# Concerns Fronting Engineering Education in Sudan: A Review

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**Abstract**
For decades Sudan, like most of Sub-Saharan African countries, has been facing profound engineering education issues, namely: poor funding, outdated curricula, ineffective teaching and learning methods, inadequate human capacity, poor research/publishing condition, inappropriate facilities, inadequate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, and missing of quality control and accreditation measures. The paper discussed these issues, and proposed solutions such as redesign of flexible curriculum, adopting learner-centered approach, and developing hiring structure that focuses on recruiting and retaining qualified educators, with the goal of graduating a high rate of qualified engineers, ready for the 21st century.

**Keywords**: Engineering Education, Sudan, Sub-Saharan Africa.

## 1. Introduction on Engineering Education in Sudan

Sudan is one of Sub-Saharan African (SSA) countries. It is located in Northeast Africa, and has boarders with seven countries: Egypt, Libya, Chad, Central African Republic, South Sudan, Ethiopia and Eritrea, in addition to the Red Sea coastline. Ethnoculturally, the country is amid of North Africa/Middle East Arab countries and the SSA countries.

The country is known of its abundant natural resources, which include: water, land, agriculture, forestry, livestock, crude oil, and minerals. In 2020, Sudan Natural Capital (NC) rank was 78 out of 180 countries. NC reflects the country's ability to sustain the population and the economy, now and into the future. However, globally Sudan is ranked very low in both Sustainability Competitiveness Index (SCI) and Intellectual Capital Index (ICI). Sudan is considered one of the lower-middle-income countries, and its GDP per capita is about $1990 (Sudan GSCI, 2020).

Since the country's independence in January of 1956, Sudan political system has been engaging in what is known as a 'Vicious Cycle', which consisted, of three cycles, of multi-party democracy, followed by a military coup, and ended with transitional period due to people uprising 'Intifada' against the military regimes. 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 these disastrous political practices, which include corrupt politicians, misallocation of limited resources, and exploitation of natural resources by both national and international corrupt companies, led to the country's significant social instability, civil war and great economic depression, in spite of the country's abundant natural resources. However, deterioration of all aspects of life on the country- socially, economically, and politically- has been attributed, to great extent, to the last military regime, which lasted for 30 years since June 30th of 1989. However, after throwing it out of power in April of 2019, the hope is high on the current transitional civilian government to lead the country into a proper democratic system, and hence, a prosperous country (UNDP Report, 2020; Sudan: a country study, 2015).

Schools of engineering prepare most of their graduates for employment in various industries as professional engineers; however small part of engineering graduates may seek other career paths as researchers and/or academicians. Hence, engineering education is different from vocational training; the latter prepares students to work as apprentices in many professions (Goodhew, 2010).

Accordingly, engineering education in Sudan is provided by higher colleges and universities. These academic institutions must be recognized and accredited by Ministry of Higher Education and Scientific Research (MoHESR), and all engineering graduates must be licensed and registered by the Sudanese Engineering Council (SEC).

To better-understand the situation of engineering education and its related issues, the evolution of engineering education in Sudan may be split into three periods. The first period was during the British Colonialism, from the actual start of engineering education in 1939 to 1956; the second period was from the independence of the country, in January 1956 to 1989; and the most recent period, lasted for 30 years between 1989 and 2019. The higher education in general, and engineering education in particular, have gone through very distinctive transformation during each of these three periods.

The first period, the inception of engineering education was in 1939, as part of the high school programs, to provide the British Colonial Government (BCG) with technical skills, for municipality functions.

Soon after, engineering college (EC), as part of Gordon Memorial College (GMC); and Khartoum Technical Institute (KTI) were established to offer their graduates bachelor of science and diploma in engineering, respectively. Both of EC and KTI were characterized by their limited enrolment and engineering graduates (Khojali, 2014).

The second period, after the independence of the country in January 1956, the EC has become part of University of Khartoum (UofK), which was known as GMC. EC has been expanding, and by 1976, its engineering programs included: mechanical, civil, architecture, electrical, chemical, surveying and agricultural engineering programs (Khojali, 2014; Osman, 2014; Berry, 2015). During the same period KTI has become Khartoum Polytechnic Institute (KPI). KPI has been offering both diploma and bachelor of engineering in electrical, electronics, mechanical, surveying, textile, and civil engineering (MoHESR, 1984-85 Census Data). The expansion of EC and PTI has resulted in gradual increase in engineering programs, enrolment, which passed 5000 engineering students by 1988, and engineering graduates that reached 624, by 1989. Additional two engineering colleges have been established as part of University of Juba and Jazeera University. They were established in 1975 (MoHESR, 1988-89 Census Data; Berry, 2015).

The third period has lasted for 30 years, between 1989 and 2019. During this period, engineering education, like all other social and economic sectors, has been influenced significantly by the autocratic government that took over in June of 1989 via a military coup. For quick political gain the government has organized a higher education conference, which was developed into what is known as 'Higher Education Revolution'. Thereafter, drastic changes were implemented to resolve the issue of limited capacity of higher education in the country. Accordingly, the number of public universities has increased by 9 folds, or from only 4 in 1989 to 36 public universities by 2018. Around 26 out of them have engineering programs. While the number of the private universities has increased from just 2 in 1989 to 13 private universities, or an increase of 6.5 times. Eleven of the them offer engineering programs. During the same period, technical institutes have increased by almost 7-fold, or from 12 to 83 technical institutes; about 25 out of them granted their graduates diploma in various engineering programs. As well, the capacity of these academic institutions has expanded significantly. The increase in tertiary enrolment, between 1989 and 2018, was increased 9 times, or from 57,000 to 680,000 students. At the same period, engineering students has increased by more than 20 times, or from 3000 to 61,600. Still engineering students, in 2018, made about 9% of the total tertiary enrolment. While the number of engineering graduates increased from 624 (in 1989) to more than 10,000 (in 2018) (Elhadary, 2010; Gasim, 2010; World Bank, 2012; Osman, 2014; Ettridge and Sharma, 2020; World Bank and MoHESR, 2020).

Nevertheless, the quality of engineering graduates has been compromised due to many reasons, of them are: Poor infrastructure of the engineering education, low government expenditure in education sector, and students under preparedness (El-Hassan, 1992; Gasim, 2010).

## 2. Engineering Education Issues in Sudan

For many decades, the issues of engineering education in SSA countries have been the focus of many researchers. In 1993, the World Bank described the state of engineering education in 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' (World Bank, 1993). On top of that, many research papers proved the situation is worsening rather than getting any better (UNESCO, 2010 and 2019; Idris, 2012; Mohamedbhai, 2014). Many researchers have been investigating challenges facing engineering education in Africa, such as: insufficient funding, outdated curricula, inappropriate facilities, lack of adequate human capacity, brain drain due to absence of academic freedom, as well as unattractive working environment in SSA, and missing of quality control and accreditation measures (Kumar et al., 2004; Afonja et al., 2005; Falade, 2008; UNESCO, 2010; RAE, 2012; Mohamedbhai, 2014).

The situation of the Sudanese engineering education is, more or less, similar to the situation in other SSA countries, except SA; and for decades, the deterioration rate has been accelerating, rather than improving (Elhadary, 2010; Gasim, 2010). Moreover, Sudan has never been included in the Engineering index (EI) ranking that was developed by the Royal Academy of Engineering (RAE), based on eight engineering indicators: Employment in engineering related industries, human capital investment in engineering, number of engineering businesses, the quality of infrastructure, the gender balance of engineers, the quality of digital infrastructure, wages and salaries of engineers, and exports of engineering-related goods. This is because of the country's weak performance related to all these engineering indicators (Ettridge and Sharma, 2020). In Table 1, the researcher summarizes the current issues of engineering education in the country.

The quality of engineering education depends on the role of the academic administration, at the institution level, in setting and monitoring efficiently the elements of engineering education, namely: curriculum, teaching and learning methods, capacity building, faculty and engineering environment (Smith, 2006; Webber, 2016; Osman, 2014). Any effort to improve engineering education in Sudan should start

**Table 1. The Current Issues of Engineering Education in Sudan**

| List of Current Engineering Education Issues | |
|---|---|
| i. | Poor Funding |
| ii. | Outdated curricula |
| iii. | Ineffective teaching and learning methods |
| iv. | Inadequate human capacity |
| v. | Students' under preparedness for College |
| vi. | Inadequate number and quality of facilities |
| vii. | Issues of quality control and accreditation measures |
| viii. | Other Issues:<br>o Absence of academic freedom<br>o Brains drain<br>o poor research/publishing condition<br>o inadequate educational technology and ICT environment |

with addressing the inadequate elements of engineering education as summarized in Table 1. Below is a brief about each of these issues:

*i. Poor funding*

Poor funding, which is due to the country's poor economic situation, could be considered the main reason for the most engineering education issues in Sudan. However, the root cause of this economic situation is due to bad political practices since the independence of Sudan. These political practices include corrupt politicians, misallocation of limited resources, and exploitation of natural resources by both national and international corrupt companies. Of course, engineering education sector, similar to all other social and economic sectors, has been facing severe financial crises. This financial crisis is evident by the education sector low share of only 2.7% of the GDP (in 2008), which has been decreasing until it reached 1.4% in 2014 (World Bank and MoHESR, 2020).

*ii. Outdated Engineering Education Curriculum*

Since the beginning of this century engineering profession has been undergoing another wave of innovation, which include, sustainability, radical resource productivity, whole system design, biomimicry, green chemistry, industrial ecology, renewable energy, and green nanotechnology (Hargroves et al, 2005). In-line with the same engineering innovation, Rugarcia et al. (2000) have predicted seven challenges that would face engineers of the 21st century. These challenges are: Proliferating information, multidisciplinary technological development, globalized market, endangered environment, emerging social responsibility, participatory corporate structures, and rapid changes.

Nevertheless, Sudanese engineering programs have not yet experienced significant changes to match the notable current wave of engineering innovation, along with the evolution of engineering education. Furthermore, at the very least, engineering programs in Sudan could be considered outdated, traditional programs with rigid curricular structure, heavy loaded with theoretical math and science courses; and even, teaching applied and design courses, which makes less than 10% of the engineering curriculum, has been affected by inadequate facilities (UofK website; World Bank and MoHESR, 2020). These theoretical courses are not aligned with the industry needs, and they are far from graduating qualified engineers, ready for the 21st century, in terms of knowledge and competencies. Lack of connection between the traditional engineering curriculum and the engineering as a professional career has been the main concern of engineering educators and researchers for more than 100 years; for instance, C. Mann (1918) said, '... engineering education will never be satisfactory until theory and practice are taught simultaneously. …'

On top of that, traditional curriculum does not consider diverse engineering students, in terms of different styles of learning and prior knowledge; and it lacks differential entry points and flexible progression pathways. According to Grayson et al (2013), there are five transition points that engineering students must pass during their bachelor program '1. From high school to university; 2. From basic sciences to engineering sciences; 3. From acquisition of knowledge to design; 4. From knowledge of discrete subjects to analysis of systems and integration of knowledge; and 5. From short, lecturer-led courses to extended student-led projects.'

*iii. Ineffective traditional Teaching and Learning Methods*

The traditional engineering curriculum, in Sudan, has been taught following the traditional teacher-centred philosophy (Osman, 2014). Prince and Felder (2006) defined teacher-centred 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 method does not promote active learning, deep understanding, based on learner's prior knowledge and learning style (Demirel, 2004; Prince et al., 2006; Felder, 2017).

*iv. Inadequate Human Capacity- Academic and non-Academic Staff*

Academic staffing of engineering programs in Sudan is two-fold issue: one is the low instructor-to-student ratio, which was estimated (in 2018) to be 1:34 compared to the required ratio, by regulatory agencies of the engineering education, of 1:15 (MoHESR, 2017-

18 Census Data). The other fold is the pre-service and in-service training of academic staff. According to Gasim (2014), about two third of all engineering academic staff have no doctorate degree in their discipline; add to that the inadequate professional development programs for engineering educators. (Osman, 2014; World Bank and MoHESR, 2020)

Poor financial compensation and the lack of academic freedom, between 1989 and 2019, have been the main reasons for brains drain; hence the shortage of highly qualified academicians in engineering education (Khojali, 2014; Osman, 2014).

*v. Students Under Preparedness for College*

Redesign of engineering curriculum has to consider the level of preparation of high school graduates, which has been influenced mainly by: the 11-year general education ladder, instead of 12-year standard general education, low education budget, inadequate curriculum, obsolete teaching methods, and lack of qualified schoolteachers (The Federal Ministry of Education, 2004; Osman, 2014; World Bank and MoHESR, 2020). 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 (World Bank and MoHESR, 2020).

*vi. Issues of quality control and accreditation measures*

There are two engineering and engineering education regulatory bodies, in Sudan: the MoHESR and the Sudanese Engineering Council (SEC). While SEC has been in charged with licensing and registering of all engineering graduates, in the country, MoHESR has been dealing with recognition and accreditation of engineering education programs based on rigorous accreditation procedures. In addition, in 2003, MoHESR established an academic, technical, and administrative accreditation and evaluation unit, with the following goals: i) to improve the quality and the performance of the higher academic institutions, ii) establish self-evaluation units within academic institutions, iii) upskilling the human resources, and iv) adopt and disseminate a culture of quality (World Bank and MoHESR, 2020). However, none of engineering programs has even applied for an international academic accreditation, such as ABET. This means that all quality control and accreditation measures of engineering programs should be revised from international accreditation perspectives.

vii. *Inadequate Facilities for Engineering Education*

The low number and poor quality of engineering facilities (libraries, laboratories, equipment, instruments, and supplies) are far less than the need of engineering colleges. As well, shortage of supplies and consumables is a real obstacle for conducting practical and hands-on work necessary for teaching and training engineering students.

*viii. Other issues*

Absence of academic freedom and brain drain, between 1989 and 2019, have been attributed to the autocratic government during this period. Fortunately, and due to the 'December 2018 Revolution', academic institutions have started claiming their academic freedom (World Bank and MoHESR, 2020).

Poor research/publishing conditions is the main reason for too low research and publishing activities, especially in engineering with H-index of 34, which based on only 138 documents (in 2020), (Kenoma.com. World Data Atlas; SCImago Journal & Country Rank).

## 3. Engineering Education Research in Sudan

While searching graduate studies programs at UofK and Sudan University of Science and Technology (SUST), known as KPI, in addition to the google scholar, the researcher found a wealth of information about Sudanese general education (K-12). These studies split into: (i) descriptive research, without proper frameworks or models for evaluating the general education; and (ii) at a lesser extent, studies based on some learning theories and/or educational frameworks/models. Searching SCOPUS over the last 20 year, only 21 engineering related documents were found compared to more than 900 all education documentation, see Figure 2.

In addition to general education research, many descriptive studies were found about the tertiary education in Sudan; nevertheless, only a limited number of them were based on learning theories and frameworks. Examples are: ICT integration in technical and vocational education and training, Sudan (Ramadan et al., 2018); investigating the success of business intelligence in aligning higher education and labor market (Elhassan, 2020); barriers for implementing ICT for higher education in Sudan (Suliman et al., 2007); bridging higher education and market dynamics in a business intelligence framework (Elhassan & Klett, 2015); barriers facing English language teachers in applying the learner-centred approach; a business intelligence-based framework to align higher education output with labor market in Sudan (Elhassan, 2020); investigation of the 'Learning Modes' and its Learner-Centeredness in Higher Education Institutions in Sudan (Arman, 2020); investigated the challenges of implementing performance measurement systems (PMS), by one of the public Sudanese university (Alboushra et al., 2015); higher education in Sudan- a situational overview (Elhadary, 2010); change and development of higher education in Sudan (Mohamed & Abdul Rahman, 2020).

However, none of the above examples were addressing engineering education. In fact, only limited descriptive studies were related to engineering education, for instance: role of technical scientific research education in sustainable development and conservation in Sudan (Omer, 2011); trends in electronic teaching and learning in engineering education, (Taha, 2013); engineering education for sustainability and economic growth in developing countries, the Sudanese case (Abu-Goukh et al., 2013); biomedical engineering education challenges and opportunities in Sudan (Elhadary, 2010); and none of them were based on educational theories and/or proper frameworks. Without a proper framework, no one would be able, objectively, to identify factors that, negatively or positively, impact the engineering education in Sudan, and to lay out the foundation for designing learning environment capable of advancing the engineering education, as a whole, within the context of Sudan.

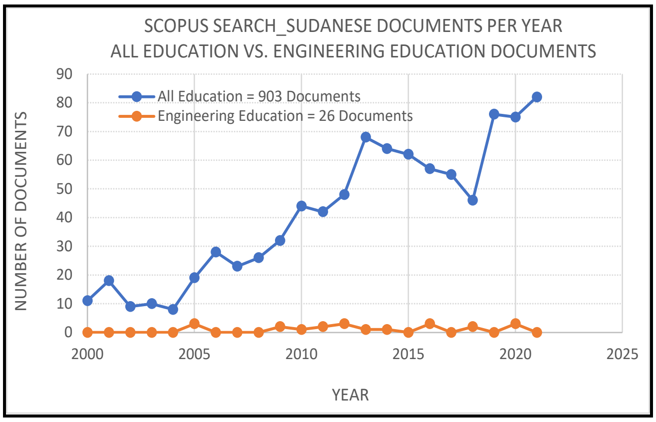


**Figure 1. Sudanese Documentation- All Education vs. Engineering Education**

Clearly, there is a big gap as far as engineering education research in Sudan is concerned. Therefore, there is a need for a lot of research efforts to fill the gap. This study is just a step in bridging this gap, and hence building better engineering programs for prosperous Sudan.

## 4. Proposed Solutions

The issues of the Sudanese engineering education are very deep and complex. Therefore, efforts for resolving them must be creative, patience, and inclusive, with input from all stakeholders. As well, solutions must consider the 21st century development in the areas of engineering profession and engineering education.

### *i. Curriculum Renewal*

To graduate a high throughput qualified engineers, ready for the 21st century, with the right sets of knowledge and competencies, curriculum must be redesigned and must undergo continuous revisions. Curriculum renewal could be underpinned on the principle of flexible and extended curriculum:

Flexible curriculum should extend over a six-year period that includes 5-year engineering program in addition to an extra foundation year. The foundation year is to help students, who need it, to make a smooth transition from high school to college atmosphere. The foundation year may cover additional math, sciences, and pre-college engineering courses. However, the design of the curriculum should permit capable students to complete the engineering program in 4 years. In addition to foundational courses, the curriculum should include developmental courses to help engineering students to get through above-mentioned transitional points.

Overloading of engineering students with too many courses might not necessarily a good recipe for graduating knowledgeable and skilful engineer, ready for the 21st century. Therefore, re-design of a flexible curriculum should specify just required topics, including attributes, to graduate qualified engineers; then distribute all these topics over a 5-year program, with a logical sequence of concurrent courses, horizontal coherence, and successive courses, vertical coherence.

### *ii. Teaching and learning approach*

Redesigned curriculum goes hand on hand with a suitable, learner-centred teaching and learning approach (T&L). In order to promote students' progression in engineering program, and to well-prepare engineers for facing 21st challenges, T&L approach could be underpinned on the following principles:

Constructivism: Biggs (1996) noted the significance of constructivism in improving the tertiary education because constructivism sees learners actively construct meaning by using individual and social activities. Constructivism is a widespread theory, which deals with human constructing their knowledge through experience and learning through active process (Newstetter, 2014). With the learner in control, he/she create and stores mental models (Bartlett, 1932; Dewey, 1916; Piaget, 1973 &1978; Glasersfeld, 1989). These learned models (constructions) vary among learners based on their prior experiences. Moreover, Price & Felder (2006) consider Problem-based Learning (PBL), Project-based Learning (PjBL), and Collaborative learning (CL) as strategies that most of the time follow constructivism framework.

How People Learn (HPL): HPL is based on three learning principles: active learning- learner in control (metacognitive skills) and educator act as a facilitator; learner constructs and stores models (cognitive) based on learner's prior knowledge; in depth knowledge (deep understanding); and student-centred learning philosophy.

Outcome-Based Education (OBE): Outcome-Based (OBE) was developed by W. Spady in 1994. Since then OBE has been adopted effectively by many countries worldwide. He believed that the purpose of school is to prepare learners for their role in life after school years, which could be achieved following what is known as transformational.

Constructive Alignment (CA): Biggs introduced CA to ensure that OBE is following constructivism theory, and to fill the gap between learning outcomes and teaching/learning activities. CA aligns assessment and teaching activities with learning outcomes (Biggs, 2011).

*iii. Academic and non-academic staff*

Teaching and learning, in tertiary education, are complex and hard because of a faculty multiple role in instruction, course and content design, material construction, mentoring and advising, etc. (Fink, 2008; Simonson et al. 2021); it requires three levels of appropriate faculty preparation: i) content knowledge, ii) general pedagogical knowledge, and iii) content pedagogical knowledge. The former content knowledge is based on a proper pre-service qualification; however, the latter two levels of professional knowledge are achieved through proper professional development programs, in-service training (Fink, 2008).

Therefore, the starting point to resolve the issue is to revise any malpractices, during 1989-2019, with the goal of identifying and eliminating all types of wastes related to staffing issues; then to develop and implement a hiring structure that focuses on recruiting and retaining qualified educators, with proper pre-service qualification, and linking their pay scale and promotion to professional development programs, in-service training.

*iv. 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.

## Conclusion

There are many concerns fronting engineering education in Sudan. However, poor funding represents the main concern, which is directly affecting the infrastructure issues (inadequate human capacity, poor research/publishing condition, inappropriate facilities, inadequate educational technology and ICT environment, weak university/industry relationship), and indirectly affecting the issues of outdated engineering curricula and ineffective teaching and learning methods. The paper discussed and proposed solutions to increase the rate of well-trained engineers ready to face the 21st engineering challenges. Enough number of qualified engineers is a necessary condition for a sustainable development of any nation.

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