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The Royal Academy of Engineering, UK and The Enriching of Engineering Education Training and Practice Programme in Sub-Saharan Africa

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ABSTRACT

This paper elucidates initiatives taken by the Royal Academy of Engineering, UK, to overcome barriers in education and training in Sub-Sahara African higher learning engineering institutions. The said barriers include mismatches of curriculum, ineffectual teaching and learning and little exposure of academic staff to engineering practice. In order to overcome such barriers, the Royal Academy of Engineering established the two programmes in the region. The first one, Enriching Engineering Education Programme (EEEP) from 2014/15 to 2015/16 where the University of Dar es Salaam coordinated this programme as a hub for East African universities namely; Makerere University (Uganda), Moi University (Kenya), Dedaan Kimathi (Kenya) and Kenyatta Technical University (Kenya). A second programme which was implemented from 2015/16 to 2023/24, the University of Dar es Salaam also acted as a Hub for the local higher learning institutions namely; the Dar es Salaam Institute of Technology, Nelson Mandela, Mbeya University of Science and Technology, Sokoine University of Agriculture and National Institute of Transport under the new Higher Education Partnerships programme in Sub-Saharan Africa (HEPSSA); leaving Moi University and Makerere also to coordinate their own local universities under HEPSSA programme. All the above programmes involved capacity building in enhancing the outcome-based curriculum, problem-based learning, academia and industry staff exchange, student placements in industries, and technology business incubators/hubs practices. Conversely, the paper emphasizes the need establishing concordats of universities that will enhance collaboration of universities with industries in establishing joint research and development programmes for practical applications to technical and business problems facing the industry/private sector and the nation as a whole.

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INTRODUCTION

Governments in Sub-Sahara Africa established higher learning engineering institutions to educate and train engineers who would provide practical solutions to problems, ensuring socio-economic and technological progress in the ever-changing world. Thus, higher learning engineering institutions are expected to offer the best forms of education intertwined with the most critical intellectual abilities that would, and should, enable the learners to be of practical service to their society and the world as a whole.

A number of reports (Royal Academy of Engineering 2012; Mohammedbhai, 2015; UNESCO 2021) indicates that there is a shortage of experienced and skilled engineers in Sub-Saharan Africa, while the truth on the ground is that there exists a significant number of engineering graduates who are finding it difficult to find jobs within their fields. The above dissonance seems to emerge partly from the competencies of engineering graduates (IUCEA 2014; Sheikheldin et *el*., 2023) as caused by the type of curriculum in place, ineffectual teaching and learning resulting from poor institutional infrastructures, inadequate facilities, and limited use of new teaching techniques (SADC 2018, Sheikheld and Nyichomba, 2019). The said dissonance is also contributed by higher learning institutions having engineering academic staff, who despite being highly qualified they have "very little exposure to engineering practice (in industries and public works)".

Conversely, another critical obstacle is the limited capability and experience of academic staff in higher learning institutions to convert research results into useful processes, products, and services. It should be noted that over the years researches in higher learning institutions have been carried out in silos and in a few selected areas, thereby contributing lowly to the socio-economic development of the country. As such, the countries in Sub-Saharan Africa continue to struggle to meet the best needs of their people, such as adequate food, clothing, shelter, health, and education, to raise their living standards substantially. One of the major obstacles here is inadequate linkages and knowledge flow between engineers, entrepreneurs and the capital.

The paper also looks into the challenges and mitigating measures that have been taken by the Royal Academy of Engineering, UK, to realize the engineering education and training that immensely contribute to national socio-economic development. This obviously required the prospects of adopting modern curriculum, teaching and learning practices as well as establishing joint research between the higher learning institutions and industries that will enhance skills and knowledge for engineering graduates and thereby be able to translate research into products, processes and services.

Review of engineering practices for enriching engineering education and practices

This section elucidates the status of education and training in higher learning engineering education in Sub-Saharan Africa, including the type of curriculum used, the teaching practices or the delivery mode, the physical infrastructure, the human resources, and industrial training. The section goes further to establish the type of curriculum, teaching practices, i infrastructures, and industrial training programmes used in developed countries in Europe and Asia.

Teaching and Learning

The Quality of Curriculum and Relevance of Higher Learning Institutions in Sub-Sahara Africa

The quality and relevance of the current curricula content in higher education institutions in Sub-Sahara Africa (SSA) responsible for STI capacity building falls short of meeting new and emerging technologies and labour market demands (Mohammedbhai, 2015). A study, undertaken by the Inter-University Council for East Africa in 2014, reported that a large proportion of university graduates were not equipped with job market skills with Uganda leading at 63%. The status for other countries were Tanzania, 61%; Burundi, 55%; Rwanda, 52%; and Kenya, 51% (Nganga, 2014). At the same time, a number of reports (CTI, 2018; Mohamedbhai, 2021) show that there is a shortage of engineers in African countries, while the truth on the ground is that a significant number of engineering graduates find it difficult to get jobs within their fields. The above dissonance seems to emerge, partly, from the competencies of engineering graduates (Sheikheldin et *el*., 2023) caused by curriculum used, ineffectual teaching and learning resulting from poor institutional infrastructures, inadequate facilities, and limited use of new teaching techniques (Sheikheld and Nyichomba, 2019).

It is worth noting that the content delivered by higher education learning institutions do not often provide skills that are more responsive to market demands> Further, many higher learning institutions have not mainstreamed scientific concepts and thought patterns into a curriculum that dips into and exploits indigenous knowledge and technology for innovations, creative sufficient level production and of guarantee of intellectual property ownership and rights (SADC 2019). In addition, the HEIs training institutions often fail to target such demands more pro-actively, address the growing and changing needs of the private sector, and fail to carry out regular surveys of occupations and the labour market unmet demands. The HEIs curricula delivery, is not student centred but based on inputs from lecturers to students – Knowledge Based Curriculum (Gallow, 2014).

Delivery Mode

Most teaching staff use conventional teaching delivery mode, which involves class lectures, practical, assignments and seminars. Usage of ICT in program delivery in conventional teaching has become increasingly crucial in enhancing the overall learning experience. In this regard, ICT tools and technologies are utilized in various aspects of program delivery in higher learning institutions to improve efficiency, accessibility, and engagement. However, despite all the modern facilities in teaching and learning, the curriculum focuses on 'inputs', i.e. transmission of theoretical knowledge delivered through lectures based on textbooks and disciplinary needs for contents and coverage rather than outputs (ARCEE, 2008). It is worth noting that in traditional education, one tends to concentrate on the resources available to the student and the time and methods of delivery of the course content in the form of facts and methods. Usually the curriculum will have two components. The first is the subject matter that students need to study. The second component consists of the tests and exams designed to assess student mastery of the content. Consequently, students climb up the ladder of education through memorizing the subject matters rather than understanding. Group works is extremely rare, there is very little student participation in classrooms and hence little "know how".

Other factors include having engineering academic staff with "very little exposure to engineering practice (in industries and public works)" despite being well-qualified. Many universities are insisting that all their lecturers should have a Ph.D (WB-2014). This may not necessarily be the right approach for all engineering lecturers, and in any case may not be feasible.

Physical Infrastructure

There is gross shortage of the necessary infrastructure (i.e. laboratories, equipment and machines and the corresponding supplies). Thus, many HEIs institutions have out-dated, worn out or poorly maintained equipment. Currently, the few available laboratory resources are shared by many students (UNESCO, 2010). If the sharing is not well co-ordinated, this results in a situation where only a few students learn while others are mere spectators. This is not acceptable if quality graduates who are potential researchers are to be expected from the education system. This has been observed as a major gap in building a strong innovation culture in HEIs (UNESCO, 2021). Further, most of the institutions offering engineering courses have inadequate resources as well as critical shortage of academics. It is hence emphasized that investment should be made in strengthening the established institutions to produce the desired calibre of graduates.

The poor state of research equipment in HEIs may be responsible in part for the tendency of students and researchers at higher education institutions to conduct superficial fact-finding, survey-type and non-innovative research, as opposed to targeted, mission-oriented research. This is the general situation in almost in all HEIs in Sub-Saharan Africa (UNESCO 2010). Such research endeavours cannot lead to any meaningful scientific developments and produce innovations. The optimal utilization of the much needed research equipment and which are expensive for a single institution to acquire is hampered by lack of a culture of sharing and support to access such facilities. The Industrialization Strategy (2015-2063) identifies lack of adequate infrastructure, skills and capacities in science, technology, engineering and mathematics (STEM) as among the binding constraints for industrial development. Of particular importance is the inadequate engineering skills in construction; manufacturing; mining; energy, gas and water; transport and communication; and, in specific aspects of agriculture. There exists very low level of linkage between industrial firms and knowledge organizations resulting into poor uptake of research outputs from the higher education institutions or low sponsorship of R&D at these institutions.

Education and Training in Engineering Industry - Sub-Saharan Africa

One of the practices used world-wide in in enhancing engineering practical skills to students undergoing engineering studies in higher learning institutions is that of secondment of students to industries for their industrial or practical training. A previous survey by STIPRO in 2022 (Sheikheldin, 2022) showed that Universities, in Uganda, Kenya, Tanzania and Rwanda have similar industrial programmes, in in which 8 and 12 weeks, depending on the course programme, are spent in industries. In the College of Science and Technology, at the University of Rwanda, industrial attachment is typically assigned after the student completes the third year of studies and this lasts for 10 weeks. Students are given logbooks to record their daily assignments and universities ensure that students report to their respective attachment places through an assessment form.

Other studies on industrial training in higher learning institutions in Zimbabwe showed that , this programme started a way back in 1980s (Munyoro et.*al*., 2016) with reported classical benefits to students, Higher Learning Institutions (HLIs) and industries. Similar benefits and challenges to those industrial trainings in Zimbabwe seem to appear in other countries such as Ghana (Adjei, et *al* 2014; Nduro et *al*. 2015). Nigeria has the largest higher education system in Africa and has the Students Industrial Work Experience Scheme (SIWES) in which almost all universities participate, as part of fulfilling course requirements for graduation. This program is aimed for all students that study in the engineering programmes and other related programmes (Oyeniyi, 2012). What is significant about SIWES is that it requires longer than 24 weeks (six months) as the minimum duration of an industrial training, for engineering students, to be recognized.

Although students do write reports upon completion of their industrial training, these reports are only used for fulfilling course requirements for graduation as well as feed backs to higher learning institutions and industries for the future improvement of their training. However, one would have expected that students and academic staff should have worked on industrial problems or projects established by students during their practical training so as to provide solutions through collaborative work between the academia and the industry (Hackettet al. 1998; Friel1995). Incidentally this has not been the case. It is worth noting that the industry can only evolve through adoption and implementation of research results and innovations from the academia for its improved industrial competitiveness and growth (NEPAD, 2014). This is a challenge which needs to be addressed.

Current Practices of Education and Training in Higher Learning Institutions at Global Level

The Quality of Curriculum and Relevance of Higher Learning Developed Countries

Experiences from other countries show that the East Asian "Tigers" including Korea, Singapore and now China, took a much different approach to building engineering capacity than countries in other regions (UNCTAD 2003). While each country's approach in East Asia was necessarily unique, they shared the one distinct feature of not focusing initially on the frontiers of science, but rather on building labour force skills through education at all levels, creating incentives and public institutions for discovering and adapting needed foreign technologies, effectively using foreign investments. This in turn created technological spill-overs, and building focused projects for supporting the technology needs of industry (Richard, 2018). There is therefore a need to have a scientific and technical manpower in Sub-Saharan Africa that not only better absorb and adapt foreign technologies, but also develop local capability of maintaining and operating the industries, build infrastructure and provide service to agriculture, industry and other economic sectors (UN 2016). This obviously requires a curriculum with intense teaching and learning using competence-based curriculum or Outcome based Curriculum as used by Asian countries

Outcome Based Curriculum (OBE) is a student-centered learning process which requires students to demonstrate the skills and competencies they have acquired at the completion of their studies. Therefore, OBE measures the student's performance at the completion of studies. This is in fact an assessment of the Outcome of the curriculum. Outcomes should be measurable. For example, a student should be able to design a two-storey building, rather than being familiar or knowing the principles of building design. Outcome-based curriculum looks for results; it puts the burden of professionalism more on the shoulders of the student and lets the instructor decide how to get results. It is best described as 'developmental training'—development of the individual in terms of building competences and skills. Students/learners are held accountable for what they should already know and bring to the next course.

Delivery Mode

Experiences from other countries such as Denmark and Finland shows that these countries have migrated from the traditional teaching and learning practices which is teacher/lecturer centred to Problem Based Learning (Aalborg University, nd). This initiative has shown to improve skills and knowledge of graduates in higher learning institutions thereby increasing start-up and spin-off firms as a result of problem based research outputs and learning including developed entrepreneurial mind sets. Problem Based Learning completely redefines the role of the teacher in the learning process. In this case, rather than the teacher communicating knowledge to students (chalk and talk), often in lecture setting, the teacher instead acts as an initiator and facilitator in the collaborative process of knowledge transfer and development (Duch et al, 2001).

Problem-Based Learning (PBL) is a teaching method in which complex real-world problems are used as the vehicle to promote student learning of concepts and principles as opposed to direct presentation of facts and concepts. In addition to course content, PBL can promote the development of critical thinking skills, problem-solving abilities, and communication skills. It can also provide opportunities for working in groups, finding and evaluating research materials, and life-long learning (Duch et al, 2001). Problem-based learning is an attempt to overcome problems and confront the concerns presented by a number of stakeholders about our graduates (Wissema (2009). Problem-based learning emphasizes learning as a process that involves problem solving and critical thinking in situated contexts. It provides opportunities to address broader learning goals that focus on preparing students for active and responsible citizenship. Students gain experience in tackling realistic problems, and emphasis is placed on using communication, cooperation, and resources to formulate ideas and develop reasoning skills *(*WCES (2012).

Education and Training in Engineering Industry

This section focuses on recent strategies adopted in selected developed countries such as UK, Canada and Austria to improve education and training through sturdier academia-industry linkages. The strategies include student internships, work integrated learning, visiting professor programs and the teaching factories which apart from providing students with industry experience, provides feedbacks for curriculum improvement, teaching and learning as well as in research and innovation. This incorporation of hands-on experience from the industry into academic work, creates a vibrant learning environment which improves skills and nurtures innovation and allows training and education to make an impact to the society.

Student Experience Internships (SEI) programme in Europe

The University of Manchester, UK has a Student Experience Internships (SEI) programme which offers penultimate year undergraduates i.e. in second year of a three-year course or the third year of a four-year course the opportunity to undertake industrial training within the University or with a local charity/not-for-profit organisation. The programme is managed by the Careers Service's Internships and Placements team who are able to provide full support to colleagues during the engagement of their interns. The team also provides full support in managing the payment of the student interns which is undertaken through the casual staff process. Each School is able to engage their own students to work on particular projects, e.g., employability focused activities.

Student internships are carried out through a mixture of in-person and hybrid working up to eight weeks. such programmes gives the student the benefit of returning to final year of study knowing that they have secured professional work experience to demonstrate to graduate employers alongside their academic record and keeps them ahead of the competition. In a competitive graduate market, employers are looking for both high academic ability and relevant work experience. Further, many employers use placement opportunities as a way to recruit into their graduate jobs with many of them returning to their placement providers after their final year of study.

Work Integrated Learning (Co-ops – Canada)

Integrating work experience into educational programs is one approach to ease transition to the labour market in Canada. Work-integrated learning (WIL) is meant to serve as a bridge from university education to the labour market by facilitating the chance to gain labour market experience during, or interspersed with, educational studies (Barry et *al*.). Students gain the knowledge and skills they need in academic studies, and subsequently learn to apply those skills in a professional work environment. Similarly, following a work term, students can use their experience in the labour market to inform their course selections and apply their practical learning as they complete their education. These programs tend to take longer to complete, and may require higher investment in the form of tuition but have the following advantages:

(a) Co-op programs have significant benefits associated with participation in the form of easing transition into the labour market and higher incomes after graduation; they also might play a role in overcoming wage gaps associated with bias toward individual characteristics;
(b) Participation in co-op programs is also associated with a higher likelihood that a graduate's first job will be permanent and highly related to the graduate's field of study; three years after graduation, co-op participants are more likely to be employed full time and to have extended health benefits through work; and
(c) Co-op programs have a feedback system to Universities aimed at improving their curricula and hence courses in place.

UK's Visiting Professors Scheme

The scheme supports the appointment of experienced industrial engineers, entrepreneurs or consultants as Visiting Professors in engineering (and related) academic units (for example faculties, schools or departments) at UK universities (Royal Academy (2023). This industry-into-academia initiative aims to utilize the knowledge and experience of the Visiting Professors (VPs) —industrialists to enhance student learning as well as improve the employability and skills of UK engineering graduates while strengthening university partnerships with industry. The intention is that VPs act as 'change agents' in aligning and updating the teaching and learning activities of engineering higher education departments with modern educational practice and the needs of modern industry. The scheme particularly supports activity - and experience-based learning approaches. It does not directly support research interactions between industry and academia, for which separate schemes exist. The main objectives of the scheme are to:

(a) Facilitate closer collaboration between industry and universities.
(b) Inspire the next generation of engineers to the benefit of UK industry.
(c) Provide advice and guidance to universities on degree programme strategies/curriculum to align with industry needs.
(d) Deliver teaching and learning on relevant engineering degree programmes.
(e) Provide students with real-life industrial contexts and scenarios

It is important to learn that a VP is not an additional pair of hands to share in the routine teaching and learning and administrative activities of a university engineering department. Rather, it is an opportunity for suitably experienced industry practitioners to participate (for example) in curriculum development, face-to-face teaching, or mentoring of engineering undergraduates/postgraduates on taught courses. This may be through the introduction of specialist subjects (e.g. AI, digital skills, big data, cryptology, sustainability) or of new teaching and learning methodologies, (such as 'Active Learning') or of key skills identified by industry. VP scheme has a minimum requirement for the equivalent of 12 days engagement of the VP with the university each year (~96 hours).

The Teaching Factory

A number of universities in countries such as USA, Europe and Asia are currently adopting the teaching factory concept aimed at strengthening the academia-industry linkages and hence engineering education training, research and innovation ((Mavvriokios et al. 2013). Teaching Factories both at international levels have been established to offer a supportive environment in the co-working spaces located either in higher learning institutions or the industry so as to integrate research, innovation and engineering education activities into a single initiative of achieving knowledge based competitive and sustainable engineering capacity (Abelle, 2015). It is worth noting that industrial projects that take place in teaching factories provide students with the integration of learning experiences in a contextual setting, where emphasis is given to competence and effective application. The teaching factory also facilitates interactions between industrialists and university researchers working on real life engineering problems and involves interdisciplinary hands on design projects with strong links between academia and industry.

In the teaching factory, industrial companies provide knowledge gained from their industrial experience while academic contribution would be their scientific knowledge, equipment and tools. The research projects outputs developed within the industrial projects by the academia could be concurrently fed back to industry and academia. Innovation activities employ knowledge transfer schemes to keep the industry at the technological forefront by supporting the continuous comprehension of technical essence and business potential of new knowledge and technology derived from research projects (Chryssolouris et al.,2013). These activities would employ teaching and learning programs to students resulting into students gaining new knowledge, business like working methods and attitude, real life industrial practice or hands on experience (learning by doing) and entrepreneurial activity as shown in the teaching factory models in Figure 1.

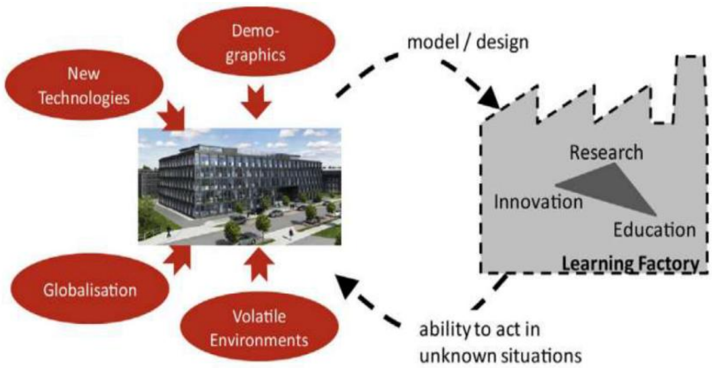

Figure: 1: The learning/teaching factory as a model of a real factory incorporating the three poles of the "knowledge triangle" (as adopted from Abele et al., 2017).

University-Industry partnerships and collaborations (UIC), a concordat of universities

Experiences from countries such as United Kingdom, shows that in 2018/19, 136 universities established a representative body for university colleges and other institutions, each with a distinctive mission and priorities. These universities work closely with industries and professionals and include major providers in technical and professional subject areas such as art, design and media, music and the performing arts; agriculture, food and the natural environment; the built environment; education; law; health and sports. In return, they received £4.9 billion from knowledge exchange activities, helping fund activities to boost scientific, technological, medical and cultural breakthroughs (Kulaya, 2023). Thus, the use of knowledge created from University-Industry partnerships and collaborations (UIC) in Sub-Saharan Africa could be created where universities collaborate with industry for their mutual benefit (Secundo et *al.* 2023). With the concordat in place, the country could contribute significantly to the creation of new economic activities such as increasing farm productivity, identifying of new markets for farm products, creating new enterprises and diversifying of rural economies. The concordat provides a better structure for the sharing and development of life-saving research and in-demand skills by outlining good practice and showing what works

Summary and Conclusion of the Review of Literature

Findings by a number of scholars including the Royal Academy of Engineering UK reported that much as there is a shortage of engineers, engineering graduates remain unemployed or are under-employed. The reason being engineers were graduating without the necessary skills and knowledge to be employable. Further, the literature showed that academic staff in higher learning institutions in the region had very little exposure to engineering practice with no pedagogical skills in teaching although well-qualified academically. Infrastructures used in teaching and learning leaves a lot to be desired.

Conversely, of the literature also shows that education and training in higher learning engineering institutions can be enhanced through industrial staff secondments or visiting professor scheme professor as initiated by the Royal Academy of Engineering, secondments of academic staff to industry under the teaching factories concept. Further to that, the instruction of outcome-based curriculum integrated with problem-based learning is very important at ensuring that students graduate with adequate skills and knowledge apart from being innovative.

Thus, the use of knowledge created from University-Industry Collaborations – UIC (through the teaching Factory)), a **concordat** of universities could be created where universities collaborate with industry for their mutual benefit. With the concordat in place, the country could contribute significantly to the creation of new economic activities such as increasing farm productivity, identifying new markets for farm products, creating new enterprises and diversifying of rural economies.

Initiatives taken by the royal academy to strengthen education and training in Sub-Saharan Africa

Section two has provided a clear status on the higher learning engineering institutions in terms of education and training in Sub-Saharan Africa both in class and industry including identified key weaknesses that contribute to inadequate engineering capacity in the region. The Section has gone further to expose best practices of enhancing engineering education at global level. section three elucidates steps taken by the Royal Academy of Engineering in establishing programmes that aimed at enhancing education and training in Sub-Saharan Africa by selecting the best practices from the literature review in Chapter two which were established and carried out in the Sub-Sahara Africa namely; the Enriching Engineering Education Programme (EEEP) and the

Higher Education Partnerships in Sub-Saharan Africa (HEPSSA).

Enriching Engineering Education Programme (EEEP) in Sub-Saharan Region

The University of Dar es Salaam (UDSM) was one of the two Hub Universities which was nominated by the Royal Academy of Engineering, UK to host the programme of Enriching Engineering Education Programme (EEEP) in East Africa for 2 years as from 2014 to 2018. The other Hub was the University of Zimbabwe which coordinated EEEP in the Southern Region. While UDSM coordinated the programme for universities in the East African sub region namely; Makerere, Dedan Kimathi, Kenyatta Technical and Moi universities as spoke universities, the University of Zimbabwe coordinated the programme for universities in the Southern Sub-Region — Namibia and Botswana.

The main objective of EEEP was to ensure that higher education engineering institutions in Sub-Saharan Region produces engineers with the skills and knowledge that are required to meet the needs of industry and the society as a whole. Thus, specific objectives of the Programme included the following:

(a) Addressing persistent and documented deficiencies in engineering skills capacity in Sub-Saharan Africa.

(b) Increasing the engineering curriculum’s relevance to regional development priorities and business needs, and

(c) Building valuable, mutually beneficial links between African engineering faculties and business.

In order to address the noted deficiencies in higher engineering education in Sub-Saharan Africa, EEEP was designed to carry out its schemes under the Hub University and Spoke universities model. The principle behind the hub and spoke model is that the majority of the scheme is focussed on the hub university while the spoke universities are given access to lessons learned, teaching materials developed and to the workshops. Thus, EEEP schemes comprised the following:

(a) Secondments of academic staff from the Hub University to a local industry for a period of two months for two years. In return to this practical training the staff were required to produce the following:
   - (i) Passing on what they have learnt to other engineering teaching staff in both at the hub university and at spoke universities;
   - (ii) Generating new case studies and ideas for student project works for the purpose of curriculum modernisation; and
   - (iii) Exploring ways of building links between academia and the industry with a view to strengthening such collaborations.

(b) Secondment of one industrial engineer from the local industry to the Hub University for a period of two months for two years and in return the industrial engineer was expected to deliver the following:
   - (i) Use his/her frontline industrial experience to support the development of a modernised teaching material and practices reflective of current industrial practice;
   - (ii) Aid the development of a professional development programme to up-skill teaching staff in the delivery of a dynamic, modernised curriculum;
   - (iii) Deliver lectures and seminars;
   - (iv) Support student project work;

(v) Establish, develop and strengthen mutually beneficial links between the host faculty and business;
(vi) Connect departments with the realities of professional engineering practice and encourage this to be reflected in the curriculum; and
(vii) Provide students with formal and ad-hoc careers advice.

(c) Holding three (3) Workshops over a period of two years that comprises about sixty (60) participants or more per Workshop from both the Hub and Spoke universities as well as supporting one Dissemination Workshop. The three workshops were aimed at sharing lessons learnt from industrial secondments including the impact on teaching methods and curricula, with staff from Spoke institutions as well as from other academia. The Dissemination Workshop was aimed at sharing the findings of the 3 workshops and industrial secondments. Participants for all the workshops comprised a good mix of academia from EAC universities, the media, industry and government stakeholders. It is worth noting that the said workshops were carried out in a rotary manner in the five collaborating institutions.

Higher Education Partnerships in Sub-Saharan Africa -HEPSSA (2016 to 2024)

The first phase of the programme on Higher Education Partnerships in Sub-Saharan Africa (HEPSSA) started in 2016/17 and was established by building on what had already been achieved by EEEP programme and involved the same activities as indicated in Section 3.1. However, this time around the programme activities were honed down on local engineering institutions namely Dar es Salaam Institute of Technology, Nelson Mandela Africa’s Institute of Science and Technology, Sokoine University of Agriculture, Mbeya University of Science and Technology and National Institute of Transport. In this phase, Moi and Makerere universities were also given a status of becoming hub universities in their countries and other East African countries such as Rwanda, Burundi and Sudan.

Outputs of EEEP and HEPSSA Programmes

While the workshops during EEEP programme were involved in awareness creation of the outcome based curriculum (OBC) and problem based learning (PBL) which were very new in people’s ears, HEPSSA programme concentrated on training of trainers in CBC and PBL for selected academic staff members in the higher learning institutions in East Africa. This was aimed at equipping academic staff with skills and knowledge for the development of outcome based curriculum as well as the new teaching pedagogy – problem based learning. Other courses which were carried out apart from OBC and PBL were incubation management (2018) and entrepreneurship and innovation (2020)– all carried out at UDSM. It should be noted that during this phase all workshops which were organized by one country, were attended by participants from collaborating universities. For example the workshop on Training of Trainers on Incubation Management organized by UDSM in 2018 was attended by participants from universities of Uganda and Kenya.

Overall Achievements of EEEP and HEPSSA Programmes

Table 3.1 shows the number of trained academic staff on Outcome Based Curriculum and Problem Based Learning while Table 3.2 summarises the number of academic staff seconded to industries and the number of industrial fellows seconded to higher learning institutions. Table 3.3 shows the overall goals and achievements for HEPSSA programme with regard to Outcome Based Curriculum and Problem Based Learning in East Africa

Table 3.1: The number of trained academic staff on OBE and PBL

Year	Kenya		Uganda		Tanzania	
	Male	Female	Male	Female	Male	Female
2014 to 2016	29	3	28	7	12	0
2016 to 2018	19	0	27	11	162	37
2018 to 2020	17	15	15	15	192	75
2022 to 2024	-	-	-	-	150	50
Sub-total	**65**	**15**	**79**	**33**	**516**	**162**
Total	**80**		**112**		**678**	

Table 3.2: The number academic and industrial fellow supported by the programme

S/No	Year	Academic staff seconded to industries	Industrial fellow seconded to industries	Remarks
1.	2014/15	2	1	**Piloting EEEP Project**
2.	2015/16	2	1	**Piloting EEEP Project**
3.	2016/17	5	0	**HEPSSA Project**
4.	2017/18	5	3	**-do-**
5.	2018/19	5	0	**-do-**
6.	2019/20	6	1	**-do-**
7	2022/23	10	3	**-do-**
8.	2023/24	11	3	**-do**
	Total	**46**	**12**	**-do-**

Table 3.3: Project Beneficiaries and Stakeholders

Type of beneficiaries	Stakeholders	Skills and knowledge gained
Immediate beneficiaries	Engineering Academic Staff from higher learning institutions in East Africa	Acquired skills and knowledge on how to develop Outcome Based Curriculum and Problem Based Learning so as produce engineers with skills and knowledge that are required to meet the needs of industry and the society as a whole.
	Engineering students from higher learning students in East Africa	Acquiring of innovative skills and knowledge that will enable to start up and manage business firms/new economic activities
	Top Management of higher learning institutions in East Africa	Evidence based results for setting policies that that have started transforming engineering curricula to emphasis required skills,

		knowledge and attitude apply engineering and technology to global issues and challenges
Secondary Beneficiaries	Non Engineering academic staff from higher learning institutions in East Africa	Awareness on the benefits Outcome Based Curriculum and Problem Based Learning.
	Regulatory bodies in East Africa	Evidence based results for setting up policies that shall allow the use of Problem Based Learning , and Outcome Based Curriculum in higher learning institutions
Other Stakeholders/Beneficiaries	Policy Makers in East Africa	Evidence based results for providing a "**Ring fenced budget"** for higher education institutions in curriculum development.

Unplanned or unexpected achievements during the project

Other unplanned achievements by the project included:

(a) Establishment of the University Innovation Hub: Through HEPSSA Workshops, UDSM decided to establish the Innovation Hub apart from the existing of Dar e s Salaam Innovation and Entrepreneurship Centre (UDIEC) which was established in 2017. The Innovation Hub shall act as a gateway between higher learning institutions, R&D institutions and the surroundings society and shall provide the capacity to stimulate and drive innovation in the country.

(b) Mainstreaming PBL at the University of Dar es Salaam: The University is in a move to mainstream PBL in its curriculum and it has already appointed a team of 6 staff including the HEPSSA Coordinator who are currently working on how to mainstream PBL in the University curriculum while taking on board local structures, resources and arrangements.

(c) Training of Innovation and Entrepreneurship courses to graduates of Higher learning Institutions in the Country: With experiences gained from HEPPSA workshops, the University has trained more than 5,000 graduates country-wide on how to establish businesses using the knowledge gained after graduation. The said trainings were funded by UDSM.

(d) The Coordinator HEPSSA was able to facilitate trainings on Problem Based Learning (PBL) and Outcome based curriculum which were supported by other donors such as

(i) International Development Research Council (IDRC): This programme and took place in Dar es Salaam, Tanzania from 18^{th} to 20^{th} August 2019 and was aimed at equipping graduates (80) from universities Makerere, University of Dar es Salaam and Moi University specializing on Clean Water and Sanitation to be able to establish businesses using knowledge and skills gained from their studies.

(ii) Aalto University under PBL East Africa: Created awareness workshop on “Strengthening Problem-Based Education in East African Universities project (2017-2019). About 260 academic staff from University of Dar es

Salaam, Makerere and Nairobi attended.

(e) Students Industrial Secondments (SIS): Through HEPSSA programme the University of Dare s Salaam collaborated with the Science, Technology, and Innovation Policy Research Organization (STIPRO) to support the project titled "Students Industrial Secondments (SIS)". So far, the project supported four third year students from universities from Rwanda and Tanzania who underwent their practical training in industries for one year before coming back to the University to complete their fourth year/final years of study. The ultimate goal is to see if by so doing, students will have adequate skills and knowledge that are suitable for employment.

(f) Commercialization of research results for selected higher learning engineering institutions: As a result of the previous workshops on Establishment of Incubators for Higher learning Institutions, the University received USD 13,500 (British Pounds 10,600) for carrying out research on a project titled "Mapping and accelerating the commercialization of University –Based Research results: A case Study of Universities in Tanzania". This study involved all HEPSSA collaborating higher learning engineering institutions in Tanzania namely:

  (i) Nelson Mandela Africa Institution for Science and Technology
  (ii) Dar es Salaam Institute of Technology
  (iii) Mbeya University for Science and Technology
  (iv) Sokoine University of Agriculture

Outputs: Paths, structures and mechanisms for translation of research results from selected higher learning institutions into spin-off firms in Tanzania established/proposed.

The future outlook for the hepssa programme in Tanzania higher learning institutions

This Section sets up the future direction of academic –industry collaboration (concordat) through the teaching factory model involving selected number of higher learning engineering institutions, industry and governments. This time around it will involve postgraduate students instead of undergraduate students, academic staff, industrialists and key Government ministry that are relevant to education and training. Thus, the Section elaborates arrangements that will involve the Technology Transfer Centers or Innovation Hubs as teaching factories and key for facilitating the concordat activities that will be emerging from collaborative research and innovation projects between the academia and industries.

Setting up the Teaching Factory

Higher learning institutions in Sub-Sahara Africa have the obligations of addressing challenges related to imparting the right skills and knowledge to students. In this regard, it is important that students or university researchers acquire learning experiences in a contextual setting, where emphasis is given to competence and effective application through the teaching factory settings. The teaching factories will facilitate interactions between industrialists and university researchers working on real life engineering problems and involves interdisciplinary hands on design projects with strong links between academia and industry. Also, activities within the teaching factory employ teaching and learning programs to students resulting into students gaining new knowledge, business like working methods and attitude, real life industrial practice or hands on experience (learning by doing) and entrepreneurial activity. The proposed model for the teaching factory is as seen in Figure 1 and is usually not for profit.

Services to be offered by the Teaching Factories

The detailed account of the functions of a typical teaching factory will include:

(a) To provide an active, learner-cantered, and competence-orientated didactic setting with the aim of acquiring knowledge and skills for developing effective technical problem-solving skills in specific application contexts.

(b) To strengthen students' interdisciplinary hands-on engineering design and manufacturing projects with strong links and interactions with the industry.

(c) To enhance student collaboration with industrialists in solving industrial problems or solving scientific researched problems which will be translated into innovations/spin-off firms.

(d) To train Industrialists/employees so as to catch up with new technologies through self-reinforcing systemic interaction that creates environment for teamwork, innovation, strong linkage with industry, and a strong focus on capability development.

(e) To offer internship opportunities to students so as to expose them to early entrepreneurships via industry-targeted research that has the potential of financially benefiting the students.

(f) To market and sell its products in a well-established market segments within the country and abroad.

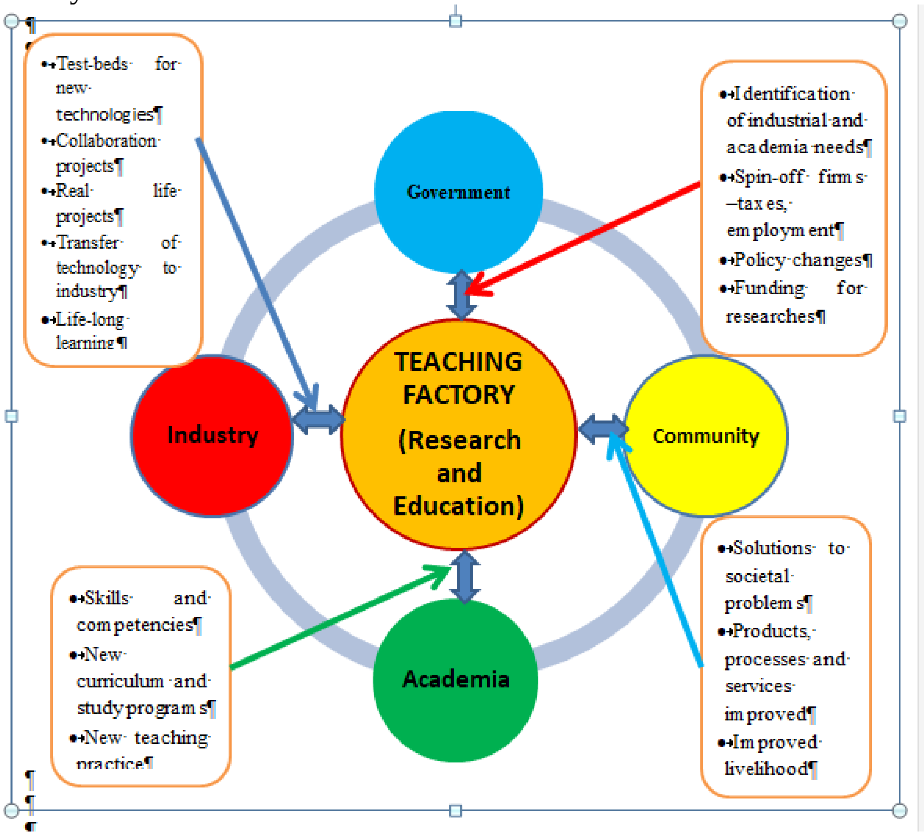

Figure 1: Commercial set up of the teaching factory model.

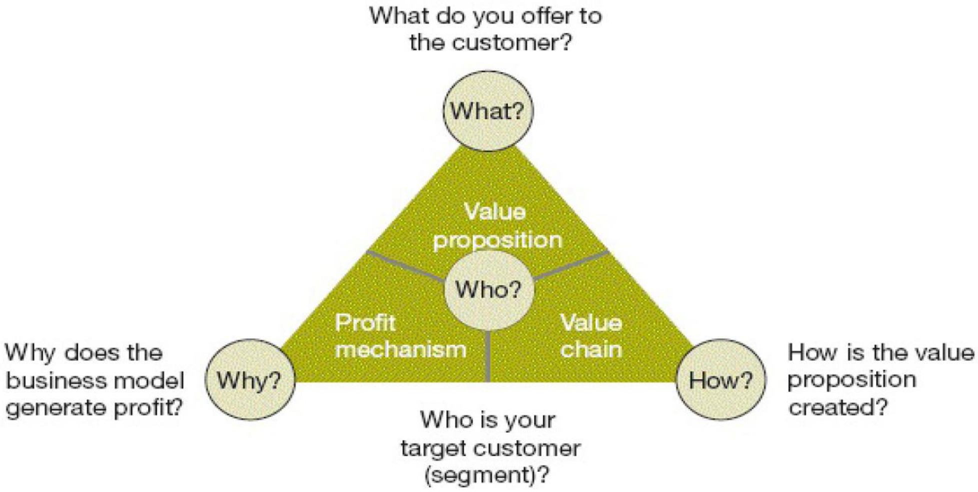

Figure 2: Proposed Commercial set-up for teaching factories in Sub-Saharan Africa HLIs (Abele et al., 2020).

Unlike normal conventional teaching factories which deal with teaching research and innovation, the proposed teaching factory will have to operate commercially. This means that in addition to imparting skills to staff, students and industrialists, it will have to come up with products, processes and services while competing in the open market locally and regionally to start with. Figure 2 shows a business model that provides a holistic picture of how the commercial teaching factory can create and capture value. The model has four main dimensions: Who (the customer), the What (value proposition), the How (value chain) and the Why of the business (how to generate profit).

Setting up A Concordat

A **concordat** is a group of universities created to collaborate with the industry for their mutual benefit and thereby contributing significantly to the creation of new economic activities such as increasing farm productivity, identification of new markets for farm products, creation of new enterprises and diversifying of rural economies. The Concordat ensures complex interaction of industrialist, technologist/academia/students, and entrepreneur/manager, so as to avoid contradicting interests/mindsets in consideration while maintaining close relationship with financial institutions at national, regional and international levels.

Services to be Offered by the Concordat

(a) Coordinating and setting broad policy for handling research and innovation for the whole engineering institutions and industries. Specific terms and policy involving various disciplines shall be set accordingly.

(b) Networking with various institutions at national, regional and global levels as well as attracting resources and ideas for innovation, development and commercialization of technology country-wide including multi-disciplinary contracted research and consultancy works.

(c) Formation of the teams involving academia, industrialists and Government officers in the execution of large multi-disciplinary contracted research projects with regard to research and innovation that caters across various disciplines through the teaching factory or Innovation Hubs.

(d) Assessing the demand and supply side of technology and innovation towards the country’s competitiveness and hence new economic activities in the country

(e) Strengthen the relationship between Universities and Industry for knowledge sharing and the transformation of ideas into valuable products or services.
(f) Disseminating information on available capabilities to the potential customers and/or source of customers at national, regional and international levels.
(g) Working closely with teaching factories from higher learning engineering institutions and regulatory institutions at enhancing the professional quality of the academic staff through trainings, seminars, workshops and short courses.

The proposed Concordat structure is shown in Figure 4.3 and applies the system thinking collaboration model – where the Government, industry and academia interconnect and behave to produce a desired function (Nyemba et.al.2020) attainment of industrial needs through Government-Academia-Industry collaboration. The Target Clients (internal, external) and will include, but not limited to:

(a) Academic staff, students, industrialists, various graduates, entrepreneurs from the wider community, corporations, producers and manufacturers, public organizations with innovation challenges and innovation financing institutions.
(b) Government agencies and non-profit organizations with similar interests of promoting development through innovation and entrepreneurship
(c) Development Stakeholders including Diaspora
(d) Various suppliers of raw materials
(e) Market and distributors of products
(f) Overseeing collaborative projects being carried out by academia and industrialists

As for Tanzania, a concordat of universities can be created by bringing together a group of universities and industries to develop a shared understanding of their specific roles and responsibilities.

(a) Relevant Governmental Institutions (Ministry of Trade and Investment, Ministry of Finance, R& D institutions, Tanzania Chamber of Commerce, Industry and Agriculture (TCCIA), Tanzania Private Sector Foundation (TPSF, Confederation of Tanzania Industries (CTI) Bank of Tanzania (BoT) etc.)
(b) The Private Sector (Financial institutions such as; FINCA Microfinance Bank,, Small and Medium Entreprises (SMEs), Associations of Micro finance institutions etc.).
(c) Development partners (Royal Academy of Engineering, United Nations Industrial development Organization (UNIDO), International Development Research Centre – International Development Research Council (IDRC), Commonwealth & Development Office (FCDO).

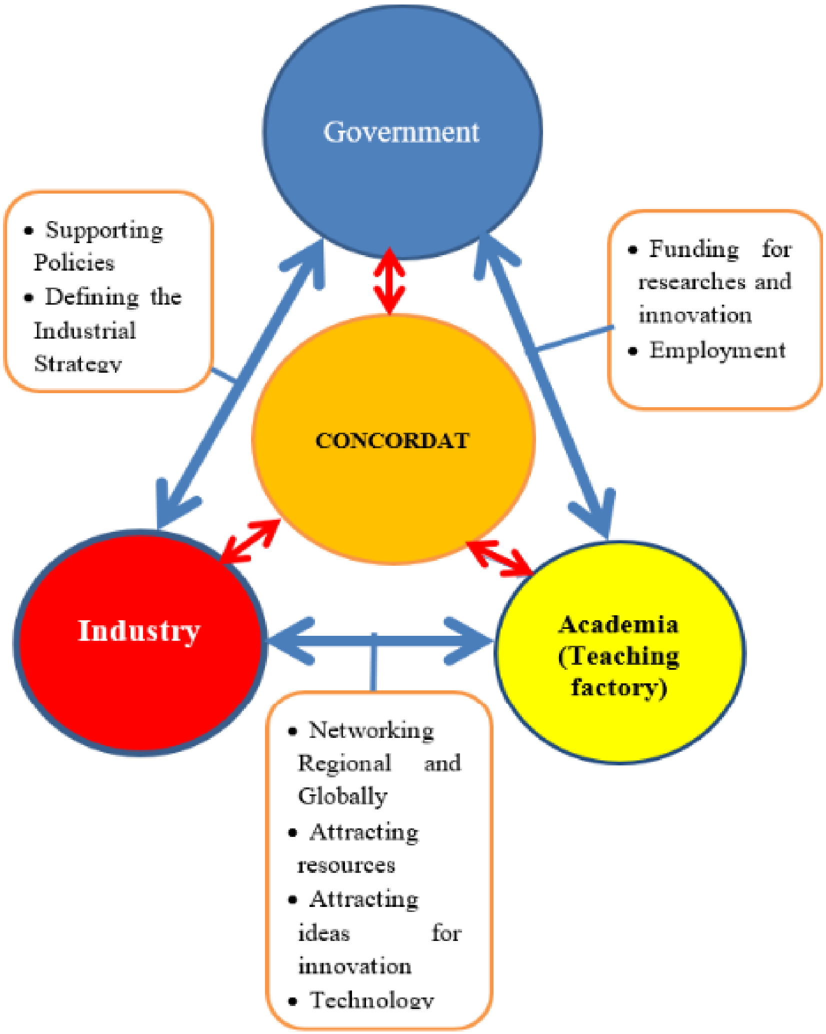

Figure 3: **The proposed framework for collaboration through the Concordat.**

CONCLUSION AND RECOMMENDATIONS

The Support of the Royal Academy of Engineering has over the years provided a paradigm shift for higher learning engineering institutions in East African countries in terms of training a number of academic staff in Outcome Based Curriculum, Problem Based Learning and Management of Incubators and as a result the following have been achieved:

(a) Nearly all engineering institutions are now changing their curricula from Knowledge Based to Outcome Based.
(b) There are efforts for higher learning institutions to integrate Outcome Based Curriculum and Problem Based Curriculum.
(c) A number of young academicians have been upskilled through the industrial secondments of 2 months of each phase of two years for the 4 phases.
(d) Preliminary establishment of a learning factories in 2022 to 2024 with secondment of undergraduate students and academic staff to industries – much as it did not fair well.

Having the Knowledge Exchange Concordat unit at the national level, it will be possible to coordinate academia and industrial partners including the Government and other partners in solving national regional and global challenges while at the same time realizing finances to support research and innovation budgets for the academia and the industry as a whole.

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