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Engineering education, development and growth in Africa☆,☆☆

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Africa is trying to overcome the challenge of having significant shortage of engineering skills [17]. The shortage is felt throughout the continent while amplified in some parts. For example, in 2013, UNESCO Director-General, said that, “in Namibia, Zimbabwe and Tanzania, there is one qualified engineer for a population of 6000 people–compared to one engineer per 200 people in China [and 1/311 in UK; 1/227 in Brazil].” In one sector (water and sanitation), it was estimated that 2.5 million new engineers and technicians are required in sub-Saharan Africa (SSA) in order to meet the development goals on access to clean water and sanitation.

Yet, paradoxically, many engineering graduates in the same countries mentioned above, and others, find it difficult to land employment in engineering fields. Although it may sound confusing at first, that demand for engineers and unemployment of engineers happen simultaneously, a valid explanation is not only about the number of engineers in the job market, but the number of engineers (and engineering practitioners in general) with matching skills for the jobs awaiting them. What this means is that the bottleneck in this line of progress–from studying to graduation to professional career–may be found around how and when new engineers are prepared for work with combined employment skills that are not all ‘core’ engineering skills (i.e., the basic skills taught in standard engineering academic programs). Such combined skills may be called ‘employability skills’ and they encompass, besides core engineering skills, others such as reliable communication, task and time management, familiarity with local processes and industrial standards, and related administrative skills. In addition to that, other explanations could evoke policies and practices related to incentive frameworks for engineering skills in any given society (e.g., career satisfaction, financial incentives and work environments). In any case, all possible, valid explanations deserve investigation.

A study that was carried out by the Royal Academy of Engineering [14] concluded that engineering academic staff in higher learning institutions in SSA “had very little exposure to engineering practice [in industries and public works]” despite

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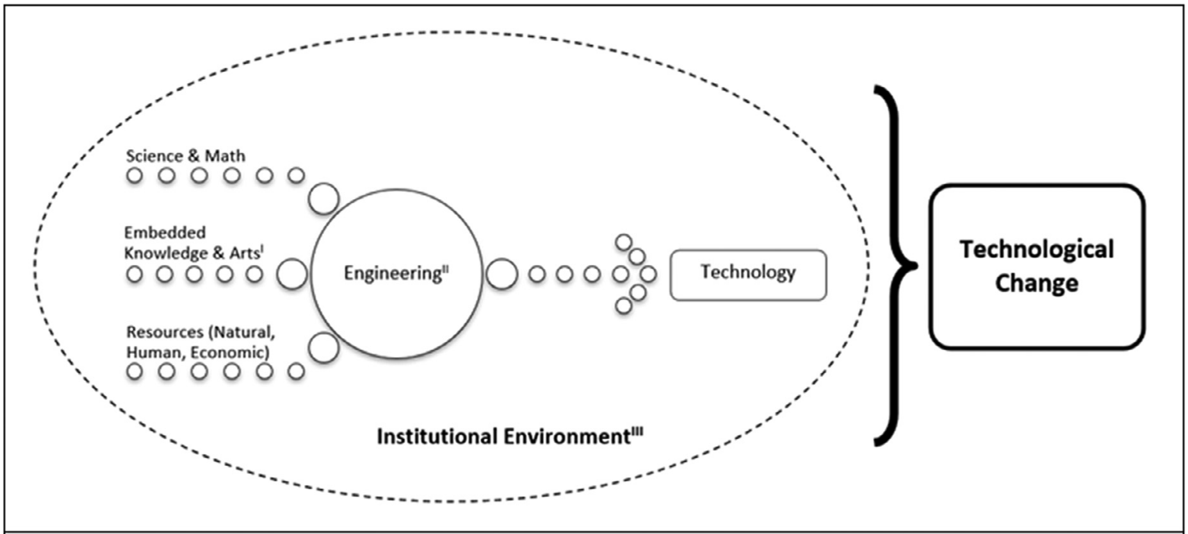

I. Embedded Knowledge & Arts: representing indigenous technical knowledge, customary technologies and local artisans' expertise.
II. Engineering here refers to the conscious process of digesting and combining the factors of Science & Math + Embedded Knowledge & Arts + Resources to create and operationalize technology. Not the exclusive modern academic definition of engineering.
III. The dotted area represents all the enveloping institutions – i.e. the institutional environment – with which all the factors' dynamic interaction takes place.

Fig. 1. Visualization of the definition of technological change
Source: [15], p. 22.

being well-qualified. The teaching style in most academic institutions in the region was described as "chalk and talk" as opposed to problem-based learning (PBL). Another study, in 2014, by the Inter-University Council for East Africa, reported that in Uganda about 63% of university graduates were not equipped with job market skills—Tanzania, 61%; Burundi, 55%; Rwanda, 52%; and Kenya, 51% [12]. In Tanzania, a study on local technological capabilities and foreign direct investment, by the Science, Technology and Innovation Policy Research Organization (STIPRO), in 2011, indicated that in manufacturing, agriculture and mining, weak linkages between local and foreign investments were partly due to expressed concerns about the limited technological capabilities of local labour and firms [16]. Overall, the big picture looks like while there is indeed a quantity problem in engineering, the bottleneck in the line is a quality problem.

The role of engineering education in development

Engineering plays a key role in development: technological capabilities, industrial activities, and economic growth. It is attributed that Lawrence Joseph Henderson (1884–1942), biochemist and philosopher, said that, "Science owes more to the steam engine than the steam engine owes to science." The quote is often used to summarise the argument that, in most of history, thus far, technological breakthroughs often ushered in scientific breakthroughs more than the other way around (as typically perceived nowadays). Even in the industrial revolution, for example, it was the steam engine, a product of engineering, that opened demands and curiosities for understanding heat transfer and thermal energy, ushering investigations that led to the discovery of the laws of thermodynamics.

In the contexts of developing societies, engineering is the main catalyst of technological change, while technological change is essential for economic growth and human development. What we refer to by engineering in this context is the process of digesting and combining knowledge, resources and arts to create and operationalise technology [15]. Engineering, in this sense, is not necessarily the designated profession itself, but the designated profession is surely part of it—an important part (see Fig. 1). Sustainable growth requires increasing high-output labour (i.e., high-skill labour). Given that, engineering education should be understood as quite influential on both economic growth and innovation in Africa. As other continents, Africa had its share of advancing the field of engineering throughout history, ancient and modern [3,8], yet the contemporary conditions and challenges of development require larger attention to engineering as understood and practiced in the modern, globalised world.

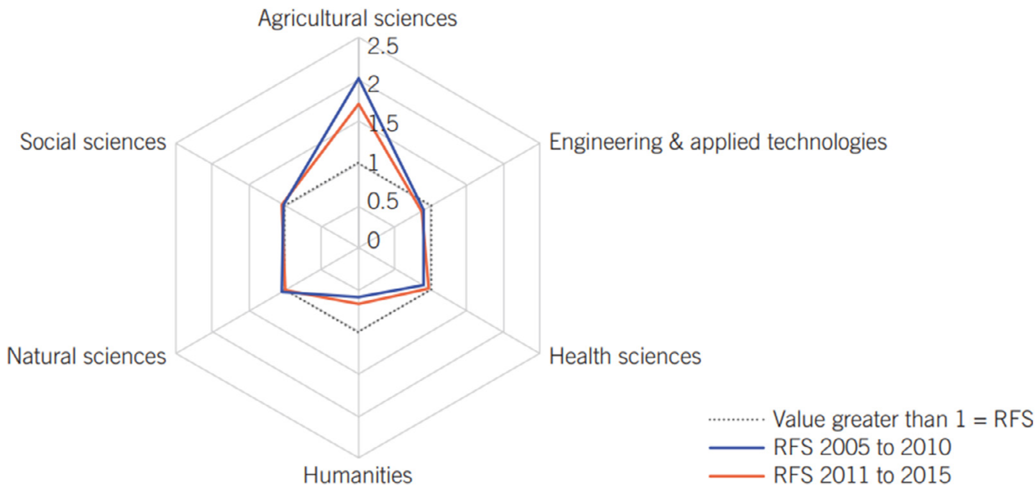

Fig. 2. Relative field strength index of Africa.
(in terms of global contribution to six main fields, from 2005 to 2015)
(*Creative Commons Attribution 4.0 International License-CC-BY).
Source: [1], p. 20*.

Gaps in policies and capacities

The current shortage in quantity and deficiency in quality, in engineering in Africa overall, can be traced more specifically to gaps in policies and capacities, which are not always specific to engineering yet inclusive of it. Based on the literature that gathered feedback from African universities, industries and public agencies, some of the main gaps are:

- Dramatic decrease of national funding for African higher learning institutions, since the late 1980s and early 1990s, which resulted in crowded classes, weaker laboratories and abilities to provide effective education/training [1].
- Increased reliance on foreign funding in Africa's higher learning institutions is generally considered a sign/symptom of the 'de-institutionalisation of science' [11]; meaning that scientific training–in science, technology, engineering and mathematics (STEM) as well as management, economics, etc.–are barely supported through national enabling environments as pillars for human and economic growth.
- Policymakers do not seem to have sufficient understanding of engineering problems. For example, the Royal Academy of Engineering [14] reported that, "42% of the professional engineers believed policymakers had a poor understanding of engineering issues, with only 14% believing they had a good understanding." This, in turn, results in other deficits, such as weak linkages between industries, training and R&D.
- Brain drain weakens human resources overall, affecting both productive capacities and purchasing powers in a country or region [13]. "In parts of sub-Saharan Africa and Central America, sometimes more than half of all university graduates migrate to OECD countries" [19]. The trend is even increasing—a 2016 report by the IMF says that "migrants [from sub-Saharan Africa] in OECD countries could increase from about 7 million in 2013 to about 34 million by 2050," while acknowledging that "the migration of young and educated workers takes a large toll on a region whose human capital is already scarce." ([6], pp. 197–98).

All the above have impacts on Africa's standing in terms of knowledge production in related fields as well. In terms of engineering and applied technologies, the last few decades witnessed a decline in Africa's contribution to global knowledge production (partly due to the increase of outputs by other countries around the world even if Africa's contribution increased a little or remained stagnant). However, there have been recent improvement in knowledge production in Africa (by African scholars), but not much in the Engineering and applied technologies (see Fig. 2).

Thinking of possible remedies

Recently, some research activities in Africa have endeavored to explore possibilities to bridge the gaps in policies and capacities, discussed above, in the 'engineering systems', nationally and regionally [7]. The aim of these activities–composed of surveys, action research studies and capacity building projects–is to enhance engineering ecosystems in multiple African countries through building more evidence for possibilities of improving engineering education by linking theory, practice and policy. These activities seem to be guided by general concepts and directions, such as:

- Employability is having the set of knowledge, skills, understanding and attributes to gain and maintain fulfilling work.
- Linkages with industries should be a reality, not an aspiration. Pedagogical approaches such as Problem Based Learning (PBL) are instrumental in realising these linkages [10].

- Research shows that quality and quantity of co-curricular training (internships, competitions, secondments and co-ops) adds significantly to the competence of engineering students [2,4,5].
- Systems have leverage points that can animate them differently. Systems are sets of things (people, machines, procedures, etc.) "Interconnected in such a way that they produce their own pattern of behaviour over time" ([9], p. 2). In this case, we are generally speaking of a 'techno-social system', where people and technologies combine efforts that fulfill various and interconnected functions in society [18].

In summary, we may think about it in simplified terms this way: if the competency of engineering graduates in Africa is increased, through enhancing and strengthening engineering education, then the employability of those graduates would likely increase, thus making an engineering degree more attractive for incoming college students to enrol in, therefore eventually increasing the number of engineers.

Finally, a general understanding is growing that policy is the catalyst of possibilities. To have broad and long-lasting impacts on engineering education in Africa, for the sake of sustainable development and growth, solutions should be articulated as policies—formulated, implemented, embedded and supported.

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