Student Industrial Secondments for engineering in East Africa

project technical report

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Executive summary

Relative shortage of engineering practitioners in sub-Saharan Africa has been reported as a major concern in many studies on industrial and technological development of the region. However, the region simultaneously records a significant number of existing engineering graduates who find it difficult to find employment in engineering fields. While that situation reflects the inability to absorb human capital in industrial processes, it can also be partly explained by a relative deficit (real or perceived) in the competency of local engineering graduates in the ever-advancing areas of science, technology, engineering and mathematics (STEM), and/or a 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) programmes can be a suitable approach to strengthening the linkages between engineering education, practice and employability. Since completing an academic engineering course is apparently not enough by itself to bridge the skill gap and prepare engineers to enter their countries' engineering practice fields, and the currently existing student industrial placements seem to have some serious flaws, the present study was launched with the aim of exploring best practices and for evidence-based policy learning in establishing and running robust engineering SIS programmes coordinated between universities and industries. Using innovation systems and systems thinking as conceptual and theoretical frameworks, the study included undertaking surveys in Tanzania, Kenya, Uganda and Rwanda, in addition to action research by piloting four SIS placements in Tanzania and Rwanda, the main objective being to observe closely, try potential models, and learn from and synthesize effective SIS experiences.

The findings of the study are broad, being more detailed in some countries than others. In Tanzania, the research team was able to get more information and talk to many informants, given that STIPRO is based in Tanzania as a registered research organization, and has broader established connections with academia, industry and public institutions in the country. It was therefore easier to get more information and insights, (in the form of documents as well as interviews from government, academia and industry – the 'triple helix'). For the other countries, the research team mostly relied on documents and public information that were openly shared by informed personnel in universities and science councils.

Similarities were observed across countries regarding experiences with student industrial training programmes and initiatives – the models, the challenges, and the feedback and perspectives of stakeholders. It was hence noted that SIS models are the same and have been like that since engineering departments were established in most of the East African region. These models worked well in the past, with limited numbers of engineering students and effective involvement of the public sector in securing useful SIS experiences. Currently, the circumstances have generally changed, but the models have remained the same, which causes stress to the old system and creates poor outcomes.

All four SIS pilot placements were completed, and student reports duly reviewed and approved by the respective industry and academic supervisors, were submitted. Across the board, students and industrial and academic supervisors reported a positive return from the SIS placements. The students' reports show similarities in two aspects: an increase in employable skills and an increase in confidence in being employable. General characteristics and patterns were revealed through this study. The four East African countries share many similarities, in history and in current challenges in university-industry interlinkages, making them a good example of a regional 'engineering ecosystem' that exists along national ecosystems as well. The study's findings support that SIS placements of a longer duration than currently practised help increase the employability of engineering students but, in view of the small number of placements, further evidence is needed.

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1. Introduction

While there is a relative shortage of engineers in East Africa, there are equally many graduate engineers who do not find employment in their fields. It is also common that foreign agencies involved in engineering-related activities in the region (as private companies, NGOs or international agencies) resolve to hire expatriate engineers before employing local engineers, citing lack of competency and knowledge of industry standards among local engineers, particularly among the young and early-career ones. For instance, a study on local technological capabilities and foreign direct investment in Tanzania, carried out by STIPRO in 2011, indicated that one of the reasons for the weak linkages between local firms and multinational enterprises (MNEs) operating in Tanzania (as foreign direct investment firms) was a common concern among MNEs about the limited capacities of local firms (and their labour force) to engage with MNEs in activities that transfer technological capabilities (Diyamett, Ngowi, and Mutambala 2012). A logical question arises from these two realities: 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 for their development? There must be a gap that is responsible for this dissonance.

Improving the status of engineering endeavours in sub-Saharan Africa in research, training, employment, standards, etc. is positively related to sustained economic development as defined by the Sustainable Development Goals (SDGs) 8 (Decent Work & Economic Growth) and 9 (Industry, Innovation & Infrastructure), particularly for its contribution to strengthening the capacity of the industrial sector which is critically needed to sustain economic growth. The same endeavour would also contribute to achieving SDG 4 (Quality Education) which is aimed at ensuring that all learners acquire the knowledge and skills needed to promote sustainable development in their private and public lives. Given their broad reach and involvement in modern societies, engineering fields can be linked to almost all the SDGs, either directly or indirectly. Yet, even when we look at the importance of engineering from the angle of economic growth, we find that there are visible correlations between GDP per capita and the number of engineering practitioners (EPs) per 100,000 persons in countries – countries that have a larger number of EPs also happen to be those with higher GDP/capita (see Table 1). A global study in 2016 found evidence to support a strong, positive link between engineering strength[1] in a country and both GDP/capita and investment/capita (Cebr and Royal Academy of Engineering 2016). The same study quotes Prof. Calestous Juma, of the Harvard Kennedy School, mentioning that "you cannot have an economy without engineering…" (p. 10).

Knowledge deficits in science, technology, engineering and mathematics (STEM) in East Africa have been partially documented, and they are both quantitative and qualitative (Mohamedbhai 2016). Besides the challenge of skilled labour size, the problem with enhancing engineering ecosystems in Africa is twofold: the relative knowledge deficit (real or perceived) in competency of engineering graduates in ever-advancing areas of STEM, and the scarcity of chances to hone and demonstrate that competency in the labour market.

One practice that has a positive contribution in preparing engineering students for employment after graduation is student industrial secondment (SIS) programmes. SISs are temporary placements of college and university students in relevant industries where they receive direct on-the-job training, with actual work responsibilities. Besides getting to put what they learned in classes and labs into practice, thus honing their theoretical attainment with practical experience, SIS placements allow students to gain tacit knowledge and an appreciation for additional important employability skills that are not often taught in academia (e.g.

[1] Engineering strength in countries was measured according to an index named 'engineering index' (Ei), which is defined as 'a measure of country's ability to conduct key engineering activities in a safe and innovative way'. Components of Ei concern the size and quality of: digital infrastructure, engineering industry, infrastructure, knowledge, labour force, and safety standards (Royal Academy of Engineering 2020).

teamwork and professional communication, performing under real-world pressures, dealing with operational and logistical constraints, and meeting industrial standards). In both developed and developing countries, correlations have been found between engineering SIS programmes and increased employability of STEM graduates (Friel 1995; Hackett, Martin, and Rosselli 1998).

Table 1: Correlation between countries' GDP/capita and EPs per 100,000 persons

Country	Approx. GDP/capita US$	Approx. EPs/100,000 pop
Seychelles	14,000	500
Mauritius	11,000	400
Botswana	7,500	275
South Africa	6,000	200
Eswatini	3,500	140
Zambia	1,700	75
Tanzania	1,000	70
Mozambique	500	35

Source: SADC 2019; Mohamedbhai 2021

It was in light of the above that STIPRO, with the support from IDRC, initiated a project to explore best practices in running robust engineering SIS programmes coordinated between universities and industries. The project was carried out in three main phases: (I) surveying of SIS best practices in East Africa and other developing countries, (II) action research by piloting long-term SIS placements, (III) synthesizing the findings and widely disseminating the results to stakeholders.

In this report, after the executive summary and introduction, a literature review of engineering education in East Africa, and experiences of SIS in Africa and other parts of the world is presented. The report then outlines the design of the project and its implementation. This is followed by the findings from phase I of the project (country-specific surveys) and from phase II (pilot SIS placements). Dissemination of the findings then follow (phase III). Finally, after the section on discussion, the report ends with conclusions, recommendations, and suggestions for future research.

2. Project design and implementation

This project proposed a study of best practices to produce evidence-based and evidence-informed policy recommendations in establishing and running robust engineering SIS programmes coordinated between universities and industries – and perhaps with support from the public sector – to serve both the industries and students. While there are currently sporadic cases of SIS placements in various university programmes, clear, broad and standardized programmes with visible outcomes are yet to be found.

2.1. Objectives

The main objectives of this project, along with its action research pilot component, were to:

(a) gain, through policy learning, reliable knowledge and understanding of the potential of tertiary SIS programmes in strengthening engineering ecosystems in East Africa;

(b) examine selected best practices in SIS pedagogical approaches, through initiating, monitoring and evaluating SIS placements;

(c) map existing and past experiences of SIS programmes within tertiary education institutions in East Africa, and produce a knowledge inventory of such experiences; and

(d) share the findings of this project with concerned circles of training and policy responsible for STI enhancement in East Africa and sub-Saharan African overall, through proper dissemination channels.

2.2. Methodology

The project used surveying and action research in learning and synthesizing effective experiences of SIS programmes from various developing countries (especially ones that achieved recent industrial successes), as well as piloting four SIS placements from two universities, and in two engineering majors, to serve as both demonstrations and close learning opportunities. The project also included exploration of conducive pedagogical methodologies, such as Problem Based Learning (PBL), as they relate to preparing SIS students for their placements. Engagement with a group of universities and science granting councils (SGCs) in East Africa was embedded in the project activities. SGCs can be instrumental in establishing policies and supporting SIS initiatives in the future (based on the expected recommendations of this project), and so their early engagement in this project will facilitate that. The pilot programme will also feed into curriculum design at higher learning engineering institutions.

The approach that was used by this project was based on the hypothesis – or lens of inquiry – that strengthening the linkage between engineering study, practice and employability is a 'leverage point' in the engineering ecosystem of a country or region. Leverage points are places of intervention in a complex system where change has a significant ripple effect throughout the entire system, influencing many components that were not touched directly (Meadows 2010). The research team postulated that promoting engineering SIS programmes can be a suitable approach to strengthening the linkage between engineering study, practice and employability. They have the potential of changing engineering curricula towards PBL, student-based teaching, and orientating academic fields towards connection with demand in industry. If such outcome is achieved – through curricula change and policy support – that in turn can increase student enrolment in engineering programmes in a country/region, and graduation, as a response to increased employability of engineers after graduation. If this hypothesis proves to be sound, the results can have significant influence on policy and practice of engineering ecosystems in East Africa.

This research lens relied mainly on the conceptual framework of national innovation systems (NIS) and the theoretical framework of systems thinking. NIS framework aims to organize the productive forces and structures, and the flow of information and skills in a country, in order to increase the output of innovative solutions to development constraints (Lundvall 1992). In this framework, STI play a central role, and thus require strategic investment. At the policy level, the NIS will include careful investments in education systems, enterprise support and labour markets (Maharajh, Scerri, and Sibanda 2013). Systems thinking, on the other hand, overlaps with such understanding of NIS, and views various phenomena as 'systems', i.e. sets "of things—people, cells, molecules, [machines, procedures, etc.]—interconnected in such a way that they produce their own pattern of behaviour over time"(Meadows 2012). If we look at the engineering ecosystem in a country from the NIS perspective, it will be critical to understand that engineering academic programmes and engineering jobs in local industries are tied together by the flow of information and technology, through human resources as well as knowledge, including economy/market feedback. Using systems thinking, we understand these relations as feedback loops that influence each other's own dynamics through the information flow, rules and connections of the whole system. The type of system we are dealing with here is a "technosocial system", where people and technologies work in combined efforts that form functional wholes (Woodhouse and Patton 2004). This project will pursue its objectives through a theory of change illustrated in Figure 1.

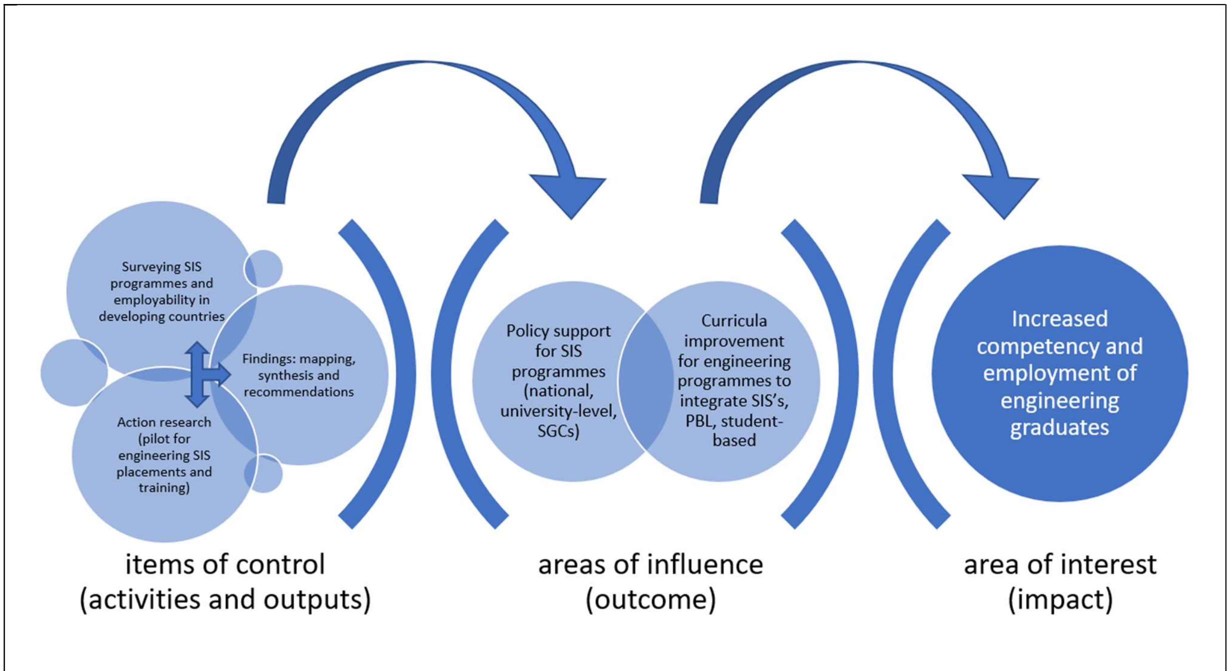

Figure 1: SIS Project theory of change

Four students from two different universities in East Africa were selected for SIS placements for one year in a number of engineering entry-level or apprenticeship positions in suitable industries. The students had just completed their junior year (i.e. one year left to graduation). The selection of the students was carried out by their respective faculty advisors – in consultation with STIPRO – who would be partners of STIPRO in this project. All placements began in the second year of this 3-year project, after surveying, partnerships, agreements with respective industries (for placements) and selection of students were completed. The students were given stipends as reasonable salaries while on SIS placements (based on stipends considered reasonable at their levels in their respective countries). Their universities handled the stipend disbursement accordingly (as well as some administrative funds specific to the project) and agreed to report them to STIPRO. Of the four students, two were from Tanzania, both females, and two from Rwanda, one male and one female. The four students were entirely funded by the project's budget itself.

2.3 Project phases

Phase I – Survey of SIS practices in East Africa

In this phase, the research team conducted three complimentary activities. The first activity was a mapping of the four East African countries of Tanzania, Kenya, Uganda and Rwanda in terms of all previous and current experiences of engineering, undergraduate SIS programmes and their indicators of effectiveness (qualitative and quantitative). The mapping involved collecting and organizing data on the history of the practices in East Africa. The second activity – conducted simultaneously with the first one – was surveying best practices among such mapped programmes (if existent within East Africa) as well as best practices known in other countries from the economic South and with comparable industrial and economic conditions to East African countries, so as to establish engineering education programme gaps. This surveying was expected to produce critical findings on recommended ways to design and implement engineering SIS programmes in the region. The third activity was to focus on identifying the second partner university for the pilot phase, selecting students for the

SIS programmes, identifying partner industries/firms that will host the SIS students, finalizing agreements between all actors for the pilot project, and preparing students for SIS placements.

Within Tanzania, we used a semi-structured interview guide. For the other countries, namely Rwanda, Uganda and Kenya, the research team mostly relied on documents and public information that can be shared with visitors, and there were general discussions with key organizations in each of the four countries, such as Uganda National Council of Science and Technology (UNCST); Rwanda National Council of Science and Technology; EASTECO (East African Science and Technology Commission); Linking Industry with Academia (LIWA); African Centre for Technology Studies (ACTS); University of Nairobi; and Kenyatta University.

An identical set of questions was put together for each country to respond to, and the research team collected as many responses as possible from each country. The questions were:

What are the current arrangements between academia and industry that involve engineering students or fresh graduates?
What are the numbers and trends that tell the story of engineering education and employability in your country?
What are the main policies and institutions that influence the current situation?
What are the observations and potentials relevant to your country's engineering ecosystem?

Phase II – Piloting student placements

This phase involved the actual placement of the SIS students, observing their work and drawing notes and lessons from the pilot project. Phase II was planned to begin after phase I as it required significant feedback from phase I. It also included gathering experiences on university engineering teaching, especially the use of problem-based-learning or PBL. One of the weakest aspects of the pilot is that it included only four students, and they were paid. We needed to do that to persuade industries and universities since the idea of training students for an extended period, as employees, was rarely tried before. We chose to make our pilot for an entire year for a number of reasons – one is that it was actually easier to get an excuse from university administrations and student loan boards, for a full academic year off than to get an excuse for a semester, because a semester will make students out of sync with year-based academic curricula.

Phase III – Synthesis and results dissemination

This phase included synthesizing the lessons learned from both previous phases, highlighting them and writing-up reports and scholarly publications, and disseminating the findings and policy recommendations to all stakeholders.

3. Main findings from phase I and II

The findings of this study were broad across countries. However, we found overwhelming consensus that the current industrial attachment programmes (IAPs) in East African countries are not only similar but also not working well and for the same reasons—mainly insufficient industrial attachment periods, the overwhelming number of students compared to the number and size of industries to receive them, and the mismatch of skills and work in IAPs (partly due to the two reasons mentioned first).

Activities of phase I took place successfully, overall, but with some challenges. Mapping of previous and existing SIS programmes took place, with many similarities found across the four countries and yet there was a general absence of reliable documentation of such experiences. Some information of best practices from past experiences was obtained, but with the realization that circumstances in the past were quite different from the present, rendering it difficult to emulate past practices. Selection of the second partner university, along with the selection of students and industries and preparation for phase II took place in partnership with the University of Dar es Salaam (College of Engineering and Technology) and the University of Rwanda (College of Science and Technology), the latter being the selected second partner. Below, the findings are presented as country-specific findings and general findings of phase I, and pilot SIS placement findings of phase II.

3.1. Findings from phase I country-specific surveys

The following brief profiles of each country are based on phase I survey information and literature:

3.1.1. Tanzania

Academia-industry student placement programmes

Annual practical training periods of eight weeks every year, except for the final year, are standard in all Tanzanian higher education engineering schools. Industries are required by the state to accept students for these periods. For engineering, after the first year of studies, students undergo their first practical training period as artisans; after the second year as technicians; and after the third as engineers. The placement pyramid was designed in this way to enable the engineering students to experience, hands-on, the various and important levels of engineering practice.

However, criticism is emerging from faculty, students and industries, with high consensus[2] that few students and industries benefit from such training due to crowdedness (as even other schools/disciplines have practical training programmes around the same period) and the short period of training. Students, faculty and industry supervisors are all less invested in elaborate learning and follow-up. On average, 2,500 students from Dar es Salaam Institute of Technology (DIT), and 1,800 students from University of Dar es Salaam (UDSM); go for practical training every year, all spread across about 200 industries, public and private, but normally not all students get placements every year, so on average around 120 industries participate each year. The number is overwhelming, and the capacities of industries are both limited and spread thin. Another constraint is that all other non-engineering final-year students, or students from other fields from other universities, also attend the practical training every year and at the same time of the year, resulting in even more crowding.

In the past, UDSM had the only engineering programmes in the country. Engineering students were few and the main industries known. Besides, most graduates were recruited for jobs, or further studies, before graduation. Smaller classroom size and relatively fewer industries allowed for focus and enabled decision makers to place almost all the graduates, who were also fully funded. Also, at UDSM, from the 1980s to early 1990s, students were allocated employers (state-owned-enterprises or parastatal organizations) by their third year, where they would go for their eight-week practical training and where they would work after they graduate. This process was done nationally but UDSM was the only university with engineering programmes. There was limited room for students to change their allocation. The placement was for five years, after which the graduate engineer was free to move around or remain in their job.

Engineering education and employability

Tanzanian registered engineers form the majority of registered engineers operating in East Africa, and they work all over the East African Community (EAC). This indeed is a testimony to Tanzania's engineering education and certification quality compared to the rest of the region. "Proportionately, 63% of the registered engineers

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[2] At DIT, the consensus exists but less than at UDSM; perhaps because DIT students are trained with a different curriculum that emphasizes hands-on engineering skills, due to the history of DIT (which was originally built as a polytechnic college).

in the EAC are from Tanzania" (Barugahara and Sebbale 2016, p. 41). However, globally speaking, Tanzania's engineering training has much room for improvement.

According to a recent SADC report on 'Engineering numbers and needs' of SADC member countries (SADC 2019), Tanzania has about 60 engineering practitioners per 100,000 persons, a low number among SADC countries. Yet, engineering is quite important to Tanzania, as activities involving engineering contributed, overall, 63.8% to the total GDP in 2015, as an example.[3] A total of about 30,000 engineering practitioners work in Tanzania, of whom 26.8% work in the public sector (government and state institutions, companies, etc.), which makes the public sector the largest employer of engineers in the country. The 'manufacturing and suppliers' sector employs around 6,000 engineers, and the same for 'contracting', while only 700 engineers work in the agriculture sector, although that sector is a main contributor to GDP and employment in the country (SADC 2019, p. 48). Around 1,800 engineers work in academia and research (including public universities and colleges).

For university level engineering degrees, there are two tracks in Tanzania: The TCU track (regulated by the Tanzania Commission for Universities which succeeded the former Higher Education Accreditation Council) and the NACTE track (regulated by the National Council for Technical Education). The two tracks differ in the percentages of theory versus hands-on content in the curricula—one with more focus on graduating students with state-of-the-art knowledge of the engineering discipline, and one with more focus on graduating students with advanced hands-on skills of engineering work. In other countries around the world, the two tracks are usually distinct, one that produces engineering graduates and the other that produces 'engineering technology/incorporated engineering' graduates (UNESCO 2010). If graduates from either track wish to continue on post-graduate paths (for Master's and PhD levels), the tracks converge. Requirements for becoming registered, certified engineers in the country appear to be the same for both tracks. Overall, it could be said that the engineering ecosystem in Tanzania is both vibrant and challenged.

For this research, the team was able to survey two types of organizations in Tanzania: universities (particularly engineering and technology colleges/departments) and partnering organizations with universities, particularly those of industrial or technological orientation and which typically receive engineering students from universities (such as UDSM, DIT, Arusha Technical College, and Mbeya University of Science and Technology). In the survey, the research team visited many organizations, but four cases summarize our findings: TANELEC (electrical equipment manufacturer), Confederation of Tanzania Industries (CTI), Tanzania Engineering Design and Manufacturing Organization (TEMDO), and the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC). These organizations are located in Dar es Salaam and Arusha. In this survey, particular information was drawn about the status of students that are received for practical training (PT) and other challenges and peculiarities related to it—all summarized in Table 3. In general, the existing PT programmes are not a complete failure, as they seem to match some students with future employers, and they also have interesting stories of success where students are almost transformed in terms of their engineering skills. However, the challenges and problems remain, and remain more or less the same across all student-receiving organizations, among which are the burden of hosting more students than organizations are able to closely supervise, and the relatively short period of time that does not allow for building reliable competence in the students.

Policies and institutions that influence the current situation

The Engineering Registration Board (ERB) is an institution that is established to regulate the engineering profession in the country through making sure that licensed engineers are competent enough to lead projects

[3] Activities involving engineering, include agriculture, construction, manufacturing, electricity, gas & water, mining operations, and transport and communication (SADC 2019, p. 8).

and missions of an engineering nature and are capable and aware of safety and quality standards. Tanzania's ERB is similar in that regard to many ERBs in other countries across the globe. The East African Community has a shared engineering registration framework.

> "Under Article 104 of the EAC treaty, partner states agree to a protocol to facilitate the free movement of persons, free movement of labour, free movement of services and the right of establishment and residence. Specifically, the Mutual Recognition Agreement (MRA) for engineering professionals in the EAC enables a professional in one state in the region to be recognised as a professional in all the member states. The MRA for EAC engineers was signed on 7th December 2012 between Uganda, Kenya and Tanzania"(Barugahara and Sebbale 2016, p. 41).

The Structured Engineers Apprenticeship Programme (SEAP) is a publicly-funded programme that was launched in 2003 and is supervised by the ERB.[4] According to the recent SADC report on engineering needs and numbers for the region, SEAP "aims to enable Tanzanian graduate engineers to qualify for registration as professional engineers in the shortest possible time. The ERB monitors progress, engages with mentors and reviews quarterly reports" (SADC 2019, p. 70) This adds additional importance to the ERB as an influencing institution in the engineering ecosystem of Tanzania.

The Higher Education Students Loans Board (HESLB), which offers loans to students to meet costs while studying in HLIs in the country, is also an important actor/influencer in the ecosystem as it plays a critical role in financing/funding mechanisms, without which the system is crippled. Big industries and industrial chambers (such as the confederation of Tanzania industries) are an obvious actor/influencer in the system. Their own policies and their level of participation in co-curricular activities for students, as well as providing work opportunities, and determine characteristics of the entire ecosystem.

Observations and potentials relevant to the engineering ecosystem

From this survey, and from established expertise with the Tanzanian scene through previous research and consulting work, it can be argued that Tanzania has functioning frameworks that build upon traditions established in the period right after independence and under the first government. However, these frameworks seem to work at the minimum capacity level now and few changes take place or divert from what was established, even when the surrounding circumstances have changed dramatically. The political stability of the country is unique in the region, yet one of its correlations is that resistance to change in existing frameworks is high, making it very hard to move gears to adjust or transform the enabling environment. Political will could maximize change, but it tends to focus on grand issues at macro-national and regional levels, while policy change remains very difficult at the meso and micro levels.

[4] It was launched by the then Minister of Works, John P. Magufuli, who in 2015 became the President of the Republic of Tanzania.

Table 2: Summary of feedback from industry partners about current state of SIS programmes (Tanzania)*				
Organization	**TANELEC (electric equipment)**	**CTI (Confederation of Tanzanian Industries)**	**TEMDO**	**CAMRTEC**
SIS/internship existence	yes	yes	Engineering students are supervised by engineers at TEMDO. They are introduced to TEMDO (orientation), and then they are assigned their jobs and supervisors. The same training as UDSM (first year artisan, second year technician, and third year engineer). For third year students, they are assigned to the design office, because they are treated like engineers.	When students come here, they feel estranged and challenged. Making the students deal directly with the technological creation work takes them away from the classroom environment to face real-world challenges. More of that is required.
Students received for training (annually)	about 12-15 every year	n/a (but with members of CTI)	Sometimes we get more than 10 students every year (roughly) from all the PT levels. They come from UDSM, SUA, ATC, DIT, etc.	Every year, over 50, but they usually come in groups of 20s or so per season.
Are some students employed after PT training with the same organization?	Yes, currently have three students from UDSM (graduates) as our employees.	Yes, experiences of member industries that take students as interns after they graduate, for about a year – some are employed.	----- (employment through public sector)	----- (employment through public sector)
General assessment about current state of SIS (problems/challenges and university-industry linkages)	- Some students are useful to have, but some students are a burden. - Our resources and capacity limit the number of students we can receive. - Many of the students find our work here quite new and interesting. When you start training them you find that there is a big difference between what they are being taught in school and what they find here.	Currently, there is a 'skills development levy' of 4.5% of basic pay of all employers (higher than most countries around), so the industries feel that they are already contributing to skills development in the country and without benefit.	Staying longer (in the SIS) will make the student learn more. At 2nd and 3rd year they need to be guided to understand how to deal with design challenges and be more accurate.	Not enough time for them to actually master any part of the process. They end up covering a little of everything, making them versed in nothing. Also, teaching them is a challenge, because there is a lot that they do not know.
**Info drawn from survey that included public documents and semi-structured interviews with leaders/representatives from each organization.*				

3.1.2. Uganda

Academia-industry student placement programmes

A similar industrial secondment programme (called 'field attachment') is in place, that also lasts about eight weeks, particularly at Makerere University and its engineering school (CEDAT – College of Engineering, Design, Art and Technology). Also, most university schools at Makerere University do the same field attachment, which means more competition for existing industries. Makerere produces the majority of engineering graduates in the country. Contrary to other countries, a tracer study of engineering graduates in Uganda showed that most of them end up working in their field (or related to their field). For Uganda, it seems that studying engineering remains a good choice for graduates in terms of employability (Barugahara and Sebbale 2016). Yet, problems in the industrial training programme persist. Similar complaints to those in Tanzania, of fatigue in the programme, where students, faculty and industry are not sure of the benefits of the programme, show that industrial training works on paper, as a requirement that has to be fulfilled, while a fair assessment may reveal an unfavourable situation.

In the past, Makerere University had the only engineering programmes in the country. Just like UDSM in Tanzania, engineering students were few and main industries known and, most graduates were recruited for jobs, or further studies, before graduation.

Engineering education and employability

According to a tracer study of Ugandan engineering graduates between 2008 and 2012, the dominant fields of engineering studies in the country over that period were civil (25.7%), mechanical (17.2%), telecommunication (17.6%), electrical (14.1%) and agricultural (5.4%) engineering.

The study also provided a number of intriguing findings, such as:

> "Most engineering graduates (74.6%) found their first job less than a year after graduation. This could be because 61.9% searched for engineering related jobs, three years prior to graduating. In this survey, 78.8% of engineering graduates were employed while 3% and 0.6% were either unemployed or inactive respectively. Most of the engineers (64.6%) were working in the Business sector. Proportionately, there were more civil engineers working in the Government sector than all the other fields of engineering combined. Over half (57.6%) of engineers were working in firms that were undertaking 'core engineering'. Most (63%) of the engineering graduates in non-core engineering firms were either sales agents, brokers, accountants, bank tellers or other related clerks. Whereas 72% of engineering graduates described their current occupation as being 'closely related' to their undergraduate training, a third (34%) of female engineers were in professions that are not related to engineering. In addition, whereas the number of male engineers in 'unrelated' professions reduced by 11%, the number of female engineers in such professions increased four-fold (400%) between 2008 and 2012. The number of engineers in 'closely-related' professions increased by 46% and 123% for female and male engineers, respectively" (Barugahara and Sebbale 2016, p. iii).

For the majority of graduates to find a job in less than a year after graduation, and for the majority of those to describe their job as 'closely related' to their field (albeit a subjective description) sheds a positive light. Yet, some aspects require revisiting, such as that 91.7% of the engineers were not formally registered, according to the tracer study; the main reason cited for that was that they lacked minimum requirements for registration. Particularly, far fewer women were registered engineers. The value of registering, and how it pushes engineering practitioners further in their engineering careers, may need to be promoted. And like Tanzania, although there are higher numbers of engineers in the population, "Uganda still has one of the smallest per capita ratios of engineers per population (one engineer per 53,000 people vs a desired global average of 1:770)" (Barugahara and Sebbale 2016, p. iv). Moreover, less engineers were involved in traditional mechanical/manufacturing and agricultural fields, which are critical fields for national developments at this stage of development in East Africa if countries are to advance into semi-industrialized economies.

Policies and institutions that influence the current situation

The Engineering Registration Board (ERB) of Uganda plays a similar role to its counterpart in Tanzania. Makerere University is also the oldest/largest academic institution, so it has broad influence. As mentioned earlier, only few Ugandan engineering graduates seek to become registered/professional/certified engineers to practise as such in the country. They cite reasons for that, but the reality remains that when looking at the number of registered engineers, the shortage becomes visible. "The number of registered engineers in Uganda is still low compared to the other countries in the East African Community (EAC). Kenya has a register of 1,400 engineers which is twice that of Uganda. (By 2015, Uganda had a register of 772 engineers of whom 494 were in practice.)" (Barugahara and Sebbale 2016, p. 41).

Observations and potentials relevant to the engineering ecosystem

Uganda's tracer study indicates that, despite engineering graduates being mostly employable, the engineering sector is still dominated at high/advanced levels by expatriates who come with companies contracting projects in the country. Additionally, professional/certified engineers from other countries in East Africa seem to fill a large gap among local (Ugandan) professional engineers. This may make Uganda more interested in seeing the regional engineering ecosystem improved.

3.1.3. Rwanda

Academia-industry student placement programmes

Rwanda has recently embarked on enhancing the STEM capacity of the country at large, with most public funding being directed towards STEM institutions and also inviting many international institutions to establish educational and research posts in the country (UNCTAD 2017). That focus also includes providing practical training opportunities for engineering students as well as implementing policies to normalize workplace training for TVET level graduates. At the University of Rwanda, students are provided practical training in their workshops as part of the curriculum (e.g., machine tools, laboratories, individual projects) in addition to an industrial attachment programme that is a compulsory credit-rated module for every specified diploma/degree programme at the College of Science and Technology. This industrial attachment is typically assigned after the student completes the third year and it lasts for 10 weeks. During the attachment, the students are expected to experience the application of learned skills in an organization related to their specialty. This is quite similar to 'practical training' and 'field attachment' placements in Tanzania and Uganda, with some variations.

Challenges of the industrial attachment programme also seem to be similar to those in Tanzania and Uganda, and they include difficulty in finding proper industry placements for students, problems with funding and students' welfare during attachment periods, constraints in finding time and resources to monitor and supervise students sufficiently during their attachments, and students' lack of motivation in maximizing learning benefits from the attachments.

Engineering education and employability

A 2014 tracer study of graduates from HLIs found that "graduates from Economics and Business, Education and Arts and Social Sciences are over-produced vis-à-vis other fields like Medicine, Engineering, and ICT" (Republic of Rwanda 2015a, p. ix). Between 1996 and 2013, 6,180 students graduated from HLIs in Rwanda with an engineering degree (compared to 2,286 from medicine and 3,739 from ICT). In 2014, the World

Economic Forum Executive opinion survey ranked Rwanda as number 74 (out of 148) in the world in terms of the availability of scientists and engineers, and the country ranked 125 in objective measurements of enrolment in tertiary education[5] (UNESCO 2015). The tracer study did not provide aggregations for engineering in particular, but the study concluded that there is a critical skill gap in fields of medicine, ICT and engineering. Overall, there was a 15% unemployment rate, and "there appears to be lack of sufficient formalised synergies and partnership between public and private employment agencies with HLIs. As a result, relevancy of internships and acquired skills to the labour market were rated weak" (UNESCO 2015, p. 114). Weaknesses were also noted by employers among graduates in the areas of hard-skills in areas of research and problem-solving skills.

In 2017, a review by United Nations Conference on Trade and Development (UNCTAD) on STI policy in Rwanda spoke about engineering graduates from the University of Rwanda, indicating that, on average, "each year, 1,400 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" (UNCTAD 2017, p. 21). The same review also indicated serious moves by the Rwandan authorities to address challenges:

> "There is growing awareness of the need to create an innovation culture among science, technology, engineering and mathematics (STEM) students and technical trainees, as well as among those training in and studying soft disciplines relevant to commerce. Technical and vocational education programs are well founded and valued among the business community. Central national policy is developing a factual and timely assessment of skill gaps and their effective narrowing through a combination of incentives and support measures" (UNCTAD 2017, p. 2).

A good example of serious trends towards change is Rwanda's national policy of workplace learning (Republic of Rwanda 2015b). Although the policy is designed for technical and vocational training, rather than for tertiary education, it reflects a general approach/thinking by authorities towards bridging skill gaps in STEM by using workplace training, a synonym of internships and industrial secondments.

Policies and institutions that influence the current situation

UNCTAD's 2017 review of STI policy in Rwanda indicates that Rwandan authorities are keen, in thinking and action, to enhance the STEM education-employability environment in the country and are being hands-on about it. In such case, state policymakers and ministries are directly leading the process.

Observations and potentials relevant to the engineering ecosystem

Being a small country, central authorities in Rwanda make and implement national policies with strong coordination, and plans seem to be more likely to be enforced once approved. This could be either good news or bad news for the engineering ecosystem, depending on the policies and institutions responsible for implementing them. If policies are sound, they have a higher chance of being materialized, but if they are not well-studied, they also have a similar chance, with unintended consequences.

Currently, a shortage of engineering practitioners in Rwanda is visible, as many related positions are filled by expatriates from various parts of the world (including from neighbouring African countries, which is not as problematic as having all major engineering leading positions filled by experts from outside the region), because expatriates from neighbouring countries are part of the regional engineering ecosystem, which is important as this study illustrates.

[5] Data taken from 2012.

3.1.4. Kenya

Academia-industry student placement programmes

Similar to Tanzania and Uganda, engineering colleges and universities in Kenya also conduct students' practical training through placements and attachments. The time allocated for the field attachment is between eight and 12 weeks depending on the course programme. Students have a logbook to record their daily assignments and universities ensure that students report to their respective attachment places through an assessment form.

University curricula require the second-year students to go for internal (in-school) hands-on training for two weeks and third year and fourth year students to go for external placements. The Linking Industries with Academia (LIWA), an organization that provides match-making internship services between industry and graduate students for industrial placement, internships and work-based training, estimates a proportion of 50% of students get internships under their initiative; and employers such as the Kenya National Highways Authority (KeNHA), which deals with the construction of major roads and comprising two more authorities such as the Kenya Urban Roads Authority (KURA) and Kenya Rural Roads Authority (KeRA) receives an average number of 70 graduates for placement; and thus the authority assigns PT tasks in consideration of the degree course; the students generally work around operating activities, workshops, and laboratories.

Engineering education and employability

Several challenges in industrial training programmes have been identified. Although students are evaluated by industries as having strong hard engineering skills, they complain that students lack soft skills. Secondly, supervision is limited in following up students' performance. In the past, engineering colleges and universities used to conduct two rounds of supervision per academic year, but this supervision arrangement has changed to one round. The decrease in the number of supervisions was explained by the number of students that keeps increasing in all the engineering institutions. The University of Nairobi, for example, registers around 290 students who go for placements per year against 20 supervisions at different students' placements. Similarly, the number of industries does not comfortably accommodate the increasing number of students in Kenya. This not only challenges students to get appropriate placement but also brings in the system different experiences about placements and attachments.

Moreover, according to the University of Nairobi, universities rely on tracer study reports to get insight in terms of employability and the way graduates perform in the labour market. The last report has informed that students perform well.

Policies and institutions that influence the current situation

Employers, such as KeNHA, recognise the existence of government policy that make early graduates' internships mandatory.

Observations and potentials relevant to the engineering ecosystem

The survey conducted in Kenya revealed different experiences in terms of students' placements and attachment, which also impact students' performance differently. Depending on the types of activities and seasons/times, industries engage different volumes of operating activities that may differ from the time universities engage students' placements.

Financing during the students' placement has also some levels of influence in the way students find relevant placements. Students opt for places where the living costs are affordable without much consideration to the volume of operating activities in industries and the course they undertake. The experience with linkages between academia and industry is manifest through the students' assessment forms designed by the universities and filled in by industries. Universities rely on those forms to understand students' performance since they record students' performance.

3.2. General findings from phase I

Similarities were observed across countries regarding experiences with student industrial training programmes and initiatives (the models, the challenges, and feedback and perspectives of stakeholders). The SIS models are the same and have been so since engineering departments were established in most of the East Africa region. They worked well in the past, with a limited number of engineering students and effective involvement of public sector in securing useful SIS experiences. Currently, the circumstances have generally changed but the models have remained the same. One cited reason is that the number of students increased dramatically, and many university colleges (non-engineering or 'professional degrees') began to seek industrial training for their students as well, which overburdened industries as they did not increase in number and capacity in the same proportion to the increase of number of students.

Weak documentation of the past and present SIS programmes (or industrial training/attachment programmes) 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 made 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.

3.3. Findings from phase II

For the pilot phase II of the project, third year undergraduate students from two East African universities, University of Dar es Salaam (College of Engineering and Technology) and University of Rwanda (College of Science and Technology), both being the major and historically principal universities in their respective countries, were selected for industrial placement. Each university had two students participating in the pilot, and they were selected and funded to undertake one full year of SIS with chosen partner industries/firms. Each university supervised their students completely, from selection and industry placements to making arrangements with industries to receiving progress reports from students and industry supervisors, as well as having faculty supervisors visiting students at workplaces to assess their performance and learning from the opportunities. Based on the agreement, the universities shared information on the pilot with STIPRO through updates by email and through sharing progress reports from the students (after review and approval by faculty supervisors). Table 4 shows the status of SIS programmes and other relevant information in each of the two universities.

All SIS pilot placements were completed, and student reports submitted (after review and approval by their industry and academic supervisors). Across the board, students, industrial supervisors and academic supervisors reported a positive return from the SIS placements. The highlights from the student reports show similarities in two aspects:

(a) Increase in employable skills: All students' reports highlight an increase in hands-on skills and understanding of practical/work environments.
(b) Increase in confidence: Comparing the level of confidence in their own skills, from the point when they began the SIS placement to the point they finalized their placement, the reports show that the students had gained significant confidence in their ability to secure employment after graduation. This is independent of whether or not they would actually secure employment (that remained to be seen),

but it showed that they had either received promises or were more confident in their ability to find the right channels and approaches to secure employment after graduation.

Tables 5 and 6 highlight the main takes from the SIS pilot placements, as well as generalized lessons and recommendations for future reference. Overall, while the experiences were positive, the fact that they were pilot placements may have not allowed for experiencing a more structured, systematic and well-planned SIS experience. In these pilots the students and their industry supervisors had to fill the SIS experience with work, and they did that well, but it made them think about how it would have been more rewarding and educational if they had been more prepared in terms of specifying the students' tasks and outputs, and in terms of setting a standard SIS programme to follow. Additional lessons and recommendations addressed challenges and opportunities that might arise if the SIS programme were to be scaled up, involving hundreds or thousands of engineering students each year. Some recommendations ventured into how a long SIS period could be adopted without adding an entire year to the students' curricula. A suggestion by a senior professor from USDM was that, instead of two months every year (the current PT programme), the students could combine them together (along with the training workshop) to have one long attachment of 6-8 months as their SIS. This is a commendable suggestion for policy consideration, especially as some other universities around the world follow a similar model (such the University of Waterloo, Canada).

3.4. Gendered dimension

It was originally planned that about half of the students joining the pilot phase of the project should be female, for gender considerations relevant to the study. Gender-based parameters of their experiences were to be documented and studied for policy lessons (in addition to investigating other SIS experiences of female engineering students). Eventually, the pilot ended up with three female engineering students and one male student. The UDSM's CoET selection committee for students selected two female students from those who applied and were informed of the SIS pilot. The CoET selection committee explained their rationale to STIPRO: from their experience in such programmes, female students were considered more likely to take the opportunity more seriously and responsibly.[6] Therefore, the reports of the SIS students, shown earlier, can be described as reflecting female engineering students 'experiences; although no significant differences could be found with the experience of the one male student.

The tracer study from Uganda also revealed important trends with regards to gender, something which East African countries could pay more attention to. As the study says, "by enhancing the contribution of women engineers, stemming the brain-drain of young engineering graduates, providing continuous professional learning through streamlined engineer registration, updating and reviewing engineering curricula and supporting engineering research and innovation, Uganda has the potential to leapfrog to middle income status by 2040" (Barugahara and Sebbale 2016, p. iv).

3.5. Challenges and limitations

Phase I did more surveying in Tanzania than in the other three East African countries partly due to financial limitations, since surveying each country would have required spending longer periods there (which was beyond our budget) while surveying Tanzania was more accessible because the research team resided in Tanzania. Additionally, the research team was not successful in obtaining research clearance to conduct surveys in Uganda or Rwanda, so we did not collect any information that was not readily available in the form of publications and shareable basic information. In phase II of the project, several main challenges were encountered:

[6] STIPRO team is only reporting what we heard from CoET faculty here.

- Initial difficulties in securing a second partner university for the pilot (SIS placements) and preparing agreements with universities to lead and supervise placements.
- Delays in locating industries and finalizing SIS placement requirements: partially for Tanzania placements and mostly for Rwanda placements.
- Due to national and international measures in response to the COVID-19 pandemic, which hit the world after phase I of the project wrapped up, the pilot phase did not end within the year planned. However, partner universities were able to coordinate with industries and students to make sure that phase II requirements were duly met. All students had a sufficient SIS experience.
- The project team sought additional funding – from sources other than IDRC – to increase number of students for SIS placements with no success.

Table 3: Status of SIS programmes in Tanzania and Rwanda's principal universities*

Institute	CoET (College of Engineering and Technology)- University of Dar es Salaam	CST (College of Science and Technology) - University of Rwanda
SIS/internship existence	Practical Training (PT) every year for 8 weeks (1st, 2nd and 3rd year degrees – artisan, technician, engineer).	Currently, both students and faculty have industrial attachment placements, coordinated and executed with industries.
Overall number of graduates	Graduates of CoET are on average 600 a year. On average CoET has 2,400 students enrolled (all years) every year.	600-1,000 graduates every year (engineering)
Students that go for training (annually)	Average 1,800 per year	Average 1,800 students per year
Industries involved with institute	Over 200 industries, but normally not all would get placements every year, so on average around 120 industries per year	Ministry of Infrastructure: there is a clause for all foreign companies to include students and faculties for industrial training.
Problems/challenges with existing industrial SIS programmes	(1) Industries have little time to help PT students with questions for learning. (2) PT students are not given proper protective equipment, or are given used ones (which is unhealthy). (3) On PT 3rd year, the student has to write a project on a practical problem, but one cannot have a well-executed project in only 8 weeks of placement. (4) Small allowances.	(1) Not enough industries, especially willing industries. (2) Student welfare during Industrial Attachment (IA) is minimal. (3) Budgetary constraints for staff to supervise IA student participation. (4) Guaranteeing student professional behaviour during IA requires close supervision.

**Info drawn from public records, shared by respective university faculties.*

Table 4: Summary of Pilot SIS placements (Tanzania and Rwanda)*				
	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Specialization and year	Chemical engineering, 3rd year completed	Civil engineering, 3rd year completed	Electronics & Telecommunication Engineering programme, 3rd year completed	Civil Engineering, 3rd year completed
Industries joined (with time)	Kilombero Sugar Company Limited (November 2019 - October 2020)	Cost Plan Group (November 2019 - July 2020) and Karanga Leather Factory (August - November 2020	Liquid Telecom Rwanda (LTR) (January 2020 – December 2020)	Rwanda Housing Authority (RHA) (January 2020 – December 2020)
Level of satisfaction with SIS (students)	"The uniqueness of SIS lays on long duration at companies largely leading to long exposure in improving hands-on skills, facing real life challenges and pressure in industrial environment, social and professional networking as well as financial management. Students are more exposed to deliver based on the integration of knowledge acquired from the university and the reality on site."	"The programme enhanced confidence in performing the work with limited interference of the industrial supervisors; it offered exposure to various disciplines."	"Gained experience in telecommunication network such as wired and wireless technologies, fibre networking such as fibre installation, configuration and trouble shoot; work with the network devices configuration, installation and troubleshoot physically as well as remotely such as router, switch, radio, IP, IP phone, access point, etc."	"SIS is a contribution to engineering education as an opportunity to enhance the level of practical competence to students; it allowed performance of different civil works."
Industrial supervisor assessment of performance	Appreciated the programme, having undertaken the ordinary engineering experience at the university, the supervisor found that SIS provided opportunities to experience challenges that companies look for from fresh engineering graduates.	Appreciated the programme, particularly for allowing the students to stay for a long period in the firm. The student was considered as one of the staff members, left with various tasks to perform. The student met the requirements of a formal employee.	"The student is assiduous, enthusiastic, hardworking, tirelessly ready to learn."	At some point COVID-19 affected the SIS pilot at Rwanda Housing Authority (March - June 2020), this was managed in assigning tasks online.

Table 4: Summary of Pilot SIS placements (Tanzania and Rwanda)*				
	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Academic supervisor commentary on benefits	----	“She benefited from the integration of consultant work and contractor work. She got exposed to various work challenges that created the learning opportunities and improved her capabilities of doing well the work; (1) the SIS programme provides a student with much more exposure to real work environment; (2) the students get more time to gain tacit knowledge, develop professional skills and competencies from performing challenging tasks; and (3) the industries get the chance to identify students who can work with them after completing their university studies.”	“SIS gave motivation, confidence and power to discover the engineering career since she opted one among different disciplines within the telecommunication field.” “Student is interested to learn and link theory to real environment. SIS has been helpful in guiding professional discussions and provision of feedback.”	“Pleased in the way the different software packages were learned: reading and interpreting drawings; however, interruption occurred at some point due to partial lockdown due to COVID-19.”
Range/list of skills gained/enhanced (according to student and industry supervisor)	(1) Leadership skills – how to adapt and best fit for working environment; exercise authority and learn from more experienced workers; responsibility and work ethics (2) Planning skills of repair and maintenance activities (3) Hands-on skills and experience in the sugar processing industry (4) Personal-finance management skills	(1) Learnt how to take electronic measurements (2) How to value the executed works at the construction site (3) How to resolve an argument in case of diverging quantities or cost in construction works between the project stakeholders (4) More knowledge on tendering procedures and contract documentation (5) How to supervise construction works, conduct site measurement, material testing and site recording	(1) Customer service and support (2) How to set up a network through a fibre internet connection and broadband internet connection (3) Time management	(1) Supervision skills (2) Execution of civil works at site (3) Confidence in work performance (4) Professional communication (5) Structural design skills using software such as etabs, robot and protastructure (6) How to operate and use detailing software like AutoCAD, ArchCAD, and Autodesk revit (7) Networking with potential stakeholders; reporting skills

Table 4: Summary of Pilot SIS placements (Tanzania and Rwanda)*				
	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Perception of employability increase from SIS (by student and supervisors)	"Acquired hands-on skills in my engineering field of study and further gained on-site experience in terms of work ethics, safety issues, introduction to different workers' associations and NSSF membership and benefits. This resulted in a boost of confidence. All these will enhance my employability in the engineering field after the completion of my studies."	(1) SIS has improved students' capabilities; making the student a good team-player, problem-solver, honest and integral communicator who is eager and capable of working under pressure and meeting deadlines, more accurate and very attentive to details. (2) Improved technical knowledge enables the student to identify the gaps in technical knowledge and skills and that went a long way to build myself and obtain an experience that would make me more marketable in a competitive industry.[7] (3) The programme offered an opportunity to network with likeminded professionals in the industry…which I believe has increased my chances of employability.	SIS enabled teamwork and networking through working with different people of different levels, gained knowledge and skills that I would not get outside the programme, enhanced a competitive mindset in the labour market.	"Engineering knowledge enhanced by practical experience from office and sites that increased the level of competitiveness for job opportunities. Yet, a contractor expressed the intention of hiring me when I was doing my seventh month internship under SIS….I could not accept until I complete my degree programme."
**Commentaries drawn from student approved reports. Academic and industrial supervisors either commented generally or simply approved the student's report.*				

[7] 'For example, at Cost Plan Group firm, I learnt how to value the works, conduct electronic measurements, tendering procedures and contract documentation while at Karanga leather company project, I learnt site supervision, site measurements, material testing and site recording, these made me fit for a competitive job market.'

Table 5: Summary of lessons and recommendations from Pilot SIS placements*

	University of Dar es Salaam		University of Rwanda	
	Student 1	Student 2	Student 3	Student 4
Lessons and recommendations for university (from student report)	(1) Collaborate with industries (organizations and production companies). (2) More funds should be raised for sustaining the programme and engage more students	Get involved in identifying gaps by analysing what the university teaches and what the industry offers, and then design capacity building which has a meaning in the development of more modern training programmes in relation to the level of technology and market in the industries together with new production methods and ideas for student projects for the purpose of improving hands on skills and innovation.	(1) Improve collaboration to facilitate student's industrial placement. (2) Pay visits to students or arrange for virtual meetings in the way to understand what is going on. (3) Ensure that students receive their stipends timely.	Ensure that the allocated funds for students reach them on time.
Lessons and recommendations for industries (from student report)	Need to collaborate with support institutions (e.g., SIS programme and universities). This assists in students' placement and also serves as a ground for engineering graduates' mentorship and recruitment.	(1) Raise awareness of the programme; and meet students in order to understand their challenges. (2) Financially, invite more donors to sponsor the programme, preferably industry to get involved in providing support. (3) Should join the SIS programme, meet the students and make clear what they expect from them; join in interviewing the students as part of selection for internship/placement; give challenging tasks to interns, not repeated tasks.	Work in collaboration with the university in running the programme; collaborate with other industries in finding and facilitating industrial placements.	Ensure that regular supervisions are undertaken; strengthen partnership with universities and industries to facilitate the internship programme.
Lessons and recommendations for coordinators	(1) Provide information on SIS programme to more students; (2) In relation to the engineering training programme at universities, SIS should serve as a way to advocate for reshaping the	Financially, invite more donors to sponsor the programme, preferably industry to get involved in providing support.	------	Sponsor more students; work together with industries to ensure availability of placements.

	university engineering programme in such a way that skills and experience are obtained through a strong link between theories taught at university and reality in industries.			
**Commentaries drawn from student approved reports. Academic and industrial supervisors either commented generally or simply approved the student's report.*				

4. Phase III: Synthesis and reflection

4.1. Workshop: Engineering Ecosystems and Education Capacities in Africa

As part of the project activities, and by way of allowing broader reflections with stakeholders on the research topic, as well as disseminating and discussing main findings from phase I and II of the project, STIPRO organized a project dissemination workshop on "Engineering Education Capacities: How Engineering Ecosystems are preparing students in Africa for Employment?" The workshop was held on the 1st and 2nd of December 2021, in Dar es Salaam, on-line attendance and presentation was also accommodated. The two-day workshop gathered engineering educators, industry representatives, engineering practitioners and engineering graduates, and policymakers from various African countries (e.g. Tanzania, Uganda, Rwanda, Kenya, Zimbabwe, and Mauritius), with some joining online from Australia. Participants discussed the supply and demand of engineers in Africa, impacts of engineering on industrial development in Africa, employability of African engineering students, and the findings of the SIS project phases I and II. Overall, about 80 participants attended the workshop, including representatives from the press. The sessions of the workshop were organized under the following issues: a) Supply and demand of engineers in Africa; b) Impacts of engineering fields on industrial development in Africa; c) Employability of African engineering students; and c) Reporting on the SIS project. Reflections and recommendations from the workshop are integrated in this report, and a separate workshop report provides more details on points and insights raised at the workshop.

Presenters at the workshop included Dr. Goolam Mohamedbhai, former Vice-Chancellor of the University of Mauritius, former Secretary-General of the Association of African Universities, former President of the International Association of Universities, and prominent engineering educator; Dr. Henry Alinaitwe, Principal of the College of Engineering, Design, Art and Technology (CEDAT) of Makerere University; Dr. Burton Mwamila, former Vice-Chancellor of the Nelson Mandela African Institute of Science and Technology (NM AIST) and Saint Joseph University; Dr. Jonathan Mbwambo, representing the Executive Secretary of the Inter-University Council of East Africa (IUCEA); STIPRO high representatives (chair of board of directors, and executive director); representative from LIWA (Linking Industry with Academia) and the Research in Engineering Education Network (REEN); and many other distinguished guests from African academia and East African related industries and state bodies.

4.2. Discussion

Engineering ecosystems are broad and interlinked. Elements (nodes or actors) and connections (relations) are diverse and influence each other in various ways. However, the systems approach that was chosen for the study still came in handy (Mutambala *et al.* 2020). Considerable evidence exists for the existing of systems phenomena, such as:

(c) feedback loops (e.g. less competent engineers graduate, less engineers get employed, less new students join engineering schools, less pressure to improve engineering curricula);
(d) system delays (changes in curricula, or training of instructors in PBL, can only show outcome in years after implementation); and
(e) possible leverage points (e.g. changes in structure and financing mechanisms of SIS programmes). 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.

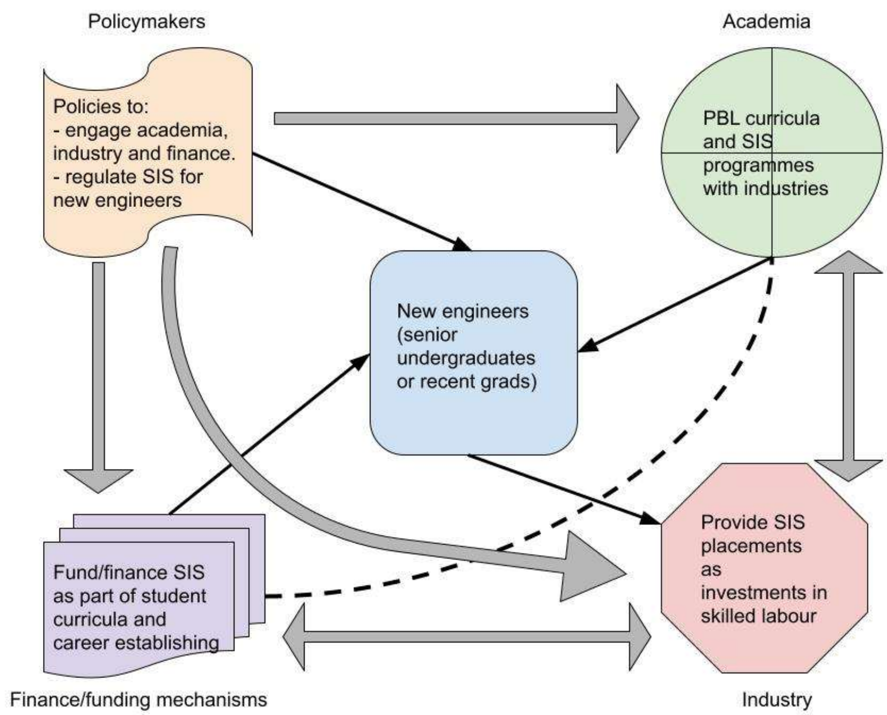
From the literature review and survey, there are examples of systems delays in response to changes in the engineering scene. For example, changes in the number of engineering graduates did not change old SIS policies; additionally, there were delays in policies of absorption of engineering practitioners in the job market and adjusting to new needs and numbers. There are several feedback loops, such as:

- ✓ shortage of local engineers (percentage per population) → current graduates don't find jobs in their field → skills are not enhanced, and industries complain about competence → less students join engineering → shortage of local engineers persists (reinforcing feedback loop)
- ✓ industries complain about competence of local engineering practitioners → graduates are expected to prove competence to find employment → requiring work opportunity in order to build competence, but work opportunities often go to expatriates or older generations → graduates unable to build competence → industries complain about competence of local engineering practitioners (balancing/negative feedback loop)
- ✓ low technology localization/transfer in African countries leads to low capacity of local industries to execute large engineering projects with local custodianship → large engineering projects are assigned to foreign industries (translational corporations or bilateral partnerships) → more foreign expatriates oversee delicate technology operations, while most local engineering practitioners are relegated to mundane tasks → large engineering projects are implemented without necessarily transferring their technology locally → low technology localization/transfer in African countries (negative feedback loop)
- ✓ Just as there are feedback loops, there are also potential leverage points. On the level of SIS programmes, perhaps they can introduce a shift in feedback loops: Graduates are armed with practical experience → employability of graduates increases → industries (local and foreign) find a larger pool of competent local engineering practitioners → study of engineering becomes appealing again→ steady enrolment and technology localization.

Other leverage points may exist in policies: standardizing long-term, hands-on SIS placements, across the triple helix, could lead to strengthening the local engineering ecosystem (i.e. advancements in industry, registration of engineering practitioners, and technology localization). Yet there might be bigger leverage points, at the level of paradigms – perhaps such research points to bigger issues of perceiving engineering practice in developing countries. The four influencers/actors of engineering ecosystems (policymakers, academia, industries, and financing/funding mechanisms) could introduce a new, more conducive paradigm.

Figure 2 provides a visualization of the main actors and connections of the engineering ecosystem if new engineers (i.e. senior undergraduates or recent graduates) are taken as the centre of attention. The visualization was developed over the project's period, based on the literature, survey and pilot, but it is still in need of further examination and consultation. In this ecosystem, 'policymakers' play a critical role, and they include regulatory bodies for engineering practice as well as other actors from the state or from regional bodies (such as science councils). Academic institutions also play a major role, particularly when they choose to innovate and tailor their programmes to include more PBL and SIS activities. Industries play a critical role as well, particularly when they realize that providing and organizing well-structured SIS placements is an investment in future skilled labour that they need to grow and innovate. Finance/funding mechanisms play a crucial part in the ecosystem because they can be catalysts that invest in proper engineering training to get returns in the form of more capable engineering practitioners (in quality and quantity) that advance and improve the ecosystem at large, for sustainable development goals.

Figure 2: Engineering ecosystem influencers/actors and employability of new engineers



Legend:
↗ from-to inputs (bolder lines between institutional actors)
---- inter-influence (various relations)
↔ indirect influence (through policy or relation)

5. Conclusions and recommendations

5.1. Conclusions

General characteristics and patterns were revealed through this study about the challenges of university-to-employment transition for engineering students in East Africa. The four East African countries of Tanzania, Rwanda, Uganda and Kenya 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. The study's findings show that there is a general consensus that short-term (8-12 weeks) industrial attachments, currently practised, do not allow students to have in-depth industrial experiences that visibly enhance their employability skills. Additionally, industries tend to receive more students in each training period than they can give tailored attention, resulting in completing industrial attachments with little experience and only fulfilling formal requirements to graduate. Weak coordination between universities/colleges and industries also contribute to a general mismatch of placements and miscommunication about how IAPs can be improved to increase the employability of engineering students.

The study's conclusions support that SIS placements over a longer period than at present help increase the employability of engineering students, according to perspectives of industrial supervisors, students and academic supervisors, but further evidence is needed (more scale SIS placements and more tracer studies). 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. Some ideas came out after recognizing the benefits of long-term SIS programmes, such as a suggestion by a senior UDSM professor of incorporating longer SIS placements by changing the structure of current practical training/industrial training programmes. Pedagogical approaches that aim for strong academia-industry linking, such as SIS and PBL, have the potential of resolving such dissonance (i.e. possible leverage points in the ecosystems), and they can work through policies that act as catalysts for change.

5.2. Project outputs (publications, presentations, and events)

a) Publications:

- Sheikheldin, G. and Nyichomba, B. 2019. 'Engineering education, development and growth in Africa.' *Scientific African*, Vol. 6. e00200.
- Mutambala, M., Sheikheldin, G., Diyamett, B. and Nyichomba, B. 2020. 'Student Industrial Secondments in East Africa: Improving Employability in Engineering' in *Disruptive Engineering Education Amidst Global Challenges: WEEF & GEDC Virtual Conference Proceedings*, 16-19 November, Danvers: IEEE.
- Mutambala, M. and Thomas, H. 2021. Engineering Education Capacities: How Engineering Ecosystems are preparing Students in Africa for Employment? Workshop report. Dar es Salaam: STIPRO.
- Sheikheldin, G., Mutambala, M., Klassen, M. and Matemba, E. 2022. Alternative models for engineering student industry placements in East Africa. Briefing paper.
- Sheikheldin, G., Mutambala, M., Diyamett, B. and Nyichomba, B. 2022. Improving Employability of Engineering Graduates Through Student Industrial Secondments: A Study in East Africa. Project report. Dar es Salaam: STIPRO (*in-print*).
- Sheikheldin, G., Mutambala, M., Diyamett, B. and Nyichomba, B. 2022. Challenges around Employability of Engineering Graduates in Africa: Can Industrial Secondments be a Remedy? Policy brief. Dar es Salaam: STIPRO (*in-print).*
- *Forthcoming*: 1-2 scholarly papers (one possible in a special journal issue, co-edited).

b) Presentations:

- Participation in AfricaLics special session: On the 4th AfricaLics conference, held in Dar es Salaam, 22-24 October, a special session was organized on 'engineering education, growth and innovation in Africa', in which the project lead presented a paper about this project, sharing the project rationale, methodology and preliminary findings.
- IDRC presentation (May 28th): Project lead, Gussai Sheikheldin, prepared a presentation on the project, in general, for IDRC, Ottawa, in a visit to Canada. That same presentation was used to present to the potential partners and other stakeholders in East Africa (particularly with the College of Science and Technology, University of Rwanda, and in Kenya).

c) Events:

- Dissemination and reflection workshop: Engineering Education Capacities: How Engineering Ecosystems are preparing students in Africa for Employment?" 1-2 December 2021, Dar es Salaam. (International attendance).

5.3. Future possibilities

- Further research on scaling is needed to strengthen evidence and better understand the ecosystem, but for undertaking such research, there needs to be buy-in from the triple helix (government-academia-industry) to increase the number of SIS placements, perhaps for a 'second' larger-sample project.
- Partnering with regional and/or continental agencies, such as the Association of African Universities and the African Union's Scientific, Technical and Research Commission (STRC), to vocalize the issues that are relevant to this project and to create more interest and generate additional ideas.
- Funding for increased SIS placements remains a challenge. Possible pathways for scaling up, and possible pathways for sustainable (continuous) funding and management should be explored.
- Looking at regulations and logistics related to engineering students taking longer periods off their university programme to pursue SIS placements. Can such SIS placements of longer periods be included in curricula (as in some universities) or be officially accommodated?

5.4. Recommendations

- Improve communication, collaboration and planning between government, academia and industries to address demand and supply of engineering practitioners (EPs).
- Long-term co-curricular activities have proven worldwide to improve graduates' preparedness for employment after graduation. Higher learning institutions should seek to enhance and invest in co-curricular activities, including long-term student industrial secondment (SIS) programmes.
- Problem Based Learning (PBL) and Challenge Based Learning (CBL) in engineering curricula can be treated as essential, not only an option. Engineering fields are often highly practical and hands-on, with physical results to produce and maintain. That level of practicality requires learning that integrates real-world problem-solving experience.
- In the same vein as promoting PBL, change from 'knowledge-based curriculum' to 'outcome-based curriculum' is also recommended to reduce the mismatch between training of engineering practitioners and requirements of industries.
- Bring engineering to the forefront of the debates and policymaking for the STI Strategy for Africa (STISA) 2024 and for the SDGs. They need to be at the forefront because they influence almost every aspect of both STISA and the SDGs.
- Collaboration and communication between East African (and African) engineering boards would enhance and promote engineering in the region because it will broaden the work/employability prospects of EPs and encourage improved and dynamic accreditation of EPs.
- African governments should legislate to ensure that transnational corporations and engineering companies from foreign countries provide professional training to local engineering students and employ local engineering graduates wherever possible to enable technology transfer.
- Incentives should be explored to make more engineering practitioners, especially fresh engineering graduates, willing to work in rural areas in Africa, where the biggest challenges to SDGs are.

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Appendix

Project Work Plan and Calendar: SIS in East Africa

	Year 1			Year 2			Year 3		Outputs	Remarks
	Third 1	Third 2	Third 3	Third 1	Third 2	Third 3	Third 1	Third 2		
Phase I: Surveying	Mapping of existing and previous engineering SIS programmes in East Africa (Tanzania, Kenya, Uganda, Rwanda) and their outcomes								Report on the history of engineering SIS programmes in East Africa (past and present) with indicators of success and lessons from shortcomings.	Through the mapping and surveying activities contact will be established with the wide network of relevant actors, to inform them of the project and recruit partners/supporters.
	Surveying and identifying of best practices in SIS programs in East Africa and other relevant cases in developing countries.								An evidence-based list of best practices learned from East African experiences and other relevant experiences.	
		Selecting engineering school from university B, selecting 2 students from each school, communicating with hosting organizations, finalizing placements and preparations with schools and industries.							University B selected, and 4 students total are selected and assigned SIS placements for coming year. MOUs with industries signed to take in students.	University B will most likely be from Uganda or Rwanda (university A is UDSM) as advised by IDRC.
Phase II: Piloting				SIS activities take place over the whole year. Each student will have a one-year placement; possibly divided into 2 firms/industries (depending on					SIS work begins (4 students, 2 countries, and possibly 4 different firms/organizations).	Aim will be for each student to have 2 SISs, divided into 6-months each, for broader exposure.

				availability of qualified and agreeing industry partners).						
					MEL*from SIS experiences. Cases will be closely observed to learn the most from.				Data, observations and lessons recorded.	*Monitoring, Evaluation and Learning.
					Advocacy for SIS programmes, learning from other relevant research (through scholarly conventions), and beginning of sharing results of phase I.				2-3 relevant workshops or conferences attended, with presentations about the project.	
Phase III: Synthesis and Result Dissemination							Data analysis among project partners, synthesis of findings, and consultations with relevant sources.			Communication with members of the triple helix (university-industry-government) for informing about project findings and recommendations, and invitations to the dissemination workshop. Report will be released and distributed shortly after the workshop, in order to capture in it any new relevant insights, information and reviews that may be revealed during the workshop by participants.
							Dissemination workshop (planning and event) + Project report (write-up and release).		One (1) knowledge dissemination workshop conducted. Workshop report is produced. Final draft of the report of the project finalized (and possibly released or in the process of being released).	