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Problematization of the Sudanese Engineering Education

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ABSTRACT

The purpose of engineering education is to prepare engineering graduates for employment as professional engineers in various industries. However, a small portion of the engineering graduates may seek other options, like research and/or graduate studies. Well-trained engineering graduates is essential for development of any country. Nevertheless, Sudan, like most of Sub Saharan African countries, has been facing profound engineering education issues; of them are: poor funding, outdated curricula, ineffective teaching and learning methods, inadequate human capacity, poor research/publishing condition, inappropriate facilities, inadequate educational technology and ICT environment, weak university/industry relationship, lack of academic freedom, imbalance between diploma and bachelor graduates from engineering college, and missing of quality control and accreditation measures. All of these issues led to low number of well-trained engineering graduates; hence, the country's development has been exceedingly suppressed. Any efforts to improve engineering education in Sudan should start with addressing those inadequate elements of engineering education. This paper discussed the current engineering education issues and concluded with recommendations that might help resolve them.

1. Introduction

The purpose of engineering education is to prepare engineering graduates for employment as professional engineers in various industries. However, a small portion of the engineering graduates may seek other options, like research and/or graduate studies. Well-trained engineering graduates is essential for development of any country. Nevertheless, Sudan, like most of Sub Saharan African countries, has been facing profound engineering education issues; of them are: poor funding, outdated curricula, ineffective teaching and learning methods, inadequate human capacity, poor research/publishing condition, inappropriate facilities, inadequate educational technology and ICT environment, weak university/industry relationship, lack of academic freedom, imbalance between diploma and bachelor graduates from engineering college, and missing of quality control and accreditation measures. All of these issues led to low number of well-trained engineering graduates; hence, the country's development has been exceedingly suppressed. Any efforts to improve

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engineering education in Sudan should start with addressing those inadequate elements of engineering education. This paper discussed the current engineering education issues and concluded with recommendations that might help resolve them.

1.1 Sudan Background

Sudan is located, geographically and ethnoculturally, midway between North Africa/Arab World and the Sub Saharan Africa (SSA) countries. However, UN geoscheme classification, which classify Africa into 5 subregions: Northern, Eastern, Middle, Southern, and Western Africa, considers Sudan as part of North Africa. The United Nations Statistics Division (UNSD) uses geoscheme classification for the statistical purposes. Therefore, this paper will benchmark Sudan to several countries from North Africa/Arab territory and the neighboring SSA [1].

Sudan is considered one of the low-middle income countries. The country is very rich in natural resources, which include water, land, agriculture, forestry, livestock, crude oil, and minerals. As shown in Table 1, in 2020, Sudan ranked 78 out of 180 countries in Natural Capital (NC), which reflects the country's ability to sustain the population and the economy, now and into the future. The country's NC score is 49.3%, which is above average of 46.7%, knowing that the highest score is 74.8%. At the same time, Sudan's ranked very low in both Sustainability Competitiveness Index (SCI) and Intellectual Capital Index (ICI). Sustainable competitiveness is the ability to generate and sustain inclusive wealth without diminishing the future capability of sustaining or increasing current wealth levels. While intellectual capital is the capability to generate wealth and jobs through innovation and value-added industries in the globalized markets. The country's SCI and ICI rank, out of 180 countries, are 163 and 145, respectively. Sudan's SCI score is 39%, which is very low relative to the global average SCI score of 45.6 and the best SCI score of 62.8%. As well, the country's ICI score is only 25.7%, which is way below the average score of 41.2, knowing that the best score is 74.8%; Table 1 shows Sudan position relative to the global sustainable competitiveness index [2].

Table 1
The global sustainable competitiveness index

Indicator	Sudan		Global	
	Rank out of 180 countries	Score	Average	Best
Natural capital	78	49.3	46.7	72.8
Sustainable competitiveness	163	39	45.6	62.1
Intellectual capital	145	25.7	41.2	74.8

However, distressed economy of Sudan, to great extent, has been caused by corrupt politicians and disastrous political practices since the country's independence in January of 1956. Sudan political system has been engaging in what is known as a 'Vicious Cycle', which consists of multi-party democracy, followed by a military coup, and ended with transitional period due to people uprising 'Intifada' against the military regimes. This cycle has repeated three times. The sum of all democratic ruling, including transitional periods, were only 13 years, while military regimes ruled the country, with an iron fist, for more than 53 years. The resultant of this disastrous political practice led to the country's significant social instability, civil war and great economic depression, in spite of the country's abundant natural resources. Eventually, Sudan has become two countries after its secession, Sudan and South Sudan, as of July 9th, 2007.

It is worth mentioning that deterioration of all aspects of life in the country- socially, economically, politically, etc.- has been greatly attributed to the last military regime, which lasted for 30 years, between June of 1989 and April of 2019. However, after throwing the regime out of power,

the hope is high on the current transitional civilian government to lead the country into a proper democratic system, and hence, a prosperous Sudan [3,4].

1.2 Engineering and Engineering Education

There are many engineering definitions. Though, a more comprehensive one is given by UNESCO [5], "Engineering is the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes".

As stated by Goodhew [6], the difference between engineering education and vocational education is, "Engineering education is not about the acquisition of specific practical skills, however useful or interesting they might be to any individual. It is not about training people to run CFD codes or send CAD designs to a CNC machine or to grow crystals or to sign off structural steelwork. It is about the conceptual, planning and design skills which should precede all these activities. It is about imagining and understanding and predicting, as quantitatively as possible, why and how an engineering objective can be realized and delivered".

Engineering is old as the history of civilization! However, engineering has become a global profession. Current and future engineers have been facing numerous challenges such as: proliferating information, multidisciplinary technological development, globalized market, endangered environment, emerging social responsibility, participatory corporate structures, and rapid changes [7].

UNESCO [5] states, "For the future of engineering, an obvious goal is the need to focus specifically on the important role engineering will play in addressing the UN Millennium Development Goals, especially poverty reduction and sustainable development, and the vital role of engineering in climate change mitigation and adaptation in the development of sustainable, green, eco-engineering and associated design, technology, production and distribution systems and infrastructure".

The purpose of engineering education is to prepare engineering graduates for employment as a professional engineer in various industries. However, a small portion of the engineering graduates may seek other options, like research and/or graduate studies. Here it should be noted that the potential employers of engineering graduates are considerably diverse; nevertheless, all employers look for the same set of skills in an engineering graduate. This means, employable engineering graduates should be acquainted with a set of certain skills, such as: problem-solving and strong analytical skills, excellent communication and leadership skills, teamwork skills, and desire for lifelong learning.

Moreover, since 2001, ABET has been implementing and revising Engineering Criteria 2000 (EC2000) as the standard for accreditation, which means engineering schools should be accountable for what engineering students learn to become equipped with the technical and professional skills required by employers [8]. In short, a successful school of engineering has to develop an educational system capable of promoting active learning of the three components of engineering education, namely: knowledge, skills, and attitudes. Rugarcia *et al.,* [7] states, ''Knowledge is the data base of a professional engineer; skills are the tools used to manipulate the knowledge in order to meet a goal dictated or strongly influenced by the attitudes".

2. Engineering Education in Sudan

Contemporary education, including engineering education, in Sudan, has been developed during the colonialism period with the goal of helping the colonial administration to meet their needs for civil servants and municipality professionals from the local job market. The philosophy of education and the design of the western curriculum were to achieve the goal of the colonial administration rather than to promote education for Sudanese [9]. Engineering education, as part of tertiary education, is regulated and administered by the Ministry of Higher Education and Scientific Research (MoHESR), and all engineering graduates must be licensed and registered by the Sudanese Engineering Council (SEC). Since its inception during early 1930s, the evolution of engineering education, in Sudan, has gone through three distinctive stages:

2.1 Stage 1, During the British Colonialism, Until January Of 1956

The start of engineering education was based on the needs for apprentices to help British Colonial Government (BCG) with municipality functions. To meet the demands for technical skills, engineering education during this period has started as part of the high school programs [9]; then, it has been developed into two academic institutions: Engineering College (EC), within Gordon Memorial College (GMC), which was associated with London University, and Khartoum Technical Institute (KTI). Both of them have been located in Khartoum, the capital of Sudan, and they used to offer engineering degree and engineering diploma, respectively. Their capacities, the intake of students and the number of graduates, have been very limited, and barely fulfilling the country's need for engineers. However, the quality of graduated diploma and bachelor engineers has been comparable to known standards, at least in United Kingdom (UK) since the EC has been associated with London University [4,9,10].

2.2 Stage 2, After the Independence of The Country, From January 1956 to 1989

After the independence of the country, in January 1956, the EC has become part of University of Khartoum (UofK), which was known as GMC. In addition to mechanical and civil engineering programs, EC expanded its programs to include Architecture engineering in 1957, electrical engineering in 1959, and chemical engineering 1964. At a later phase two more programs came into existence as part of the engineering college: surveying and agricultural engineering programs in 1975 and 1976, respectively [4,9,10].

KTI has become Khartoum Polytechnic Institute (KPI), which granted its graduates diploma and applied bachelor degree in electrical, mechanical, surveying, textile, and civil engineering [11]. Additional two engineering colleges were established as part of University of Juba and Jazeera University. They were established in 1975 [4,11].

During this period, engineering education in Sudan has been improving incrementally in terms of engineering programs, capacity of these programs, and number and quality of engineering graduates. However, the number of engineering graduates was relatively small, in order of hundreds, due to limited capacity of the engineering colleges. By 1988, the total number of engineering students reached a little over five thousand, which represented only 6% of the total students enrolled in tertiary education. In the same year, the engineering graduates were only 624 [11].

2.3 Stage 3, Lasted For 30 Years Between 1989 And 2019

During this period, the situation of engineering education, as part of the whole higher education, has been affected, to great extent, by the behavior of the 'newly' established government in June 1989. The government pledged to resolve the overwhelming problems of higher education, which has been considered the bottleneck in the process of the country's development [12-14].

The regime has implemented drastic changes in the area of education. Accordingly, the number of universities and other higher academic institutions have been increasing, at a fast-paced. Between 1989 and 2018, the number of universities has increased from only 4 public and 2 private universities to 36 public and 13 private universities, or an increase of 9 times and 6.5 times for public and private universities, respectively. About 26 out of 36 public universities, and 11 out of 13 private universities have engineering programs. During the same period, technical institutes, which offer associate degrees, have increased from 12 to 83, an increase of almost 7 times. About 25 out of these 83 technical institutes offer engineering programs.

In addition, the total number of students has increased from 57.6 thousand to 680 thousand. Engineering students represent about 9% out of the total, or 61.6 thousand students; they enrolled in 26 public and 11 private engineering colleges, respectively. While the increase in the total number of college students has estimated to almost 11 times, during the same period, the jump in engineering students has approached 20 times, or from only 3 thousand to 61,6 thousand. Table 2 shows the elevation of academic institutions, students' enrolment, and graduates between 1989 and 2018 [4,15].

Table 2
The increase in academic institutions, tertiary enrolment and graduates between 1989- 2018

Indicators	1989	2018	Number of times increased
Number of academic institutions	21	132	5.3
Academic institutions with Eng. Programs	5	62	11.4
Total students	58667	680696	10.6
Engineering students	2996	61638	19.6
% of engineering enrolment	5.1%	9.1%	..
Total graduates	7140	123887	16.4
Engineering graduates	624	10047	15.1
% of engineering graduates	8.7%	8.1%	..

Although the number of engineering graduates has expanded significantly, from less than one thousand (in 1989) to more than 10 thousand (in 2018), their quality has been compromised. The dilemma of engineering education in Sudan remains the disparity of the quality of graduate engineers. This has been attributed to many reasons, of them are:

- Expansion in higher education was implemented without consideration of the readiness of education infrastructure [12,14].
- The government has failed to secure reasonable budgets to meet its own ambitious education project. The share of education sector represented only 1.3% of the country's GDP in 2001 and was doubled in 2008, or 2.7% of the GDP [3].
- English was replaced with Arabic as a language of instruction [12,14].
- General education system was reduced to 11-year instead of 12-year system [16].

3. Benchmarking the Situation of Engineering Education in Sudan

To better evaluate the situation of Sudan's engineering education, this paper benchmarks it with the situation of engineering education in several countries, namely: Algeria, Egypt, Jordan and Saudi Arabia, from Middle East/North Africa territory; Ethiopia, Kenya, Rwanda, and South Africa from SSA; and Malaysia as an example from South East Asia. Many indicators may be used to benchmark the situation of engineering education in Sudan, with the situation in those countries. Table 3 uses the following indicators (3.1 to 3.4) [17].

3.1 Tertiary Enrolment Ratio

This indicator represents the total enrolment in tertiary education as a percentage of the total population of the five-year age group following on from high school graduation (18-23-year age group).

Sudan tertiary enrolment ratio is about 17%, which is better than the enrolment ratio in SSA countries, with an average of 9.4%; however, the same number is far lower than the average enrolment ratio of 40.6% in Middle East and North African countries. In Malaysia, this indicator is more than 45% [17].

3.2 Tertiary Enrolment Per 100K Population

Another indicator to benchmark the education situation is the number of students enrolled in higher education per 100K population. As shown in Table 3, the value of this indicator is more than 15 hundred students per 100K population. This value is almost double the average values from SSA countries, only 825 students. However, the same value is less than half the average value of the Middle East/North Africa countries, which are 3,259 students per 100K population. In the same year, Malaysia has more than 4 thousand tertiary enrolments per 100K population [17].

3.3 Percentage of Engineering Graduates

Engineering graduates in Sudan represent about 10.7% of the total tertiary graduates, which is better than the percentage of engineering graduates in all benchmarking countries, except Jordan, Algeria, and Malaysia, with engineering graduates' percentage of 16.4%, 22%, and 30.1%, respectively [17].

3.4 Education Sector % Of GDP

In 2008 Sudan's education sector share was about 2.7% of GDP, which is less than neighboring countries (3 to 7% of GDP); far less than lower-middle-income countries in SSA (4.4 to 13.1% of GDP); and less than lower-middle-income countries in North Africa (3.7 to 7.1% of GDP) [3]. Since 2008, the share of education sector of GDP, in Sudan, has been dramatically decreasing, and by 2014, it reached about 1.4% of the GDP [18]. As shown in Table 3, this governmental extremely poor expenditure on education, relative to all benchmarking countries, requires special attention from education sector stakeholders.

Table 3
Benchmarking the situation of engineering education in Sudan

Country Name	Indicators			
	3.1 tertiary enrolment ratio	3.2 enrolment per 100K population	3.3 % of engineering graduates	3.4 education % share of GDP
Sudan	17	1,562	10.7	..
Algeria	51.4	3,791	22.0	..
Egypt, Arab Rep.	35.2	2,961	6.2	..
Jordan	34.4	3,223	16.4	3.0300
Saudi Arabia	68.0	4,809	7.9	..
Middle East/North Africa	40.6	3,259	..	..
Ethiopia	8.1	693	..	4.7379
Kenya	11.5	1,095	4.2	5.2713
Rwanda	6.7	615	5.8	3.0738
South Africa	23.8	2,038	8.0	6.1590
Sub-Saharan Africa	9.4	825	..	4.4985
Malaysia	45.1	4,075	30.1	4.4813

Aside from information presented in Table 3, the number of engineers per 100K population represents a good indicator for the situation of engineering education. As stated in [10], in Sudan, this indicator is around 188 engineers per 100K population, which is very weak compare to the same indicator from Egypt, Jordan, and Saudi Arabia, which is 2800, 1000, and 460 engineers per 100K population, respectively [10]. This indicator is extremely crucial for any efforts to revamp the situation of engineering education in Sudan.

4. Current Issues in Engineering Education in Sudan

In 1993, the World Bank described the state of engineering education in Sub Saharan Africa (SSA) as, "a sorry state." To put this in perspective the reports states, "… developed countries graduate 166 times more engineers per capita than do the countries of SSA, and the quality of training, already low, is deteriorating as a result of budget constraints" [19]. In addition to insufficient budget, many research papers proved the situation is worsening rather than getting any better [6,20-22]. Other researchers were investigating challenges facing engineering education in Africa, such as insufficient funding, inappropriate facilities, lack of adequate human capacity, brain drain due to unattractive working environment in SSA, and missing of quality control and accreditation measures [22,23].

The Royal Academy of Engineering (RAE) UK, has developed a single Engineering Index (EI), which consists of eight different engineering related indicators: 1) Employment in engineering related industries, 2) human capital investment in engineering, 3) number of engineering businesses, 4) the quality of infrastructure, 5) the gender balance of engineers, 6) the quality of digital infrastructure, 7) wages and salaries of engineers, and 8) exports of engineering-related goods. In 2016, about 99 countries were ranked based on the EI; none of SSA countries was included in this ranking either due to data availability or weak indicators' values [24].

The state of engineering education in Sudan has been more or less similar to its region; still one may argue that the deterioration rate of engineering education in Sudan has been far exceeding deterioration of engineering education in similar counties [13,14]. Osman [10] summarized the problem of engineering education in Sudan into two folds: first, failure of the engineering education capacity to accommodate the increasing number of desired students to study engineering, which is necessary to meet the demand of local and regional labor market; second, inability of engineering

graduates to compete for the job market whether locally or globally, due to their improper level of training. Likewise, Sudan is very behind in all eight RAE engineering indicators.

In Table 4, the researchers summarize most of engineering education issues in Sudan, during three distinctive periods, (a), (b), and (c).

Table 4
Summary of engineering education issues in Sudan

Stages of Eng. education	Issues	Comments
(a) Colonialism period	• Western model of academic institutions • Limited enrolment, limited graduates, limited programs, limited curriculum, and limited freedom	Only two engineering programs
(b) Post-independence 1956-1989	• Poor Funding • Low number of academic institutions • Limited capacity in terms of enrollment and the number of graduates	National government kept the same western education model
(c) Current period 1989-2019	1. Poor Funding 2. Outdated curricula 3. Ineffective teaching and learning methods 4. Inadequate human capacity 5. Students under preparedness for college 6. Inadequate number and quality of facilities 7. Issues of quality control and accreditation measures 8. Other issues: • Absence of academic freedom • poor research/publishing condition • inadequate educational technology and ICT environment, • weak university/industry relationship	In addition to academic freedom, poor funding is the leading cause for all other issues.

The following subsections discuss most of the current engineering education issues, which require the utmost attention of policymakers, academic administration, industry, and engineering educators.

4.1 Poor Funding

For decades, most of African countries have been facing severe financial problems, which are mainly due to the state of the economical situations of these countries and their misallocation of scarce financial resources. According to Teferra and Altbach [25], the expenditure of higher education in Africa is ranged between 4 to 5 billion-dollar. He added, 'The total yearly expenditure for higher education in Africa as a whole does not even come close to the endowments of some of the richest universities in the United States' [25]. Likewise, higher education in Sudan, including the engineering education, has been facing similar financial crisis.

In Sudan all public academic institutions are owned by the government, and the government used to meet financial needs of these institutions. However, since the drastic expansion of tertiary education in 1990, the government not only has failed to secure the budget of its ambitious education programs, but also has started to reduce the education sector expenditure [18].

With its GDP per capita of $1990, Sudan is considered one of the lower- middle-income countries. This per capita GDP of Sudan is higher than most of its neighboring countries, and higher than some of countries in SSA; but still Sudan per capita GDP is significantly lower than countries in North Africa. On top of that Sudan spend less on education than all of these countries. As above-mentioned,

subsection 3.4, since 2008 Sudan's education sector share has been decreasing, and between 2008 and 2014, the education sector share has decreased to 1.4% of GDP [18].

4.2 Outdated Engineering Education Curriculum

One of the main engineering education issues in the country is the outdated curriculum. According to the two-engineering education regulatory bodies, MoHESR and SEC, curriculum for Bachelor of Science in engineering must contains four categories of courses: Math and Science, Engineering Science, Applied and Design Engineering, and Humanities and Social Science courses. Table 5 shows these 4 categories and associated percentages [10].

Table 5
Categories of courses for engineering Bachelor of Science

Categories of courses	Examples
25-30% Math and Science	Math, Physics, Chemistry, Programming
25-35% Engineering Science	Major-dependent
25-35% Applied and Design Engineering	Major-dependent
10-15% Humanities and Social Science	Languages, literature, philosophy, economics, geography, politics, religion, management, ...etc.

Although the overall categories of the curriculum are somehow reasonable, however the details of the curriculum demonstrate its inability to graduate engineers capable of competing neither in the local nor in the global job market. This is evident by high rate of unemployed engineers; increasing number of foreign engineers and technician for the local demand of engineering jobs; and irrelevant low-paying jobs for Sudanese engineers [18].

For example, the curriculum to obtain a bachelor degree, in chemical engineering, from UofK, which is considered the top university in Sudan, with international recognition, consists mostly of theoretical courses; even applied and design courses represent less than 10% due to inadequate facilities [26]. These theoretical courses are not related to industry. They are far from graduating employable engineers with the right sets of technical and soft skills required by industries. Lack of connection between the traditional engineering curriculum and the engineering as a professional career has been the focus of engineering educators for decades; almost 100 years ago, C. Mann, 1918, said, ". engineering education will never be satisfactory until theory and practice are taught simultaneously. …" [27].

As mentioned in subsection 1.1, Sudan is very rich in natural resources, and its NCI rank is 78 out of 180 countries. Yet it is considered one of underdeveloped countries in SSA, which is evident by the country's low GSCI ranking, 163 out of 180 countries (see Table 1). Moreover, the poverty rate in the country is about 44.3%, when the lower-middle income countries poverty line ($3.60 a day) is used [28]. Sudan's economic, social, and technological development requires an advancement in engineering education that capable of graduating sufficient, well-qualified engineers. Therefore, revamping engineering curriculum is a necessary step in elevating the quality of engineering education in the country. Revamped curriculum should enable engineering students to acquire professional and soft skills needed in the job market. Also updated curriculum should be revised on regular basis to ensure its relevance to evolving international standards of engineering education. Curriculum revision is a key to produce qualified engineering graduates, and hence their contributions to Sudan sustainable development.

Appropriate engineering curriculum goes hand in hand with other elements of engineering education, namely: suitable facilities, students' preparedness, adequate academic staff, and teaching and learning methods.

4.3 Ineffective Traditional Teaching and Learning Methods

Traditionally, educators in Sudan have adopted lecture methods as a way of teaching. Yet most, if not all, engineering colleges employ the same teaching methods [10]. Prince and Felder [29] described this traditional teaching method as deductive instruction, which implies that: the lecturer explains, to his/her students, general principles and applications of a certain topic; gives students an opportunity to practice these principles by solving a set of homework problems; and finally assesses students' abilities to resolve similar problems. This ineffective teaching style does not consider the various learning styles of engineering students [29-31]. Nevertheless, many researchers suggested alternative approaches where students are allowed to work in small groups, using different learning tools [31,32].

4.4 Inadequate Human Capacity- Academic and Non-Academic Staff

For decades, engineering education in Sudan has been suffering greatly from the scarcity of well-qualified academic staff and by low instructor-to-student ratio. On average, in 2019 the instructor-to-student ratio was estimated to 1:34, which was far below 1:15 required ratio by regulatory agencies to recognize and accredit engineering program. On top of that, the required ratio of professorial rank should be around 1:100 and 1:65 for professor-to-student and associate professor-to-student ratio, respectively. These numbers show that most of engineering programs are not satisfying the requirement of instructor-to-student ratio to be recognized or granted accreditation [10]. As stated by Gasim [14], "more than two third of all academic staff, from teaching assistant to professorial ranks, did not hold PhD degree in their field" [14].

Another issue with the academic staffing is the gender disparity of higher academic positions in tertiary education. In 2018, female represents about 48% of the total lecturer and teaching assistant positions; while, female account for only 29% of the total professorial rank positions. When it comes to engineering academic positions, male to female ratio is almost 1.9:1 [15].

Unattractive teaching environment, lack of academic freedom, and poor financial compensation led highly qualified faculties to leave the country looking for a prosperous and satisfying career elsewhere. Therefore, local engineering colleges left with only under-qualified faculties, retiree professors, and others who are awaiting their opportunities to leave. On top of that, promotion of academic staff is not linked to the professional development programs [9,14].

4.5 Inadequate Facilities for Engineering Education

Insufficient funding for the education sector has left education in general, and engineering education in particular without appropriate facilities. Most of engineering colleges have been facing devastating shortage of buildings, libraries, laboratories, equipment, instruments, and supplies necessary for teaching and training engineering students. It is worth noting that available laboratories and equipment are outdated without enough supplies and consumables. The woeful situation of engineering colleges' facilities is due to spiteful budgets that have been assigned to both public and private engineering colleges [3,18].

4.6 Students' Under Preparedness for College

The general education ladder in Sudan used to consist of 6, 3, and 3 years for primary, middle, and secondary high school, respectively, which was compulsory for children between the age of 6 and 14 years. A mandatory 2-year preschool was also mandatory for 4-6 years old children. In 1992, the education ladder was replaced with 8-year elementary and 3-year high secondary school. Thus, the duration of general education was reduced to 11-year instead of 12-year system, which is standard and globally recognized system [16,20]. 11-year general education system, combined with anemic education budget, inadequate curriculum, obsolete teaching methods, and insufficient qualified schoolteachers, led to under-prepared high school graduates for college in general, and for engineering colleges in particular [10,16,18]. Although engineering freshmen have a good knowledge of math and science, still they lack meaningful scientific concepts. This is due to missing components of technology and engineering within precollege education.

4.7 Issues of Quality Control and Accreditation Measures

As mentioned in section 2, engineering education, as part of tertiary education, is regulated and administered by the MoHESR. All engineering programs must be recognized and accredit by the MoHESR, based on rigorous accreditation procedures, and all engineering graduates must be licensed and registered by the Sudanese Engineering Council (SEC). Moreover, in 2003 MoHESR formed an academic, technical, and administrative accreditation and evaluation unit; its goal is to improve the quality and the performance of the higher academic institutions, establish self-evaluation units within academic institutions, upskilling the human resources, and adopt and disseminate a culture of quality [18]. Nevertheless, none of engineering programs has earned any-, but not even applied for, international academic accreditation, ABET for instance. This fact requires revision of the implementation of the quality control and accreditation measures from international accreditation perspectives.

4.8 Other Issues

4.8.1 Absence of academic freedom

Freedom of expression and freedom of educators to teach, research or pursue knowledge, wherever it may lead, have been completely missing from academic institutions, in Sudan, during the period between 1989 and 2019. As mentioned earlier, lack of academic freedom was one of the main reasons that has led qualified academicians to leave the country. Fortunately, and due to the 'December 2018 Revolution', academic institutions have started claiming their academic freedom.

4.8.2 Poor research/publishing condition

The research and publishing activities, in Sudan, are very low. This fact is evident by the low H-index of 110, in all subject areas, which below all H-index from all other benchmarking countries except Rwanda. While, in engineering, the H-index is even too low, only 34. According to Scimago Journal & Country Ranking, in 2020, Sudan's H-index is based on 1329 documents in all subject areas, and only 138 documents in engineering [33,34].

Needless to say, the issue of research and publishing conditions, in addition to poor funding, is due to brain drain, obsolete facilities, inadequate educational technology and ICT environment, and weak university/industry relationship.

5. Recommendations

To brain storm and initiate a serious discussion about the engineering education, among all parties, this paper recommends the following:

5.1 Curriculum

The outdated engineering curriculum in Sudan is based on the western model, where engineering curriculum concentrates on the basic science and mathematics, and deals with technically and economically advanced countries. Therefore, a framework is required to design a comprehensive engineering curriculum capable of bridging the gap between pure science and technology, bear in mind the critical technological situation in Sudan. As well, the framework should allow a continuous reviewing and updating of the curriculum and link it to the country's economic and technical development conditions. Veza *et al.,* [35] have reviewed almost similar aspect, with specific emphasize on STEM education in Indonesia and reported how education reform has begun to take place.

5.2 Hybrid Model

To increase the capacity of engineering programs, and to overcome their inadequate facilities, academic institutions may introduce hybrid model that combine both online/offline e-learning, and the traditional face-to-face course delivery mode. The latter delivery mode may be reserved for practical part of the engineering curriculum, while the former delivery mode could be utilized for the theoretical content of the curriculum. As well, this delivery mode could be helpful in delivering virtual lab, which may help to overcome the shortage of the equipment and lab facilities.

Hybrid model may secure more opportunities for students to pursue engineering programs, and hence increasing the percentage of engineering enrolment, only 9.1% out of the total tertiary enrolment in 2018. As well hybrid model could be structured to combine both diploma and bachelor degrees to resolve the issue of the imbalance between diploma and bachelor graduates from engineering college.

5.3 Teaching and Learning Approach

For more than two decades, competency-based education (CBE), also known as Outcome-Based (OBE), has been adopted by many countries worldwide, and has proved to be very effective teaching and learning approach. According to Spady [36], OBE means, 'clearly focusing and organizing everything in the education system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organizing the curriculum, instruction and assessment to make sure that learning ultimately happens" [36].

I believe engineering education regulatory agencies in Sudan should consider adopting CBE/OBE approach to grantee qualified engineering graduates with the right set of technical and soft skills required by the job market.

5.4 Academic and Non-Academic Staff

To resolve the human capacity issues, the academic administration should audit the existing job hierarchy for any malpractice related to hiring administrative and academic staff and should restructure and eliminate any redundancy within non-academic staff. Moreover, the government should consider hiring structure of academicians that focus on recruiting and retaining qualified educators and linking their promotion and pay hierarchy to professional development programs.

5.5 Research and Publishing Condition

Improving extremely poor research and publishing condition requires establishing research and publishing infrastructure: from publishing and printing materials, and organizing biannual Sudanese engineering and engineering education conference, to issuing Sudanese scientific and engineering journals. In addition, Sudanese scholars should research and publish topics that relate to Sudan, in local, regional and international forums.

6. Conclusion

Issues of engineering education in Sudan are similar to the ones of SSA countries, which led to low number of qualified engineering graduates. Moreover, Sudan has never been included in the EI ranking that has been developed by the RAE, and the country is still lagging behind in all eight above-mentioned engineering indicators. However, as shown in Table 2, the number of 62 engineering academic institutions, the number of 61.6 thousand engineering enrolment, and more than 10K engineering graduates are far better than the respective numbers from all SSA countries, except South Africa. At the same time, these numbers are extremely low compared with the same numbers from Middle East/ North Africa countries.

Lack of enough knowledgeable and skilled engineers has crippled the development of the country. Therefore, any efforts to the country's sustainable development should start with revolutionize the engineering education. This requires planning, time and money, in addition to collaboration of all stakeholders, namely: Ministries of general and higher education, academic administration at institution levels, policymakers, engineers and engineering educators, whether from within Sudan or from Sudanese diaspora.

Extreme poor funding remains the truism of the critical situation of engineering education; thus, MoHESR should spearhead the education revolution efforts, starting with pursuing the government of Sudan to secure decent expenditure on education sector in general, and tertiary education, including engineering education, in particular.

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