broad range of factors, including education, economic growth and quality of life. The HDI of developing countries have scores less than 0.80. Nigeria in perspective has HDI of 0.539. Among other factors, low HDI of the developing countries is an indication of the lower extent engineering education had been thriving. Human development index of the developed countries is strongly linked to the sustainability of engineering education.

Table 1. Human development index of developing and developed countries, Source: United Nations Development Programme Report (2022)

Developed Countries	HDI	Developing Countries	HDI (2019)
Norway	0.957	Nigeria	0.539
Ireland	0.955	Cote de Ivoire	0.538
Switzerland	0.955	Tanzania	0.529
Hong Kong, China	0.949	Madagascar	0.528
Iceland	0.949	Lesotho	0.527
Germany	0.947	Djibouti	0.524
Sweden	0.945	Togo	0.515
Australia	0.944	Senegal	0.512
Netherlands	0.944	Afghanistan	0.511
Denmark	0.940	Haiti	0.510

Research and development (RandD) have a strong link to the sustainability of engineering education in the developed world and it has been boosted by university-industry collaboration while in the developing countries research and development are supported by education tax fund. In Nigeria, tertiary education trust fund (TETFUND) is used for academic staff development and funding research. The funds are never enough for robust engineering research. TETFUND funds research in public universities, polytechnics and colleges of education. The number of institutions in Nigeria increases over the years and grants go to some selected researches from the institutions. Table 2 shows the intervention from TETFUND to universities, polytechnics and colleges of education in Nigeria for research and related areas in 2019.

Table 2. TETFUND interventions (2019), Source: TETFUND Annual Report, 2019.

Interventions	**Universities**	**Polytechnics**	**Colleges of education**	**Total (N)**
Academic staff training and Development	12,797,324,373.28	5,621,698,339.00	4,572,041,419.07	22,991,064,131.35
Conference Attendance	2,014,434,963.25	1,606,576,641.35	1,568,927,212.95	5,189,938,817.55
Institutional Based Research (IBR)	429,118,214.72	299,031,815.86	181,805,569.89	909,955,600.47
Academic Research Journals (AJR)	69,062,950.00	61,229,481.25	195,123,321.54	325,415,752.79
Academic Manuscript to Books	187,567,917.00	161,081,313.55	82,936,561.00	531,585,791.55
Academic Publishing Centre	2,491,129,889.26	-	-	12,491,129,889.26
National Research Fund (NRF)	506,817,276.70	19,343,142.00	-	526,160,418.70

In the developed world, most research fundings come from University-Industry Collaboration. Table 3 shows research income from industry to top 10 ranked university in the Unites States in 2022. Technology companies support play a vital role for higher education research.

Table 3: Research income from industry of the top 10 ranked universities, Source: Consultancy report 2020

University	Average Research Income from Industry per Academic Staff (USD)
University of Oxford	57,000
Stanford University	107,000
Harvard University	22,000
California Institute of Technology	11,8000
Massachusetts Institute of Technology	108,000
University of Cambridge	3,0000
University of California, Berkeley	90,000
Yale University	36,000
Princeton University	39,000
The University of Chicago	34,000

The average research income from industry per academic staff, Table 3 is an indicator for good university-industry collaboration in the developed world and the extent to which engineering education has been sustained by the industry.

5.2. Results

Further, figure 1 shows expenditures dedicated to RandD by top technology companies to university research in 2018 while Figure 2 shows the number of co-authored academic publications by these technology companies from 2015 to 2019. Microsoft published the largest volume of academic papers in which it is listed as a co-author. Google, Huawei and Samsung also co-authored academic paper in large volumes. University- industry collaboration in the developed world is a strong partnership. To the best of knowledge of this paper, unavailability of data for university-industry collaboration in developing countries indicates poor or lack of collaboration between the universities and industries (Figure 2).

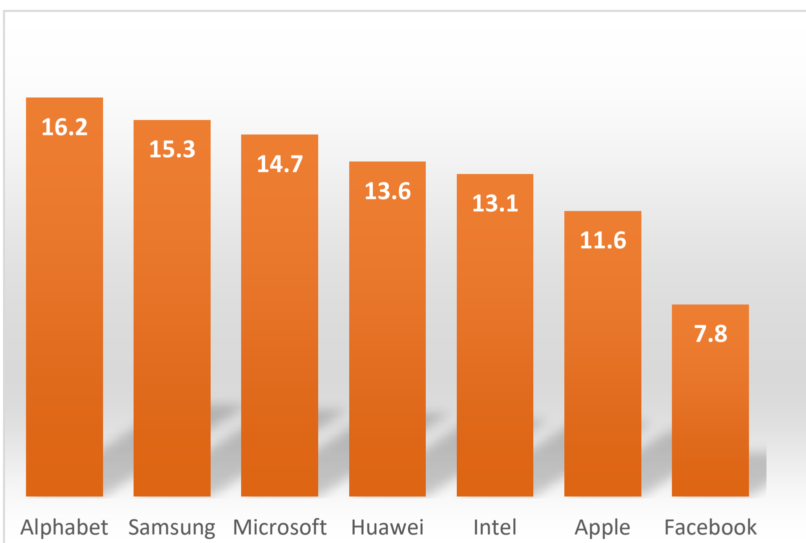

Figure 1: Total expenditure (USD, billions) dedicated to RandD (2018)

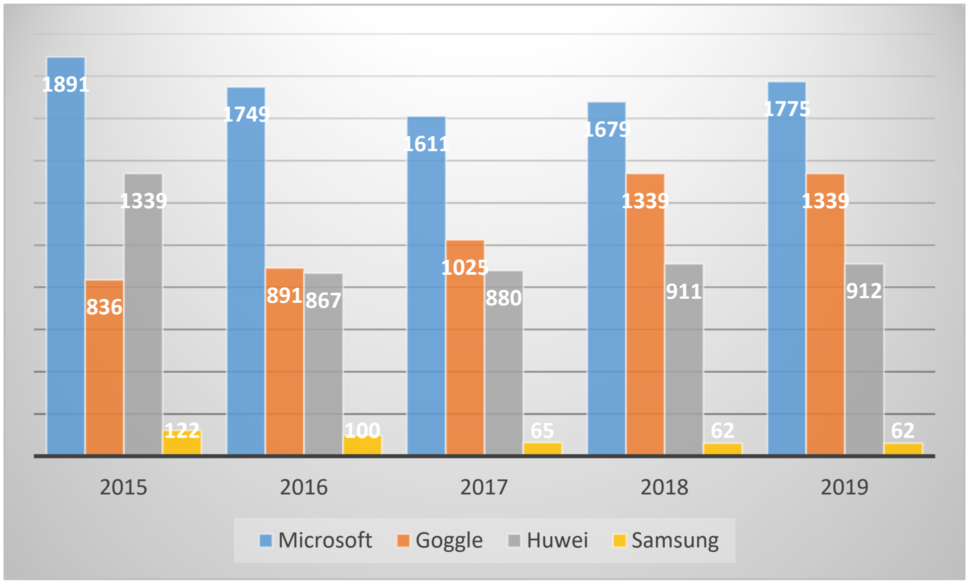

Figure 2. Number of co-authored academic publications

5.3. Enhancing sustainable engineering education and practice in developing countries

From the results and discussion, it was deduced that for sustainable engineering education and practice, there must be huge investment in research and development. Advancement in knowledge and development can only be guaranteed through research. Robust university-industry collaboration has to be established in the developing countries for sustainable engineering education and practice. To ensure university- industry collaboration, the industry must have confidence for huge investment in the institutions, and equally the institutions must be ready to reciprocate by surmounting the challenges of the industry through engineering research and development. Research and development should be sustained by the industry and universities in the developing countries to enhance learning and practice. When the academic staff of the universities improve on knowledge and innovation through research as in the developed world, students would also benefit in learning and practice. Synergy between the university and industry is the solution to challenges of obsolete equipment in the laboratories in most of the developing countries. Apart from funding by the industry, sustainable engineering education and practice in the developing countries through university industry collaboration through the following strategies.

5.4. Establishment of Institutional Factories and Industries

Establishment of institutional factories in related disciplines where students are the employees will benefit students in developing countries. Establishment of institutional factories where students will learn by doing is a good way to acquire and sustain analytical skills, design, production and management. Graduate engineers produced in such engineering education design are equipped for self-dependence and employment. In addition to equipping the students, schools generate income purposefully for improving the factories and maintenance thereby helping the government and industries in funding research and development. Establishments of institutional factories may not be huge challenge in the recent trend of alumni looking back to assist the government in funding institutions.

5.5. Revamping of Student Industrial Work Experience Scheme (SIWES)

The objectives and scope of SIWES are to provide the avenue for students in institutions of higher learning to acquire industrial skills and experiences in their course of study, prepare the students for the industrial work situation they are likely to meet after graduation, expose students to work methods and techniques in handling equipment and machinery that may not be available in their institutions, make the transition from school to the world of work easier and enhance students contact for later job placement, provides students with an opportunity to apply their knowledge in real work situations thereby bridging the gap between theory and practice, enlist and strengthens employers involvement in the entire educational process and prepare students for employment after graduation. It is an open secret that these wonderful objectives of SIWES had not been met. The six months period for industrial training is inadequate for students to prepare selves for the industrial work situation they are likely to meet after graduation. Securing a place by students for the industrial training had been a challenge left unsolved by the universities. Obviously, many students settle for any place sometimes not related to their disciplines, and these are reflected in their technical report submitted after the industrial training. Therefore, the gaps left in the institution by unavailability of machines and equipment are not also filled by the industrial training under SIWES. The intention to make transition from school to the world of work easier and get contact placement are met with stronger links and affiliation. During industrial training student grab only a handful of application of knowledge to real work situation. Student industrial work experience scheme should be reorganised or redesigned to meet the objectives. The institution has to get affiliated with the industries to be able to secure placements for their students. Such proper placement ensures the objectives of industrial training designed under SIWES are met. When the institutions are not peripherally involved, it will entrench proper supervision by the assigned school industrial training supervisors. Definitely students would be propelled to take it more seriously when these allied engineering education measures are put in place. Also as mentioned in section 2.1, the establishment of institutional factories will be industrial training made easy. Arrangement under SIWES would only attend to few areas where such experience could not be obtained in the institutional factories. When we imagine a situation where schools have factories and industries, the cascading effects would be beneficial to engineering education and practice.

5.6 Establishing Engineering Schools for Post-Graduation Training and Professionalism

Engineering schools have to be established for further quality practical orientations after graduation. Post-graduation training in engineering schools for periods of one or two years will help engineering graduates to measure in relevance like the counterparts in other professional courses like medicine, law and pharmacy which engage graduates in post-graduation training and upon completion, they are certified professionals. This measure will greatly boost engineering practice other than the current mode to only pass-through council for the regulation of engineering in Nigeria (COREN) registration.

5.7 Changing Concepts of Core Competence in Research and Development by Institutions and Industries

According to Chak (2011), core competence may be defined as knowledge and skills put into action in specific contexts". And the two basic types of core competences are cross competence which involves innovation, management, quality, networking, customer, safety, etc, whereas specific competence includes identifying possible application contexts in products, processes, research and development, engineering business administration and industry. Research and development advertently suffer neglect in the developing countries whereas it includes activities that companies undertake through technology and innovation to introduce new product and services. Inadequate funding of research makes breakthrough difficult, and as a result, staff of the higher institutions engages more in researches intended for academic appraisals than innovative and long-term researches. On the other hand, industries have not adequately engaged engineering faculties and departments in a collaborative research and design as obtainable in developed countries where companies sponsor PhD researches in specific areas of interest. Again, industries should have confidence to put the myriads of quality researches in the libraries of universities into actions. By such confidence, researchers which includes students are motivated in the efforts to do more. Engineering education and practice will be enhanced by changing concepts of core competence in research and development by institutions and industries.

5.8 Sustainable University-Industry Conferences and Workshops

The growing trend by institutions to organise conferences and workshops in collaboration with some industries has to be sustained. Institutions should affiliate with more industries in teaching and learning through conferences and workshops with a mix of resources persons from both. The synergy would in turn guarantee places of industrial training for students.

5.9 Industrial Visits

Industrial visits as a means to engineering education are gradually eroding. It has to be energised through university-industry collaboration. Where institutional factories and industries could not be established in certain disciplines, periodic industrial visit is a means to bonding universities and industries. Ultimately, industrial visits provide students with functional opportunities of combing theoretical knowledge from the classroom with industrial knowledge from the industries. Teachers also equip and enhance their knowledge during industrial visit.

6. Conclusion

Constant demand for skilled engineers is sustained and propelled by constant need to address the dynamics of technology and socio-technological challenges. This demand cannot be met without enhancing sustainable engineering education through university-industry collaboration. Some factors, which have contributed to the decay in engineering education in the developing countries, are lack of political will in funding education, inadequate collaboration of the universities and industries for cross pollination of ideas, curricular content and programmes designed to pay attention to theories than practice. Good efforts had been made in this paper to explore university-industry collaborations as one of the robust means to enhancing sustainable engineering education and practice. The following areas of collaboration between the industries and the universities in the developing countries had been identified and recommended for enhancing sustainable engineering education and practice.

a. University-industry collaboration is strongly recommended in enhancing sustainable engineering education and practice.
b. Establishment of institutional factories and industries to match theoretical knowledge of students with adequate practical training in relevant disciplines while still in school.
c. Revamping students industrial work experience scheme for institutions to adequately attend to their students and engage them usefully.
d. Fresh graduate engineers should be subjected to further compulsory quality training through establishment of graduate engineering upskilling schools. Upon training completion, certification should be obtained through the regulatory body.
e. There should be political-will by the government and trust by the industries in funding universities, especially in engineering education.

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