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# ECA POLICY BRIEF

## Building biomedical engineering innovation capacity for improved health outcomes in Africa

### *Summary*

The present policy brief examines a possible mechanism for building capacity in Africa, using biomedical engineering as an example. One common but recurring problem with most health facilities in Africa is the inadequacy and, in some cases, lack of basic medical devices that health-care professionals need to do their job well. Most countries on the continent do not have a medical devices industry and rely on imports to meet demand. They also rely on foreign expertise to install, upgrade and service most of the imported devices. Countries have tried to address the skills gap in the medical devices sector in various ways. For the most part, they have relied on training technicians and technologists. However, higher and more specialized skills than those of technicians are needed to upgrade, design and produce robust devices suitable for Africa's operating environment (i.e., unstable electricity, dust and heat), given the increasing automation, complexity and digitization of medical devices.

On the basis of a pilot initiative led by the Economic Commission for Africa (ECA) entitled "Engineering expertise for improved health-care outcomes in Africa", run largely in Eastern African countries, this policy brief outlines a proposal on how countries can, individually or collectively, establish dynamic regional technological innovation platforms that are multidisciplinary, multi-institutional and cross-boundary, and whose strengths lie in the fusion of various experiences, expertise, interests and capacities of institutions. The African Biomedical Engineering Consortium platform, which the ECA-led engineering for improved health-care outcomes in Africa initiative inspired, provides an excellent example in this regard.

Selected highlights of the outcomes of the biomedical engineering initiative of ECA include the following:

a. The number of universities and institutions participating in the ECA-inspired biomedical engineering initiative grew from 2 in 2011 to 17 in 2017, and the number of students enrolled grew during the same period;

b. The African Biomedical Engineering Consortium was launched to serve as a custodian and promoter of standards of training and research, capacity-building and resource mobilization, as well as a provider of teaching resources and networking;

c. At least three main outcomes have been achieved: the Consortium and its partners have attracted two major grants, the number of partners with innovations that have won awards has grown from one to two and the exchange of staff and students has begun;

d. The wide variation in institutional capabilities serves as a unifying factor, with some serving as training centres (e.g., South Africa), a medical design centre (e.g., Uganda), an education and

management hub (e.g., Kenya) and a student innovators design platform (e.g., Italy);

e. The existence of champions, the multifaceted nature of the project and the existence of an annual platform (i.e., innovators' summer school) has determined the success of the Consortium.

# 1. Introduction

This policy brief contains an examination of a possible mechanism to build biomedical engineering capacity in Africa, considering the rapidly evolving health-care landscape and rapid advances in technology in general and health technology in particular. Currently, Africa has the worst health indicators of any region in the world, a testimony to the general weakness and inadequacy of the health systems in African countries. One very visible area of weakness is the technological infrastructure of the health system to support the work of the continent's few but growing cadre of health professionals. Recent outbreaks of contagious diseases such as Ebola in West and Central African countries[1] and the sporadic re-emergence of diseases that had been eliminated in the rest of the developed and most of the developing world (e.g., cholera, yellow fever and polio) illustrate the depth of this problem.

Africa has one of the fastest-growing and an increasingly youthful population in the world but also one of the highest morbidity and mortality rates globally, notwithstanding recent progress. For example, the world saw the average life expectancy rise from approximately 52 years in 1960 to approximately 71 in 2014, while that of subSaharan Africa was 58.6 in 2014. This is far from the target contained in the African Union's Agenda 2063: The Africa We Want, a regional framework that is intended to see Africa "enjoying a life expectancy of above 75 years".

The mix of the major causes of death in Africa is also changing. While the major causes of death on the continent in the past were communicable diseases, improvements in health technology have resulted in significant successes in reducing death from them. There has, however, been a noticeable increase in mortality due to non-communicable diseases such as cancer and heart disease. According to ECA,[2] deaths caused by communicable diseases declined by 42.4 per cent between 2000 and 2012, while deaths due to non-communicable diseases fell by a mere 5.9 per cent during the same period.

Improving the health of citizens has been a long-running policy objective of African Governments and their development partners in the international community. In the 2030 Agenda on Sustainable Development, as in its predecessor, the Millennium Declaration, improving health outcomes is identified as one of its 17 Sustainable Development Goals. Indeed, the rallying cry of the 2030 Agenda to "leave no one behind" may not come to pass in Africa as it relates to health without significant investment in biomedical engineering skills development. Similarly, such development will be key to attaining the aspirations set out in Agenda 2063, the primary objective of which in terms of health is to ensure that "African people have a high standard of living, and quality of life, sound health and well-being [and] well educated citizens and skills revolution underpinned by science, technology and innovation for a knowledge society".[3]

African countries are paying considerable attention to the training and production of health-care professionals. However, an important complement, namely, health-care technologies, remains in chronic under-supply and, where they are supplied, are chronically out of order. Countries reporting the best health outcomes, such as a high life expectancy at birth, have invested heavily in health technologies and infrastructure, including in medical devices. They have vibrant medical technology sectors supported by solid biomedical engineering capacity, which is needed to develop new and improved medical devices that allow health-care workers and public service providers (e.g., water and sanitation) to quickly provide diagnostic services in the field, quickly share information, view deeper into the human body, offer non-invasive or minimally invasive treatment and continuously monitor the performance of patients and facilities, even from a distance.

1 See B. O'Hare, "Weak health systems and Ebola", Lancet Global Health, vol. 3, No. 2 (2015).

2 See Economic Commission for Africa, Innovating for Better Health: Building Biomedical Devices Innovation Capacity in Africa (Addis Ababa, 2017).

3 See African Union Commission, Agenda 2063: The Africa We Want (popular version) (2013).

## 2. Why biomedical engineering matters

Biomedical engineering skills and know-how help to save money and prolong and save lives. Data show that African countries import nearly all their medical devices, from the humble thermometer to sophisticated full-body scanners, from outside the continent. Trade in biomedical engineering products, principally medical devices, can also be a major source of revenue for countries. Globally, the medical devices market was estimated to be worth between $320 billion[4] and $381 billion in 2015[5] and growing at an annual average rate of approximately 6 per cent.[6] The global market for medical devices is expected to reach at least $636 billion by 2022. The largest market for medical devices is the United States of America, which accounts for 39 per cent of the world's share, followed by Japan (11.3 per cent) and Germany (7.6 per cent). It is principally for these reasons that countries invest heavily in building up their biomedical engineering capacity.

Africa's share of the world market for medical devices was estimated at $3.2 billion in 2010, and ECA estimated that it should have reached at least $3.8 billion by 2014.[2] This excludes donations from partners abroad and other sources of medical devices that are not captured in trade, such as domestically produced and consumed medical devices. In terms of growth rates, Africa was the world's fastest-growing market for medical devices, with a cumulative aggregate growth rate of 7.5 per cent during the period 2006-2010.[7]

On the basis of existing research, South Africa is Africa's largest market for medical devices, with 90 per cent of its $1.2 billion market value in 2014 being met by imports. This put the local supply of medical devices in the market at approximately $120 million. The other major markets in Africa include Egypt ($432 million), Nigeria ($155 million), Kenya ($106 million) and Ghana ($58 million). Other than South Africa, most of the other African markets depend almost exclusively on imported medical devices.[8]

Notwithstanding the rapid growth of the continent's market for medical devices, it remains the smallest market (approximately 2 per cent of the global share) and even smaller in terms of production and exports of medical devices. In addition, Africa relies on external expertise to install, maintain, repair and upgrade some of its medical devices. Given the economic realities on the continent, countries do not have adequate resources to import all the medical devices and expertise needed, which compromises their ability to improve health outcomes for all and which is central to achieving the Sustainable Development Goals and realizing the aspirations contained in Agenda 2063 regarding equitable health care.

Two key elements are also missing if a country does not invest in biomedical engineering: innovation and entrepreneurship. Medical devices, unlike drugs and vaccines, offer endless opportunities for innovation and entrepreneurship. For example, there are several ways in which medical records can be captured, stored, processed and securely transmitted and several ways of designing an autoclave or microscope. Most important, medical devices, as with most electronic products, are composed of numerous components and accessories that offer equally important options for innovation and business development (e.g., improving screen resolution, sensors, chips, storage media and software). In this regard, the chips in a medical device are not so different from those in a home appliance or communications equipment. Each component, accessory, part and software for medical devices, as well as their servicing, can serve as a basis for innovation and business development.

4 See United States of America, International Trade Administration, Top Markets Report-Medical Devices: Overview and Key Findings (undated). Available from **http://trade.gov/topmarkets/pdf/Medical_Devices_Executive_Summary.pdf**.

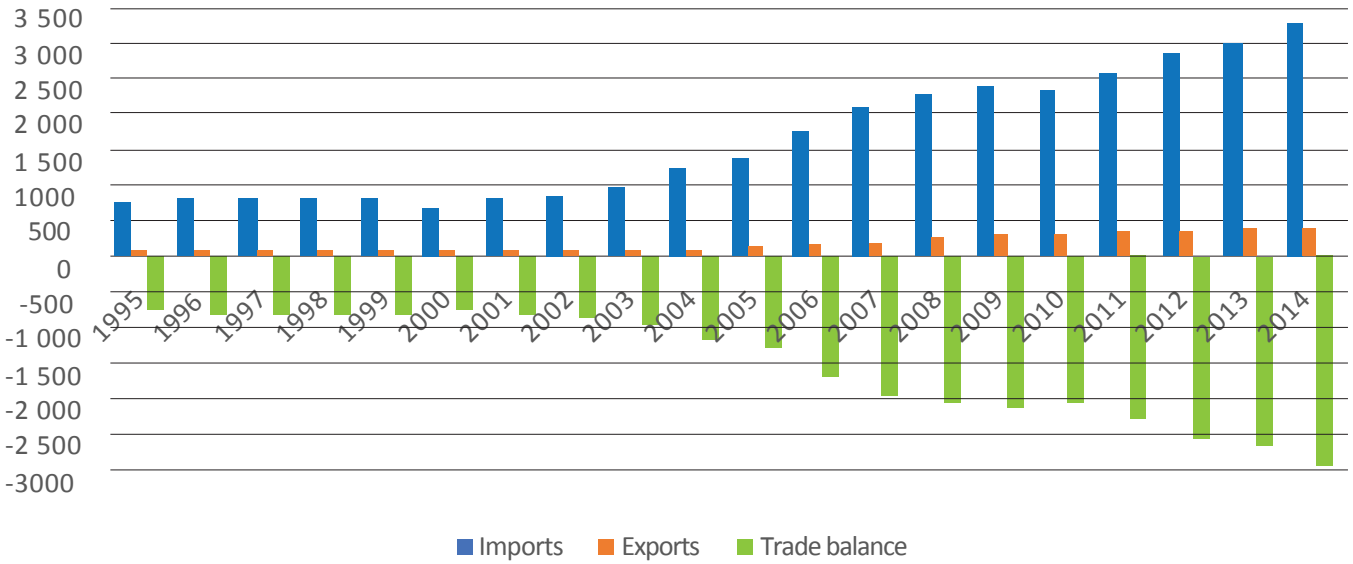
5 See Kalorama Information, The Global Market for Medical Devices (7th edition) (2016).

6 James **Cunningham and others, Medical Devices Sectoral Overview (NUI Galway and the Whitaker Institute, 2015).**

7 See Episcom, 2012 African Medical Device Market (undated).

8 Based on national market research by Espicom. Available from **www.espicom.com**.

**Figure I** Import and export of medical devices in Africa (Millions of United States dollars)




***Note:*** *Standard International Trade Classification* groups 774 (electro-diagnostic apparatus for medical sciences, etc.) and 872 (instruments and appliances, n.e.s., for medical, etc.) were combined.

***Source:*** Economic Commission for Africa analysis based on the United Nations Conference on Trade and Development Handbook of Statistics.

## 3. Towards a holistic approach

The ECA-led initiative launched in May 2011, entitled "Engineering expertise to improve health outcomes in Africa", was one of the first integrated models for building biomedical engineering skills and innovation and entrepreneurial capacity. It was designed to develop the domestic capacity of African countries to install, repair, maintain and upgrade medical devices, attract women students to engineering and instil enhanced entrepreneurial and innovation competencies to bring medical devices to market.[2]

To achieve this goal, the project had four main components:

a. Promote and support interested universities in developing a biomedical engineering undergraduate programme;

b. Stimulate innovation among young people and researchers through an international design competition;

c. Advance the technological and entrepreneurial capabilities of students and researchers through an innovators' summer school;

d. Support the development of technical skills at hospitals through short-term courses and apprenticeships to learning and industrial institutions of technicians and medical professionals.

By 2012, three components had been implemented and a number of changes introduced. First, the international design competition was combined with the innovators' summer school, while the fourth component was dropped because it was costly to run, course content was difficult to develop and the impact was seen as limited. In Uganda, however, students and researchers visited and maintained medical devices at selected hospitals. Reports suggested that the demand for biomedical engineering students in the second to final year was high.

Although the development of a generic biomedical engineering curriculum had been completed by December 2011, it was clear that most universities interested in running biomedical engineering

programmes had limited lecturers to teach biomedical engineering-specific courses at the highest level. The limited biomedical engineering industrial base and scientific infrastructure, on the one hand, and poor health-care systems, on the other, offered little room for talent that could help to teach or supervise research students.

The challenge is how to quickly mobilize the limited human, research and technological resources to promote biomedical engineering training, health innovations and entrepreneurship to meet the twin goals of improving health care and creating entrepreneurs or jobs. It was clear to ECA that both hospitals and policymakers recognized the importance of biomedical engineering even more than the universities that were to provide the learning, innovation and entrepreneurial environment necessary.

In this policy brief, this challenge is addressed through the experience of the African Biomedical Engineering Consortium. Institutions with varying levels of scientific, technical and academic experiences and their partners abroad are shown to have combined their unique strengths and passions to set minimum standards of teaching and research and attract funding for student and staff mobility and training and creating a platform for open innovation.

The African Biomedical Engineering Consortium serves as a good model that countries can undertake, individually and collectively, in order to develop an innovative and entrepreneurial medical devices culture and build the human resources necessary that are capable of bringing new and improved medical device services and technologies to market. In this case, the wide variations in technical, scientific and entrepreneurial competencies may have helped to galvanize collaboration and seek synergies that are mutually beneficial.[9]

## 3.1 Factors behind the founding of the African Biomedical Engineering Consortium

The African Biomedical Engineering Consortium was conceived for two main reasons. First, a regional innovation institution that promotes excellence in biomedical engineering training, research and innovation was viewed as critical to bridging differences in knowledge, technological and industrial development and safety standards among its members and the rest of the world. Such an institution could serve as a platform for the sharing of teaching and research materials and methods and the exchange of staff and students within its membership. It could also help to develop guidelines for standards, open-source blueprints and codes to enable users to adapt designs to their own needs and to address both regulatory approval and safety issues.

Second, and perhaps most important, the African Biomedical Engineering Consortium can mobilize resources and support from the wider donor, philanthropic and business communities to address issues that ECA is either unable to address or that are outside its mandate. Given its membership's potential range of skills and expertise and institutional affiliations and partnerships, the Consortium was seen as key to the sustainability of the initiative beyond the support of ECA. For example, ECA could support meetings, convene policymakers and stakeholders to a meeting and undertake policy research, but it would not provide financial support for post-graduate training in biomedical engineering to build the human capital base at universities or fund the purchase of laboratory equipment to improve research and innovation capacity.

ECA therefore encouraged and supported the formation of the African Biomedical Engineering Consortium at the very first innovators' summer school, in Uganda in 2012. The Consortium's membership increased from 5 to 17 universities and 1 research institute in Africa, and from 2 to 6 partner universities and institutions in the United States and Africa and Europe between 2012 and 2017. Membership in the Consortium is open to African academic, research and industrial institutes and organizations.

9 Participating universities come from Egypt (1 (2015)), Ethiopia (2), Kenya (4), Malawi (1), Nigeria (2 (2015)), South Africa (1 (adviser/observer)), Uganda (3), the United Republic of Tanzania (2) and Zambia (1). Industrial research partners come from Kenya (2), South Africa (2), Uganda (1), the United Republic of Tanzania (1) and Zambia (1). International partners are from Boston University (United States of America) and the University of Pisa (Italy). Firms/entrepreneurship partners that have supported the Consortium include Techno Mobile (Ethiopia); Enterprise Uganda, Empretec Ethiopia and SIDO (United Republic of Tanzania).

### 3.2 How is the African Biomedical Engineering Consortium organized?

The African Biomedical Engineering Consortium served as a multidisciplinary focal point for promoting the application of engineering in health-care delivery in Africa. It aims to highlight challenges, promote excellence in human capital development and research, encourage entrepreneurship among students and researchers, and mobilize resources for the development of biomedical engineering as an important field of study and research in Africa, as well as stimulate partnerships among key stakeholders in the African medical devices sector and beyond.

While the African Biomedical Engineering Consortium draws its membership primarily from African universities and research institutions, membership is also open to non-African ones. Each member institution is represented on a steering committee. ECA serves as an observer and on the steering committee in an advisory and ex officio capacity. A small secretariat selected from the membership of the steering committee oversees the day-to-day activities, sets guidelines and research agenda, reviews projects and mobilizes resources. Currently, Kenyatta University serves as Coordinator and Mbarara University of Science and Technology as Executive Secretary. The Technical University of Mombasa and the University of Pisa manage the electronic infrastructure. This structure keeps the Consortium relatively cost-effective to manage, given that the employing institution indirectly covers the cost of the involvement of their staff members in the running of the Consortium.

There is an expectation that the African Biomedical Engineering Consortium may, in the long run, ensure the sustainability and growth of the biomedical engineering initiative in Africa. Its member institutions, such as the Uganda Industrial Research Institute, Kenyatta University and Addis Ababa University in Ethiopia, are playing an active role in the development of biomedical engineering in their own countries. The team at the University of Zambia developed the generic curriculum and Boston University in the United States developed the original guidelines for the international design competition, even though it has not played a major role since then.

## 4. Strength in diversity of biomedical engineering expertise

Sustaining the interest and the support of institutions whose capabilities are very different or vary widely presents a major challenge to any network or consortium. Nevertheless, if carefully designed and choreographed, differences in strengths and skills sets can consolidate the network by encouraging collaboration and specialization and avoiding or, at least, minimizing competition, duplication and fragmentation of efforts. Rather than assign roles, institutional strengths and interests force members to take on roles that meet their realities. In the case of the African Biomedical Engineering Consortium, one can identify a few centres of specialization that have become indispensable to success and sustainability.

### 4.1 Economic Commission for Africa

Although not a member of the African Biomedical Engineering Consortium, ECA has been the key driving force behind its formation. Recognizing that its resources are limited and that long-term sustainability is critical for building biomedical engineering capacity in Africa, ECA instigated, advanced and anchored the formation of the Consortium and the design of basic guidelines. It was one of the major outcomes of the first ECA-sponsored innovators' summer schools in August 2012. This was followed by a special expert group meeting, organized and sponsored by ECA, held at Kenyatta University in December 2012, which focused exclusively on the Consortium. This meeting refined some of the key components of the Consortium, including membership status, organizational and institutional arrangements, quality assurance, knowledge-sharing and support of members in various biomedical engineering activities, as well as the growth and expansion of the network. Each meeting of the innovators' summer schools since 2013 has included a meeting of the Consortium leadership at which activities, challenges and opportunities are addressed. ECA organized an ad hoc expert group meeting on biomedical engineering in Africa in Addis Ababa in 2016.

The involvement of ECA in the African Biomedical Engineering Consortium as an independent champion of biomedical engineering in Africa, given its high convening and outreach power, has been key to the growth and performance of the Consortium. Early on in 2011, ECA undertook missions to Ethiopia, Kenya, Malawi and Uganda to encourage policymakers, industrial research institutions, hospitals and universities to support and invest in the growth of biomedical engineering. These included meetings with ministers and permanent secretaries, heads of hospitals and institutions, representatives of donors and vice-chancellors of universities.

As the founding promoter, ECA commands unrivalled influence in the African Biomedical Engineering Consortium, and its opinions, views, guidance are highly valued. ECA also serves as the neutral adviser on technical, administrative and organizational issues. For example, ECA staff serve as advisers on projects that the network submits to sponsors such as the European Union and has provided intellectual support to the Consortium's members in Africa and abroad in the development of their own initiatives and projects that would benefit the Consortium directly or indirectly. Drawing on its institutional knowledge of the Consortium's members and various partners that have supported the initiative, ECA has a wealth of knowledge that supplements the efforts of the members to secure resources within or outside its membership.

## 4.2 Emerging specializations within the African Biomedical Engineering Consortium

In this section, a few examples of institutions and the roles that they have played are highlighted. Each African Biomedical Engineering Consortium member institution comes with various advantages (and disadvantages). They are diverse in terms of the maturity of their programmes and the influence of their programme within their home institutions. This difference provides an enormous opportunity for collaboration and peer learning. Aside from ECA, a number of institutions have therefore taken on different roles on the basis of their interests, expertise and experience. Since the inception of the Consortium in 2012, Kenyatta University has offered to host the secretariat, and its Vice-Chancellor allocated an office and one staff member to the Consortium in 2013. The University also leads the African Biomedical Engineering Mobility project, which is financed by the European Union.

The Uganda Industrial Research Institute is a founding member of the ECA-led biomedical engineering initiative and co-hosted the 2012 innovators' summer school along with Makerere and Kyambongo Universities. The Institute invited Mbarara University of Science and Technology to that summer school and developed a full-fledged medical devices unit that now anchors the design and development of electronic applications in health care. The Institute has won several innovation awards for its medical device designs and products, helping to inspire young people to choose biomedical engineering as a career and profession.

In terms of academic programmes, nine universities offer undergraduate programmes, three offer a Master of Science degree and two (Cairo University and the University of Cape Town[10]) offer PhD programmes. Accordingly, the three universities with post-graduate programmes in biomedical engineering could serve as the African Biomedical Engineering Consortium's training centres for potential lecturers and researchers.

In terms of technological awareness, the team at the University of Pisa has served as consultants to the innovators' summer schools and played a pivotal role in exposing students and young researchers to emerging technologies such as 3D printing, open source design components and programming. The team coordinates the biomedical engineering summer school content and programming and provides trainers.

10 Cairo University and the University of Cape Town have well established biomedical engineering programmes and did not begin them as a result of ECA. The latter was a founding member of the Consortium, while the University of Cairo participated in an innovators' summer school in 2016 and joined Consortium in the same year.

# 5. Key results

## 5.1 Development of human capital

The number of students enrolled at participating universities has continued to grow. A total of 1,506 students were enrolled in biomedical engineering programmes of partner universities in 2017, of whom 1,431 were in undergraduate programmes and 75 were in post-graduate programmes (see figure II). Of the total, approximately 40 per cent of the undergraduate students are enrolled at institutions whose biomedical engineering programmes were either inspired or greatly informed by the ECA initiative. Enrolment has grown steadily. For example, there were some 350 undergraduate students in the regular programme and another 140 in the undergraduate extension programme, and a further 70 in the post-graduate programme at Addis Ababa University alone as of January 2017. Addis Ababa University participated in the development of the generic biomedical engineering curriculum supported by ECA and was the first to launch its programme in 2012, followed by Kenyatta University (Kenya), Malawi University of Science and Technology (Malawi) and Mbarara University of Science and Technology (Uganda). The most recent student enrolment data on some universities, such as Kyambogo University, Makerere University and the University of Cape Town, were not available, and two more universities in Ethiopia and one in Kenya are in the process of launching their biomedical engineering programmes.

The ECA initiative also helped to raise awareness among the population, especially young people, of the potential of biomedical engineering in health care and as a rewarding engineering profession. This, in turn, resulted in an increase in enrolment at participating universities. Indeed, the biomedical engineering programme at Makerere University was overenrolled in the 2012-2013 academic year following the first innovators' summer school, held in Uganda, even though it was one of the few programmes that did not have government financial aid at the time.

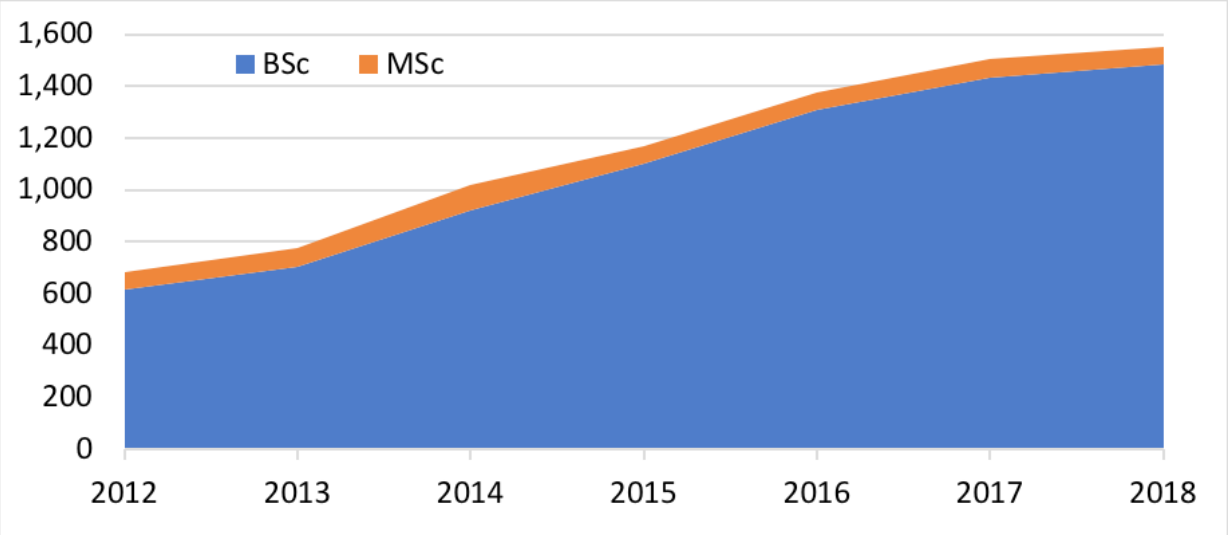
### **Box 1** Euro-African Open Biomedical Engineering e-Platform for Innovation through Education initiative

The development of an open virtual infrastructure for designing safe biomedical devices to support students and researchers in Africa and Europe is one outcome of the innovators' summer school programme of 2013, which resulted in a project document by the African Biomedical Engineering Consortium and its partners. Funded by the European Union's Horizon 2020 programme, the project, popularly referred to as UBORA (Euro-African Open Biomedical Engineering e-Platform for Innovation through Education), is developing an online open source platform for co-designing new solutions to meet the current and future health-care challenges of Europe and Africa through networking and the rapid prototyping of new ideas. The UBORA platform guides users through a design process that places patient safety and efficacy first by identifying device classification and the relevant standards and rules to be followed for ensuring regulatory compliance.

The project has two anchors in Africa: Kenyatta University as the representative of the African Biomedical Engineering Consortium and the Uganda Industrial Research Institute as its main technology design hub for biomedical devices. On the European side, the University of Pisa coordinates the projects and AgileWorks in Estonia designed the online platform. Other participants in the initiative include the Universidad Politécnica de Madrid; the University of Tartu, Estonia; and the Royal Institute of Technology, Stockholm. The first UBORA-supported design school was held at Kenyatta University in December 2017.

Source: **http://ubora-biomedical.org**.

**Figure II** Student enrolment in Biomedical engineering at participating universities




Abbreviations: BSc, Bachelor of Science; MSc, Master of Science.

## 5.2 Promoting the exchange of students and research

One way of addressing the challenge of the lack of lecturers, researchers and trainers is to encourage and promote faculty exchanges among African universities with biomedical engineering programmes. The African Biomedical Engineering Consortium has pursued this strategy over the past three years, and it is beginning to yield positive results. Under the aegis of the Consortium, a lecturer from Kenyatta University and one from University of Pisa served as visiting professors at Addis Ababa University in 2015 and 2016, respectively, helping the University to meet its short-term faculty needs. A team from the University of Cape Town visited other partner universities to explore cooperation in post-graduate training. Similarly, a team of University of Pisa experts provided hands-on training to students and researchers in Ethiopia and Kenya. Indeed, a number of professors from the Consortium's member institutions currently serve as visiting biomedical engineering professors at Kenyatta University. This effort received a boost in 2017 (see Box 2).

### Box 2 Capacity-building at universities through the African Biomedical Engineering Consortium

One of the main challenges faced by member universities is the limited number of qualified biomedical engineers and their related expertise to teach and supervise students. The African Biomedical Engineering Consortium and its partners secured 1.2 million euros in funding for a five-year initiative called the African Biomedical Engineering Mobility. The project involves six Consortium partner universities from the various regions, led by Kenyatta University. These include the University of Cape Town, Cairo University, Addis Ababa University, the Mbarara University of Science and Technology and the University of Lagos, with the University of Pisa and Uganda Industrial Institute serving as technical and associate partners, respectively. The Mobility is intended to support at least 22 Master of Science and 10 PhD students who will be trained at African universities and offer an opportunity to students, lecturers and research to visit partner universities for up to six months.

The main objective of the African Biomedical Engineering Mobility is to build capacity in biomedical engineering in Africa through student training and education and staff exchange. Some of the target institutions include those in Ethiopia, Malawi, Uganda and the United Republic of Tanzania with students who may wish to pursue a PhD at an African university such as Cairo University and the University of Cape Town. The project, which began in 2017, will run until 2022.

Source: **www.africanbmemobility.org/.**

## 6. Policy considerations and conclusions

Policymakers face the challenge of minimizing the duplication of initiatives, the fragmentation of efforts and the lack of collaboration by their institutions. This is often seen as the result of wide differences in skills, interests and experiences. The desire to ensure that all institutions achieve a higher level of teaching, research and innovation excellence often obscures the need to identify areas in which the institutions already excel and encourages them to collaborate.

The African Biomedical Engineering Consortium clearly demonstrates that successful collaboration can be achieved, even among institutions at varying levels of development, sophistication, and technological competence, as long as they have shared interests and common goals and objectives. Several factors are key to ensuring and encouraging such institutions to collaborate. In the case of the Consortium, at least four stand out. First, there must be a trusted and committed champion with sufficient influence at the regional and national levels. ECA has served in this role from the beginning.

Second, the project/initiative must be designed as a dynamic, multifaceted undertaking, providing ample latitude for institutions to collaborate and innovate, building on the comparative or competitive advantage of each partner institution. For example, the University of Cape Town and its partners collaborate more in training and in academic research, while the Uganda Industrial Research Institute participates more in providing opportunities for student attachments (internships)/mentoring and design. Policymakers who want to reinforce the sustainability and reach of their projects may wish to structure them in such a way as to harness positively the diversity (including diversity of interests) of stakeholders.

Third, competition is also key to success. The annual innovators' summer school has played a critical role in building interest among the hosting institutions and its domestic partners and built critical constituency at them. Member institutions of the African Biomedical Engineering Consortium compete to host the summer school on a rotational basis, providing opportunities to lecturers and researchers from various countries and institutions to work in mixed teams of two to three to guide mixed teams of students from various countries that compete to win prestigious awards. Over time, the teams learn as much about themselves as they do about their students. Policymakers must therefore consider organizations such as the Consortium to be a valuable platform not only for promoting learning, but also for forging strategic partnerships and exploring the frontiers of biomedical engineering.

Lastly, champions are important, especially at the institutional level. While ECA has been a champion, the greater champions are the university administrators, vice-chancellors, professors and lecturers who have, as members of the African Biomedical Engineering Consortium, made the case for biomedical engineering in their universities. They have made it possible for their students to participate in the innovators' summer schools and provided resources to host them. In this regard, the University of Pisa and Kenyatta University have played a leading role. As Consortium champions, they have promoted the biomedical engineering initiative beyond their assigned roles, ensured that all the members contribute to the growth of the network and expanded membership and engagement in the Consortium. Policymakers wishing to promote innovative in a way that ensures their long-term sustainability and growth may want to identify committed champions drawn from among peers to advance and lead the project.

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