

## Technical Papers

### Student industrial secondments in East Africa: Improving employability in engineering

**Musambya Mutambala**

*Science, Technology and Innovation Policy Research Organization (STIPRO), Dar es Salaam, Tanzania  
musambya.mutambala@stipro.or.tz*

**Gussai Sheikheldin**

*STIPRO, Dar es Salaam, Tanzania  
ORCID: 0000-0001-8734-3134*

**Bavo Nyichomba**

*College of Engineering and Technology, University of Dar Es Salaam, Tanzania  
nyichomba@udsm.ac.tz*

**Bitrina Diyamett**

*STIPRO, Dar es Salaam, Tanzania  
bitrina.diyamett@stipro.or.tz*

**Abstract**—Relative shortage of engineering practitioners in Sub-Saharan Africa has been a big concern for many studies on industrial and technological development. However, the region that suffers from this shortage simultaneously has a significant number of existing engineering graduates who find it difficult to land employment in engineering fields. While that situation reflects inability to have enough human capital in industrial processes, two scenarios partly explain the situation: a relative deficit (real or perceived) in the competency of local engineering graduates in ever-advancing areas of science, technology, engineering and mathematics (STEM), and/or scarcity in opportunities to hone and demonstrate competency of local engineering graduates in the labour market. Consequently, local engineering graduates have inadequate hands-on experience needed in industries as well as for establishing start-up engineering firms/businesses. To address this situation, it was postulated that promoting engineering student industrial secondment (SIS) programs can be a suitable approach to strengthening the linkages between engineering study, practice and employability. Since completing academic engineering majors is apparently not enough by itself to bridge the skill gap and prepare most engineers to enter their countries' engineering practice fields, and the currently existing student placements seem to have some serious flaws, the present study was launched with the aim of exploring best practices, for evidence-based policy learning in establishing and running robust engineering SIS programs coordinated between universities and industries – and perhaps with support from the public sector – to serve both industries and students. Using innovation systems and systems thinking as conceptual and theoretical framework approaches, the study included surveying in Tanzania, Kenya, Uganda and Rwanda in addition action research by piloting four SIS placements in Tanzania and Rwanda; the main objective being to observe closely, try potential modules, and learn and synthesize effective experiences of SIS program from developing countries.

*Keywords*—East Africa, employability, engineering education, student industrial secondments

#### I. INTRODUCTION

Engineering fields play a crucial role in developing solutions to the world's technical issues; they bring ideas into reality and particularly contribute to strengthening the capacity of the industrial sectors (SDG 9) which is critical for sustained economic

growth (SDG 8). In addition, improving the status of engineering is linked to achieving SDG 4 on knowledge and skills acquisition that would address both qualitative and quantitative knowledge deficits in science, technology, engineering and mathematics (STEM), which stimulates efforts to revitalize interest in paying more attention to engineering in developing countries [1]; [2]; [3] and view engineering as catalyst of technological change. On the other hand, technological change is essential for economic growth and human development. Engineering in this sense is the process of digesting and combining knowledge, resources and arts to create and operationalise technology [4].

Historically, engineering education in East Africa (EA) began later than many other disciplines, such as the social sciences. With the ambition to increase high-output labour (i.e. high-skill labour) in order to push economic growth forward, engineering education at post-secondary levels was established to increase local engineering practitioners. The formation of the East African Community (EAC) in 1967, shortly after independence, helped unify the education system across the countries in the region, especially that higher education institutes were not many [5]; [6]. At the time, engineering students from Tanzania and Uganda used to study at the University of Nairobi, Kenya, as the nearest engineering school in the region.

Things evolved from there and the number of engineering schools and graduates increased as well, however, not in concert with the increasing needs for qualified engineering practitioners in EA [7]. Structural adjustment programs, promoted by in the 1980s by the World Bank and International Monetary Fund (IMF), affected the education sector in African countries in visible ways. "The back on full state funding saw cost-sharing introduced across most levels of the [education] system; the gains in expansion particularly of schooling stagnated and even reversed in the economic decline of the 1990s" [8]. Tanzania, for example, received a significant blow to university-level education quality, and sought to mitigate it by increasing classroom size, introducing measures of cost-sharing with student families, and even cutting budgets on items and services such as maintenance of laboratories and updating curricula; Kenya was not a very different case as well [8]. The picture in EA, however, is not different from the average situation in the continent. A global report by UNESCO, published 2010, emphasized that Africa was struggling with a serious shortage of engineers and technicians – i.e. engineering practitioners – compared to the needs of development, and estimated that, for example, 2.5 million more engineering practitioners are needed to meet the millennium development goals (MDGs) for water and sanitation alone [2]. Later on, surveys from academia and industry

indicate both numbers and competencies of local engineering practitioners in the continent require improvement [10]; [11].

Nevertheless, where EA and SSA overall experience such a relative shortage of engineers, there are also plenty of graduate engineers who do not land employment in their fields. It is also common that foreign agencies involved in engineering-related activities in the region (as private companies, transnational corporations, NGOs or international agencies) resolve to hiring expatriate engineers and technicians before hiring a satisfying quota of local engineering practitioners, citing limited competency and knowledge of industry's standards among local engineers (particularly young and early-career ones) as reasons for doing so. At country levels, the status of engineering in EA shows varieties of differences between demand and existing opportunities.

A logical question arises from the two realities (of relative shortage of engineers and inability of many existing engineering graduates to land engineering employment): if significant numbers of the existing engineering graduates find it difficult to find employment in engineering fields, how can it be concluded that African economies require more engineering graduates? There must be a gap that is responsible for this dissonance.

Some studies point towards a possible explanation that, for engineering education to produce favourable results in bridging theory and practice, practical training has to be integrated in a number of co-curricular activities such as industrial training/attachment, internships with industries after graduation, voluntary activities related to field of study, and joint clubs or organizations [12]. Literature in North America and Europe has widely shown the importance of co-ops – what we call student industrial secondments (SIS) – and industrial attachment programs in increasing capacities of students in solving real-world problems.

Studies indicate that such co-curricular activities particularly enhance leadership skills and ethical development [12], enable satisfaction of both students and employers [13]; [14], increase chances of employability shortly after graduation [15]; [14], and reduce companies' training costs for newly hired graduates due to hiring better prepared graduates [14, p.6]. Other pedagogical approaches, particularly in Europe and Africa, that complement co-curricular activities in order to produce competent, work-ready engineering graduates include the context-based curriculum design [8] and problem-based learning (PBL) [16].

The context-based curriculum approach takes into account the level of technological capabilities, as well as needs and priorities in the country/region so that they reflect on such context and help graduate students that are familiar with it and can positively influence it. PBL, on the other hand, has shown relevance and utility in addressing development challenges at both local and global scales, whereby students are engaged in projects taken from real-world cases (past or on-going) to work on. The projects need to be exemplary, that is “learning outcomes achieved during concrete project work are transferable to similar situations encountered by students in their professional careers.” [16] Engineering education programs in EA and Africa at large have experience with implementing co-curricular activities and practical training programs.

In some countries such as Uganda most local engineering graduates find employment within one year of graduation [22] while other countries report a significant number of local engineering graduates finding it difficult to land jobs within their

fields [11]; [23]. Studies have therefore called for investigation of the competence of engineering graduates as the findings have revealed deficiencies whereby in Uganda at 63% of graduates lack job market skills, while in Tanzania, 61% were found to be ill prepared. In Burundi, and Rwanda 55% and 52% respectively were perceived to be incompetent, and 51% of graduates in Kenya were believed to unfit for jobs [7]. Other sources [24] similarly report weak linkages between foreign investments, local skills and capabilities were partly explained by limited technological capabilities of local labour and firms in the Tanzania manufacturing, agriculture and mining sectors. Other studies [11] report existence of very little exposure to engineering practice in industries and public works, and described the teaching as dominated by “chalk and talk” as opposed to PBL and more practical/engaging style of learning.

One way of approaching these challenges in engineering education in EA is to look at it within “engineering ecosystems”. The notion of ‘ecosystem’ implies many things, such as multiple actors with interdependency between them, and the important role of aspects of systems, such communication channels, feedback loops, timeframes (short-term, medium-term and long-term), unintended consequences, and so on. It is a promising approach because it admits complexity and seeks to navigate ways of dealing with it, instead of reducing it into separate components (often referred to as ‘analysis’) to identify problems located in components separately, while such problems are likely located in how components interact in a complex system than located in one particular component [3]; [9].

A critical question is therefore “what are the opportunities and challenges to enhancing students’ employability?” The discussion around the best practices is an important aspect of responding to the question..

In this study, we take the critical question above as our research question, and we examine the best practices, and the findings are relevant for evidence-based policy learning in establishing and running robust engineering SIS programs coordinated between universities and industries – and perhaps with support from the public sector – to serve both industries and students. The study aims at contributing toward measures with which EA policies (national and regional) could explore the approach of enhancing SIS programs.

## II. METHODOLOGY

This study used innovation systems (IS) (as a conceptual framework) and systems thinking (as a theoretical framework) to gain knowledge and understanding of the potential of tertiary student industrial secondment (SIS) programs in strengthening engineering ecosystems in East Africa. IS is important in organizing the productive forces and structures, and the flow of information and skills in order to increase the output of innovative solutions to development constraints [27]. It involves a careful investment in education systems, enterprise support and labour markets [28]. Systems thinking, on the other hand, overlaps with such understanding of IS, and views various phenomena as “systems”, i.e. sets “of things – people, people, cells, molecules, [machines, procedures, etc.] – interconnected in such a way that they produce their own pattern of behavior over time [29]. The use of these approaches was meant to strengthen the linkage between engineering study, practice and employability through understanding leverage points in engineering ecosystems, as the study postulate that promoting engineering SIS programs can be

a suitable approach to strengthening these linkages. The study mainly aimed at observing closely, trying potential models and learning and synthesizing effective experiences of SIS programs from East African countries.

Methodologically, the study used a qualitative approach - historical case study strategy - and employed both primary and secondary data through survey and review of different reports that synthesize effective experiences of SIS programs in EA and from other parts of the world. The survey exercise was conducted in the four (4) EA countries of Tanzania, Kenya, Uganda and Rwanda in terms of previous and current experiences of engineering, undergraduate SIS programs and their indicators of effectiveness (qualitative and quantitative).

In Tanzania, we conducted key-informant interviews with university faculty, state officials in research councils and engineering boards, and industries and industry bodies that were involved in and familiar with engineering students' practical training programs. A similar process - on a smaller scale - took place in Kenya. In Rwanda and Uganda we had general meetings with engineering university faculty and public officials in research councils who were able to provide us with lists of public sources of information and comprehensive studies (i.e. secondary data) that were relevant to our research questions.

The secondary data were collected from the public documents in relation to the study objectives. Generally, data focused the history of the practices in EA and on the best practices among the reviewed programs (within EA) as well as best practices known in other countries with comparable industrial conditions to EA, to recognize gaps in the status quo. These activities were meant to produce critical findings on ways to design and implement engineering SIS programs in EA.

The study is currently half-way through and as of now has completed phase I (survey activities), which is treated in this respect as stand-alone. Phase II (pilot - action research) is ongoing, after which synthesis and learning from both phases will be combined to produce policy lessons.

### III. PRELIMINARY FINDINGS AND DISCUSSION

Preliminary findings indicate several similar experiences with student industrial training programs and initiatives in terms of models, challenges, feedback loops and perspectives of stakeholders. SIS models are the same and have been so since engineering departments were established in most of the East Africa region.

#### A. *Arrangement between academia and industry in involving engineering students*

The arrangement between academia and industry in major EA engineering programs, in universities and institutes of technology, that involve engineering students or fresh graduates shows that the period for practical training program has been designed in a way to build engineering experience from artisans/hands-on to higher levels of engineering practices. Engineering schools prepare first year students as artisans, second year as technicians and third year students as engineers. In Tanzania, for example, on average, 2500 students from the Dar Es Salaam Institute of Technology (DIT) and 1800 students from the University of Dar Es Salaam (UDSM) go for practical training every year. The capacity to accommodate the students is also limited as on average it was

estimated around 120 industries per year host the students. All the engineering schools and students compete for placements in the limited existing industries. In Rwanda, industrial attachments take 10 weeks in organizations of students' specialty just after the completion of the third year. In Kenya, students in industrial attachments have logbooks on which they are expected to record daily assignments, and universities ensure that students report to their respective attachment places through an assessment form.

#### B. *Engineering education and employability: numbers and trends*

Tanzania leads in terms of registered engineers in the region. 63% of the registered engineers in the EAC are from Tanzania [22, p.41]. However, benchmarking in the Southern African Development Community (SADC) shows that Tanzania has about 60 engineers practitioners per 100,000 persons, which is actually low in the region [25]. In Uganda, a tracer study conducted between 2008 and 2012 on "Ugandan engineering graduates" shows that civil engineering graduates lead in proportion (25.7%), followed by telecommunication (17.6%), mechanical (17.2%), electrical (14.1%) and agricultural (5.4%) engineering. Despite having a good record of employment shortly after graduation, according to the tracer study, the majority of Ugandan engineering graduates (91.7%) were not formally registered due to, among many other reasons, lack of minimum requirements for registration. Like Tanzania, Uganda has a small per capita ratio of engineers per population (one engineer per 53,000 people versus a desired global average of 1:770). In Rwanda, although no aggregated data were provided, the 2014 tracer study of graduates from higher learning institutions (HLIs) revealed that engineering graduates lead compared to other disciplines. Between 1996 and 2013, the report shows that 6180 students graduated with engineering degree as compared to 2286 from medicine and 3739 from ICT. According to the World Economic Forum Executive opinion survey, Rwanda ranked 74th (out of 148) in the world in terms of availability of scientists and engineers, and 125th in objective measurements of enrollment in tertiary education [21]. The UNESCO Go-Spin report on Rwanda concludes that the fields of medicine, ICT and engineering experience critical skills gaps. In addition, Rwanda has a 15% unemployment rate, which is explained by challenges in synergy and partnerships between public and private employers with HLIs. A 2017 UNCTAD report on Rwanda says that "each year, 1400 engineering students successfully graduate. In the last promotion [2016], 300 had found a job in government structures and 200 in the private sector, while the others are searching for a job, and this in spite of an unresolved skills gap." [20, p21]

#### C. *Main policies and institutions that Influence the engineering ecosystem*

EAC member states have in place institutions and policy framework that play an important role in influencing the engineering ecosystem in the region. Academic institutions are mostly at the centre of the system, and the synergy among the actors is influenced by the nature and quality of the policy and institutions in place. For example, the EAC treaty (article 104) allows free movement of persons, labour, services and right of establishment and residence. The Mutual Recognition Agreement (MRA) for engineering professionals signed on the 7th of December 2012 enables recognition of professionals (registered) of one member state in other member states [22, p.41]. Engineering Registration Boards (ERB) exists in each country with a similar mandate: to make sure that licensed engineers are competent enough to lead projects and missions of engineering nature and that they are capable and aware of safety and quality standards.

At the national level, for example, in Rwanda, the achievements observed in engineering education in terms of enrollment and the level of performance as revealed by different reports indicate serious trends toward change in the national policy of workplace learning [26]. Although the existing policy is designed for technical and vocational training, rather than tertiary, it reflects a general approach toward bridging skill gaps in STEM by using workplace training (internships) and industrial secondments.

In Tanzania, on the other hand, the Higher Education Students' Loans Boards (HELSB) is a funding mechanism that offering loans to students and plays an important role in the engineering ecosystem through having a say in terms of access to education and time the students are required to finish their studies and pay back loans. In addition, there exists the Structural Engineering Apprenticeship Program (SEAP) - a program established under ERB that funds engagement of fresh engineering graduates to qualify for registration as professional engineers.

Kenya has in place a new body called the National Industrial Training Authority (NITA) that engages in sponsoring students' placements in industries. In addition, organizations such as Linking Industries with Academia (LIWA) provide training and linkages between industries and academia through, for example, facilitating students' placements at industries.

#### D. Observation and Potentials relevant to Engineering Ecosystem

General observations and potentials relevant to engineering ecosystem in the region show the existence of functioning frameworks. In Tanzania for example, frameworks have mostly built upon early establishments from the post-independence period, and they seem to work at the minimum capacity level since few changes take place or divert from what is established, calling for political will to take advantage of the stability to move gears to adjust or transform the enabling environment.

Uganda has many cases of engineering expatriates who come with foreign companies contracting projects in the country. Also, certified engineers from other countries in EA come and work in Uganda, while few Ugandan engineering practitioners are licensed/registered engineers. Under such conditions there is little 'know-how transfer' between foreign and local engineering practitioners, a situation that begs to be addressed.

In Rwanda, taking advantage of the smallness of the country, national policies go with strong coordination, and plans are enforced once approved. In fact, such a situation may sound good or bad depending on the type of policies and implementing institutions. Sound policies – evidence-based or strategy-informed – trigger real opportunities of improvement, while unsound policies bring unintended consequences.

The experience with linkages in Kenya between academia and industry is manifested through the students' assessment forms designed by universities and filled in by industries. Universities rely on those forms to understand students' performance.

Furthermore, the study recorded similar challenges across countries, voiced by student, faculties and industries alike. For example, all four countries reported insufficiency of supervision, placement and financing for students in industrial attachments or practical training programs. The insufficiency in the level of supervision was explained by the number of engineering students that keeps increasing compared to the number of industries in operation in each country.

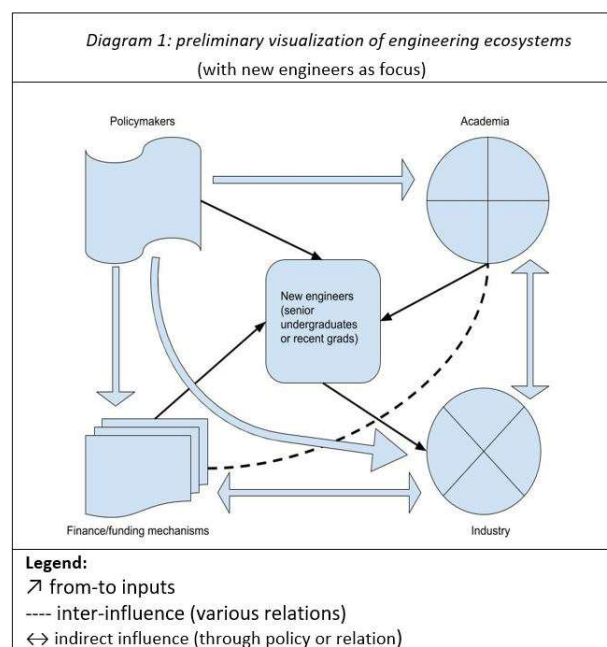
## IV. PRELIMINARY DISCUSSIONS

Weak documentation of the history and present of SIS programs (or industrial training/attachment programs) was one major challenge faced by the study team. Most stakeholders that the study team met could not offer more than verbal information, although the team requested that any relevant documentation be shared. The unavailability of, or weak access to, such records makes it a challenge to have a rigorous investigation –for this study team or for universities and industries in general – to make informed decisions that could improve the status quo.

However, the systems approach that was chosen for the study still came in handy. Engineering ecosystems are broad and interlinked. Elements (nodes) and connections (relations) are diverse and influence each other in various ways. Considerable evidence exists for the existing of systems phenomena, such as:

- reinforcing feedback loops (e.g. less competent engineers graduate, less employed, less new students join engineering schools, less pressure to improve engineering curricula);
- system delays (changes in curricula, or training of instructors in PBL, can only show outcome in years after implementation); and
- possible leverage points (e.g. changes in structure and financing mechanisms of SIS programs). This particular part is the main focus of this study, and it will require clearer documentation and investigation of data (analysis and synthesis) to draw an abstract, broad picture of the engineering ecosystem. Diagram 1 provides a preliminary visualization of the main elements and connections of the engineering ecosystem if new engineers (i.e. senior undergraduates or recent graduates) are taken as the center of attention.

More information also is needed– through the pilot phase (currently ongoing) and second round of stakeholder consultation, after more information and conceptual/theoretical framework (or system mapping) is constructed – to either concretize or challenge the preliminary findings and theoretical argumentation.



**FIGURE 1** Preliminary visualization of engineering ecosystems (with new engineers as focus).



## V. CONCLUSIONS

From Phase I of the study, general characteristics and patterns already appear. The four East African countries share many similarities, in history and current challenges and interlinkages, making them a good example of a regional 'engineering ecosystem' that exists along national ecosystems as well.

A system's approach points towards a need for recognizing feedback loops and delays in the engineering ecosystems as they respond to a twofold problem: the relative shortage of engineering practitioners and the limitations to employability for the existing practitioners. Pedagogical approaches that aim for strong academia- industry linking, such as SIS and PBL, have the potential of resolving such dissonance (i.e. they could be leverage points in the ecosystems). They deserve a chance.

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