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Modelling an African Research University: Notes towards an Interdisciplinary, Cross-Cultural and Anticipative Curriculum

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Abstract

What kind of education do we want our students to have in order to meet the opportunities and challenges facing Africa? What kind of ingredients and tools does such an education require to be responsive to the needs of all of Africa's people? Mobilising around engineering education and its synergies with entrepreneurial education, vocational education, and the social sciences and humanities, this essay argues for an interdisciplinary, cross-cultural and anticipative curriculum that emphasises research, problematising and problem-solving. The article is organised around five potential ingredients a research university could prioritise: research capability, not just capacity; financial means to do research; partnership with society (the informal economy); entrepreneurship; and an interdisciplinary, cross-cultural ethos that addresses current and anticipates future challenges.

Keywords: diaspora, engineering education, entrepreneurial education, vocational education

Résumé

Quel type de formation nos étudiants devraient-ils suivre afin de saisir les occasions et de relever les défis qui confrontent l'Afrique ? Quels sont les ingrédients et les outils requis pour que ce type de formation soit en mesure de répondre aux besoins des populations en Afrique ? Cet article s'articule autour de la formation des ingénieurs et ses synergies avec la formation à l'entrepreneuriat, la formation professionnelle, les sciences humaines et sociales, et préconise un programme d'études interdisciplinaires, interculturelles et anticipatives qui mettent l'accent sur la recherche,

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la problématique et la résolution des problèmes. Il s'articule autour de cinq ingrédients potentiels qu'une université de recherche devrait prioriser : la capacité de recherche, pas seulement l'aptitude ; les moyens financiers pour mener les recherches ; le partenariat avec la société (économie informelle) ; l'entrepreneuriat ; et une éthique interdisciplinaire et interculturelle qui permet de relever les défis actuels et d'anticiper les défis futurs.

Mots-clés : diaspora, formation des ingénieurs, formation à l'entrepreneuriat, formation professionnelle

Introduction

What kind of education do we want our students to have in order to meet the opportunities and challenges facing Africa? What kind of ingredients and tools does our education require to be responsive to the needs of all of Africa's people? How do we go about setting up and sustaining that kind of university, bearing in mind that over 70 per cent of Africa's employment is currently within the informal sector, not in research and development (R&D)?

In 1997, an expert group composed of deans of engineering schools met at a summit convened by the United Nations Educational, Scientific and Cultural Organisation and the African Network of Scientific and Technological Institutions. On its agenda was a review of quality assurance and the relevance of engineering programmes in Africa's higher education institutions (HEIs).

The diagnosis started where it should start: with Africa's enduring colonial legacy and Africans' efforts which have both sought to escape this legacy and further entrenched it. Many of the engineering schools and curricula at that time were for, not by, Africans. They still follow the disciplinary structures European colonisers set for us, consistent with the economic exploitation they were meant to effect. Most schools of engineering started with agricultural, civil, electrical and electronic, and mechanical engineering, as well as surveying, with other programmes being added after independence to cater for post-independence exigencies. Today, many engineering programmes are true to their local economies and have been crafted in specific response to requests from government and industry (Kumapley 1997; Kunje 1997; Markwardt 2014; Massaquoi and Luti 1997). In general, the engineering education was imported from the Global North and therefore designed for other societies (Simbi and Chinyamakobvu 1997). The buildings, campuses, degree programmes and even courses were new, but the 'universities of science and technology' continued to be subjected to the traditional lectures that funnelled 'content knowledge' into students'

heads without developing and stimulating 'any spirit of inquiry or initiative in the student'. The students' duty was that of 'memorizing lecture notes for the sake of passing examinations only' (Simbi and Chinyamakobvu 1997:48; Kunje 1997; Senzanje, Moyo and Samakande 2006). African engineering content and syllabi are generally both continuations of colonial traditions of engineering (pompous titles, little or no tangible and visible product) and models borrowed from and imitating those of the West. The curricula are still too theoretical and of little relevance to their contexts (Matthews, Ryan-Collins, Wells, Sillem and Wright 2012). Our engineering model operates in exclusion of the society to it, one that it engineers *for* rather than *with*. It's engineering without social responsibility, engineering without any creativity.

At the end of its deliberations, the expert group called for a curriculum with 'more social sciences, computer courses and industrial attachment'; dissertations reflecting 'real life situations' and graduates capable of 'solving regional problems' (Massaquoi and Luti 1997:8). The deans spoke against an imitative model that failed to 'address African needs' but simply put 'an African complexion to imported copies', thus continuing 'a cycle of dependence which makes us lie back and await changes in foreign systems' and then react with minor adjustment to suit our needs (1997:8). The professors called for 'committed scholars with creative minds' to critically engage with global ideas and instruments to generate new technologies and provide indigenous oversight on decisions pertaining to foreign things to which locals assign technological value (Massaquoi and Luti 1997:8; Masu 1997). Two decades later, that call remains unanswered; the high rate of unemployment among engineering graduates confirms that Africa's HEIs are churning out graduates with unemployable skills (EARC 2014).

The deans' call predated a current debate among engineer educators in the West. Engineering education generally passes on disciplinary, well-understood and already existing formulae for problem-solving; seldom does it try out new methodologies or take creative risks (Beer, Johnston and DeWolf 2006; Bucciarelli 1994, 2003; Seely 2005; Sheppard, Macatangay, Colby and Sullivan 2008). The calls for engineering education reform in the United States (US), for example, boil down to one question: 'How can one teach engineering science courses so that students come to understand what they are not learning?' (Downey 2005:592).

To answer this question means that engineering has to be opened up more aggressively to the humanities, arts and social sciences so that engineers better understand the social and political context within which they do engineering (Grasso and Burkins 2010). Top engineering institutions like the Massachusetts Institute of Technology (MIT) require their students to take a significant

number of social sciences and humanities subjects to graduate (MIT 2017). Technical skill is only one among many other skills sets an engineer requires to negotiate the complex social, political, cultural, environmental and ethical challenges of the profession (Faler 1981; Noble 1977). The idea of 'holistic engineering', emphasising context-specificity, teamwork, transdisciplinary communication and lifelong learning, has generally emphasised collaboration between different branches in engineering (Duderstadt 2010; Grasso and Burkins 2010; Ramadi, Ramadi and Nasr 2016).

By 2007, US universities had begun focusing on engineering science (hi-tech subjects) at the expense of the traditional engineering disciplines (mechanical, civil, electrical, chemical and aeronautical), with a resulting critical shortage of engineers of physical infrastructure. An acute dependence on international students and workers followed (Frankel 2008). Today, the antiquated US road, rail and electricity infrastructure needs upgrading.

Nor should we blindly follow China's model. Engineers are not in short supply: engineering is the country's largest discipline, with 2,222 (or 92.2 per cent) of its 2,409 institutions running an undergraduate programme in 2011 – and counting. That same year, 8,689 million undergraduate and 0.588 million graduate students (a third of China's enrolment) were engineering majors. This is understandable – China has more than 1.3 billion people and is the world's second largest economy; it is the factory of the world! But like most of Africa's HEIs, China's curriculum prioritises knowledge accumulation and dissemination and building knowledge systems, not knowledge mastery and practical ability. And it is obsessed with rankings vis-à-vis its competitors as opposed to meeting the needs of industry (Bai et al. 2009; Rutto 2015).

The last thing Africans can afford is to replace Western imports with Eastern ones. The argument advanced is that science and engineering should be brought into multidisciplinary conversation with the social sciences and humanities to forge a new covenant for solving Africa's problems and generating made-in-Africa products and opportunities. It is not enough when training an engineer for Africa to simply make engineering sciences, laboratory experiments and design legitimate topics for the social sciences, humanities and arts, or to help engineers 'get it' (i.e. better understand the social and political context within which they do engineering). One key obstacle inherited is the colonial mentality that the engineer designs *for*, not *with*, society. It reduces society to a spectator when it should be a comrade-in-arms in research and problem-solving.

By adopting an inclusive, multi-optic approach to conception, not implementation or use, and by identifying, conceptualising and solving problems together, solutions cease to be imposed from the top down by governments, by foreign countries using 'donations' or by 'donor agencies' using 'soft power' to dominate Africa. Solutions then emerge organically from and with the people affected by the problem. This communality of research and knowledge production is the embodiment of *umoja*, *ujamaa*, *hunhu* and ubuntu. Picture an engineer, physician, lawyer and a specialist in investment finance working with a historian, sociologist, political scientist, environmentalist, philosopher, linguist, an informal trader, blacksmith, pottery maker, healer, youths and an elderly custodian of indigenous knowledge all working within one team, each bringing their skills to bear upon one problem.

This article argues that an African research university must foster within its students and faculty a culture of inclusive, multi-optic problematising and problem-solving, that is, one that deploys multiple skills sets and sees issues from many angles. To accomplish this, we must invest in programmes that synergise and even synthesise the science and engineering curricula with the humanities, arts and social sciences in order to generate opportunities, solve problems and create physical and intellectual infrastructures for that purpose.

It is argued further that the solution ought not to be an end in itself, but also a platform for staging completely new innovations. This multiplier effect takes valuable lessons from the value-addition Africans are contributing to mobile technology. The mobile money transfer app M-pesa, for example, can be interpreted as value-addition to the cellphone and an innovation with multiplier effects. To acquire this research, problematising and problem-solving capability, the African research university must:

- Have research capability, not just capacity;
- Have financial means to do research;
- Engage with the informal economy;
- Be entrepreneurial (in an innovative and market sense); and
- Be interdisciplinary, cross-cultural and anticipative of a post-disciplinary world yet to come.

The argument is not simply that we have no such university that embodies who we are as Africans and what we could be. I am much more worried that we are not even thinking about it with our eye on the realities that

define Africa and the futures we may not live to see but which our (grand) children will have to face. As a discipline that makes and builds things, engineering occupies an important space it should open up and share in order to achieve the immense power it potentially has to help African societies build positive, happy futures.

Research Capability

> I teach … 2 First yr. tutorials per wk., 9 First yr. tutorials per week, 4 Second Yr. Seminars per week, 3 Third Year Lectures per week, 2 Third Year Seminars per week. Add up and then add 4 PhD students to supervise. That should give you 20 lectures…Those are the lectures I was giving from July to the end of this week (October 14th). And every second semester. So, I hope you have softened your judgement of a brother after looking at the stats.[1]

These are the words of a friend, a faculty member at the University of the Witwatersrand (Wits), explaining to me why it was impossible for him to join me in a workshop I was trying to organise as a visiting professor in July 2016. It drove home a reality I had witnessed when I taught at the University of Zimbabwe from 2000 to 2002 – that generally, the African university continues to be a teaching university, with big classes, heavy workloads, poor to non-existent research funding, and little time off for faculty to conduct research. This is called the 'massification of higher education', where students are empty containers whose job it is for the *lecturer* to fill up. Students' job is to open their ears, imbibe, memorise for and take an exam, pass, graduate and look for a job. Students approach research as just another exam and in many instances lecturers' own publication records are razor-thin (Kanyandago 2010; Openjuru 2010; Zeelen 2012).

Capability is not to be confused with ability or capacity. Capability refers to talent, skill or proficiency; the friend cited above, for example, could walk into any Ivy League university and thrive as a research professor as he possesses the necessary capability. Capacity refers to being in a position to do research if one has the ability. All the constraints my friend referred to above impede his capacity to do so. Usually our solutions target one and leave out the other.

The research figures speak for themselves. Based on 2011 figures, the highest performing African country, South Africa, had 818 researchers per one million people. Compare that to South Korea's 4,627 per million. South Korea produces 3,124.6 science and engineering articles per year; the

US produces 212,394.2; Brazil, 13,148.1; and India, 22,480.5 (Cyranoski, Gilbert, Ledford, Nayar and Yahia 2011; UNECA 2013). Fifteen per cent of the world population live in Africa yet the continent has just 1.1 per cent of the world's scientific researchers (one scientist or engineer per 10,000 people) compared with 20–50 per 10,000 in more industrialised nations. Africa owns just 0.1 per cent of global patents (UNESCO 2015). Institutional rankings put pressure on faculty to publish, and promotion and salary scales are based on them. Individualism, which is detrimental to research collaboration, creeps in (Soudiena and Grippera 2016).

Interestingly, one of the major causes of the problem is beginning to be a potential solution. Especially in the past two decades, Africa has seen its most skilled human resource, graduate students, either drained or draining itself out to greener pastures owing to poor salaries and conditions of service. Graduate students educated on taxpayer-funded subsidies have studied for PhDs abroad, found employment there and never returned to plow back their skills into the homeland. The statistics are staggering: 43 per cent of Zimbabwe's highly educated population live in Organisation for Economic Cooperation and Development (OECD) countries, with Mauritius (41 per cent) and the Congo Republic (38 per cent) close behind. About 20,000 medical doctors, engineers, professors and other professionals leave Africa each year. Some 30,000 of the estimated 300,000 Africans who live abroad have PhDs, the vacancies they leave in their homelands being filled by expatriates at a cost of US$4 billion annually. Europe and North America benefit from skills acquired at great cost; for example, in Kenya it costs US$40,000 to train a medical doctor and US$10,000–15,000 to educate a university student for four years (Mills et al. 2011). The money used to train these students comes from a budget that includes loans from the International Monetary Fund and the World Bank that African countries must pay back, but the graduates they expended it on now work in the very countries that lent the money.

Africa no longer talks about the brain drain as Lalla Ben Barka of the UN Economic Commission for Africa did in 2014 when she said: 'In 25 years, Africa will be empty of brains' (Tebeje 2014). Out-migration has depleted university faculties and most remaining lecturers have master's degrees rather than PhDs (Chinyemba 2011). Africa is now embracing its capacity to be present throughout the world, to see, learn, master, internalise and bring back skills to develop the continent – hence the emphasis on the developmental diaspora (Plaza and Ratha 2011).

Two programmes funded by the Carnegie Corporation of New York are proving just how wrong Barka was by offering the African diaspora and Africa at large a wonderful opportunity to return even *while* and *because of* staying where they are. One is the Council for the Development of Social Science Research in Africa's African Diaspora Support to African Universities programme dedicated to social sciences and humanities; the other is the Carnegie Corporation of New York African Diaspora Fellowship programme, which has a much broader remit. On the one hand, the programmes are helping African intellectuals based in North American universities to forge links with African universities. On the other, they are providing financial resources to African universities to identify and host the African diaspora intellectuals they want, through whom they create inter-university partnerships. Both programmes have been mobilising African academics in the diaspora to contribute to 'the strengthening of PhD programs and the curricula', 'the filling of gaps and dealing with shortages in teaching', mentoring of young scholars in Africa, and 'strengthening relations between African academics in the diaspora and the institutions where they are based and African universities' (CODESRIA 2014; Foulds and Zeleza 2014). The author of this article is one of these diaspora intellectuals and this article is an outcome of these collaborations to not only forge overseas partnerships, but also create and strengthen intra-African inter-university connections.

Funding

However, such brain circulation will not solve a perennial research capability problem: funding. How does the university remain financially viable? The students are poor, and the university needs a budget to maintain its operations. The often state-funded universities have no money; research requires money. What is to be done?

The channels through which Africans ended up in North America and Europe reveal our education system's enduring colonial ties to and financial dependence on the West and our struggle to evade colonial legacies and be institutionally independent. Our universities have expanded but funding remains inadequate and susceptible to government budget cuts. This affects research and salaries, discouraging prospective talent and leading to the loss of staff to private sector and overseas competition. At 0.5 per cent of gross domestic product (GDP), African investment in R&D is the lowest in the world. There have been individual country improvements, for instance Kenya's and Botswana's recent pledge to commit 2 per cent of

GDP to research since 2015. Ethiopia already commits 1.06 per cent. The bulk of Africa, however, commits much less to research, instead prioritising primary, secondary and undergraduate education (APLU 2014; Divala 2016; HESA 2014; Trayler-Smith 2014; UNESCO 2015).

Genuine international partnerships with African institutions have acted as capacity-building vehicles for universities and individual faculty, bringing in much-needed funding, equipment and staff development, with overseas partners also benefiting from the collaboration (Rampedi 2003). But there are also deceitful, neocolonial partnerships that continue colonial infrastructures of dependency and that reduce and use Africa-based faculty and institutions as the equivalent of data-mining offshore rigs (Ishengoma 2016; Kot 2016). Most of these partnerships are initiated by universities, foundations and donor agencies in the global North (Samoff and Carroll 2004). What is seldom highlighted is that most university initiatives start with well-meaning individual faculty and students, with institutions getting involved only later.

Some donor-funded programmes continue to serve US, British and European interests. For example, donor agency partnerships involving the US Agency for International Development are inextricable from US 'soft power' – the use of aid and diplomacy in the national interest. Other programmes, such as those by the Centers for Disease Control and the National Institutes of Health, are aimed at containing and preventing deadly diseases and their agents from coming to the US. The United Kingdom (UK) and Europe have similar 'soft power' and 'containment' partnerships (CDC 2015; Kot 2016).

Critics say the escalation of these overseas partnerships is happening at the expense of intra-African linkages, thus exacerbating a trend begun under colonialism. Living in the US has given those of us in diaspora an appreciation of the pragmatic national interests that drive these host countries' interventions in our homelands. They have interests in Africa; Africans have interests in the US. That is common ground for building solid bridges and mutually beneficial postcolonial relationships rather than privileging populist but empty political rhetoric that scuttles innovation opportunities. Every North American, European, Chinese and Australian institution will now have to rethink its African partnership strategy around the African faculty in their employ. In turn, African intellectuals will have to strategically position themselves as bridges facilitating mutual benefit between their host institutions and Africa.

Our universities are still young; most depend on annual central government budgets for their operations and for faculty and other staff salaries. Endowments are the exception; where they exist, they are very small. For example, as of 2010, endowments for some African HEIs were as follows: the University of South Africa, US$300 million; University of Pretoria, US$165 million; University of Cape Town, US$150 million; and Wits, US$100 million (UNISA 2011; UCT 2010; UP 2010; Wits 2011). Comparatively, Harvard's as of 2015 was US$36 billion; Yale, US$25 billion; the University of Texas System, US$24 billion; Stanford and Princeton, US$22 billion; and MIT, US$13 billion. The endowment total of US universities is US$394.94 billion, up from US$219.37 billion in 2005, composed of gifts from alumni and other well-wishers, as well as investment portfolios (Commonfund Institute 2016). Africa's rich and famous tend to build themselves mansions and buy expensive vehicles rather than investing in Africa's education systems. In 2015, the richest person in Africa was Nigerian Aliko Dangote (net worth US$12.6 billion). Twenty-six of the top fifty richest people in Africa are each worth US$1 billion or more (Forbes 2016). Commendably, Dangote has established a foundation called the Dangote Foundation, 'the main objective of...[which] is to reduce the number of lives lost to malnutrition and disease'.[2] Strive Masiyiwa, chairman of telecommunications group ECONET, and his wife Tsitsi, sponsor talented African students to attend prestigious universities overseas under the Yale Young African Scholars Program (Office of Public Affairs & Communications 2016). That is how it should be. What is still needed is to fund research targeting problem-solving at local universities, and to create spaces where diasporic talent can come home, walk tall on the African soil and 'do their thing'. It does not have to be for free; it is, quite simply, business and the diaspora is an investor.

A People's University: Towards Informal-Sector Partnership

In Mozambique, only 11.1 per cent of the population is employed in the formal sector, 4.1 per cent of whom are government employees. Of the 10.1 million labour force, 52.3 per cent are self-employed (Robb, Valerio and Parton 2014). In neighbouring Zimbabwe, some 50 per cent (5.7 million) of Zimbabweans are employed in agriculture; 42 per cent of them are communal farmers or farmworkers. In 2012, 67 per cent of Zimbabweans were economically active. The employment rate was 89 per cent. About 60 per cent of the economy is informal; that is where

20 per cent of the country's GDP comes from. Without counting those (self-)employed in the informal economy, the unemployment rate is 80 to 90 per cent (ZimStat 2012).

Youth unemployment throughout Africa is increasing rapidly and employment-creation programmes have had little impact (Hilson and Osei 2014). Fifty per cent of graduates on the continent are unemployed (ACET 2016). Simply put, Africa's problem is that it trains for employment when it should be training employers and problem-solvers. Universities' yardstick for successful training is the employability and performance of graduates internationally and their admission into MSc and PhD programmes inside and outside the country. Industries require employees with practical skills, since they are subsidiaries of overseas firms and thus do not do R&D locally (Simbi and Chinyamakobvu 1997).

It is a cliché that our universities are not producing graduates who meet the needs of industry (Matthews et al. 2012; McCowan 2014). Our higher education's lack of applicable value to the economy and society explains the high rates of unemployment among graduates.

Examples of courses that produce employable graduates include the University of Zimbabwe's applied engineering and science programmes, which began in 1992. This included a shift from the BSc general degree that trained school teachers to an honours programme geared to industrial applications as Zimbabwe placed itself on an IMF–World Bank-funded market economy footing. The applied physics programme offers courses in industrial, medical, laser and plasma and environmental physics. Most students chose industrial physics, with courses in workshop practice, computer applications software, theory of devices, computer interfacing, instrumentation physics, quality control, digital signal processing and data communications and networks, and industrial applications of laser and plasma physics, as well as biomedical instrumentation. Upon graduating, they have not struggled to find jobs in industry (Carelse 2002). The applied geology programme was a response to expansion in the mining industry, and includes a vacation placement for students doing basic geological jobs like core logging and sampling (Walsh 1999).

These initiatives are geared towards supplying industry with employees. However, if, hypothetically, somebody removed the jobs that these graduates occupy, the initiatives would cease to be effective or relevant. In that sense, our university system is apocalyptic.

Here we come face to face with the street and the village as (possible and actual) workplaces. What in Africa we call the informal sector in the US is called small businesses, including home businesses. People in these businesses are self-employed, not unemployed; contrast that with Africa, where only formal employment counts. A paid cattle herder, a street vendor, a farmer, a welder, or somebody who rears livestock in their rural home does not count as employed. Billions of dollars circulate informally, seldom entering the formal banking system – hence Zimbabwe's unending cash crisis (Murwira 2014).

Deindustrialisation threw experienced Zimbabwean workers onto the streets, where they created employment for themselves and others – underneath trees, on pavements, at shopping centres in urban and rural townships, at road intersections, in backyards, on rural homesteads, in wetland gardens, in the fields. Mechanics at Gazaland (Highfield) and Chikwanha, carpenters and leather upholsterers in Glen View, and steelworkers and boilermakers at Makoni – these small entrepreneurs have used their artisanship to dominate manufacturing in the country.[3]

Critics rightly say their record-keeping and customer service is poor, and government enforcement of standards impossible because there are too many of them. Few workers have formal contracts and their rights get violated daily. With no registration, most informal entrepreneurs pay no taxes. 'Instead of celebrating mediocrity and hiding behind the fallacy of empowerment,' one observer notes, 'perhaps Zimbabwe should be looking for ways to grow formal industry and get the manufacturing sector working again' (Rudzuna 2014). Small and medium-sized enterprises (SMEs) in Glen View Area 8 face challenges like capital availability, difficulties in procuring raw materials, low technological capabilities and difficulties in securing permits and licences, with the result that SMEs are neither growing nor surviving. Policy frameworks, including the SMEs Policy and Strategy Framework, 2002–2007 and the Industrial Development Policy for 2012–2016 are weak on informal-sector participation (Mbizi, Hove, Thondhlana and Kakava 2013).

Traditionally, an employee is 'somebody who has got a pay slip and can get certain privileges like accessing credit'; therefore, the strategy has been to formalise the informal sector and tax individual workers' monthly salaries (Munanga 2013; Oxford Analytica 2010). In Mauritius, hawkers are licensed and registered with the registrar of companies, the Small and Medium Enterprise Development Authority or municipalities, and taxed

15 per cent of all profits. They are only allowed to sell at designated points. Such measures have faced resistance in Zimbabwe. Vendors say they make very little, that banks cannot lend to them, charge exorbitant fees and interest rates, and risk collapsing at any time (Ndebele 2015). Between US$3 billion and US$7 billion circulates in the informal sector (ZEPARU and BAZ 2014). Government says it will 'follow where the money now is…in the informal sector'. It wants informal entrepreneurs to keep books, even if 'very simply, very elementary and show the taxman' (Business Writer 2015).

The informal sector, the mainstay of most African economies, is not properly accounted for in the curricula of Africa. The reason is simple: there is no place for community as knowledge producer or partner, comparable to industry–university and transcontinental inter-university and funder–university partnerships. At most, universities engage in 'community outreach' – they send students for service attachments and 'allow' people from the community to participate in university activities as part of the 'developmental university' (*Pitlane Magazine* 2017). The closest example of a society-responsive university in Africa to date was Tanzanian Julius Nyerere's notion of 'education for self-reliance', a mutually beneficial university–community partnership wherein students acquired real-life experience and the community benefited from academic knowledge, thus creating 'a sense of commitment to the total community' (Nyerere 1968:239). However, Nyerere's revolutionary project lacked entrepreneurship and the capacity to be self-sustaining and profitable. What Nyerere – and all our governments – have done right, we should consolidate and build upon. Whatever errors and weaknesses there are, we should analyse and correct. What tools we can make, we should make. What we do not have, we should import, adapt and use.

Research has demonstrated the urgency of escalating the technical efficiency of informal-sector entrepreneurship: farming, metal manufacturing, transportation and marketing are still excessively labour intensive – 75 per cent of their gross added value is labour (Mujeyi, Siziba, Sadomba and Mutambara 2016). The case for mechanisation of land preparation, weeding and harvesting is obvious (Thebe and Koza 2012). Very interesting grassroots innovation and entrepreneurship is taking place in the dambo gardens of Chihota (Zimbabwe) as farmers import and deploy petrol- and diesel-powered water pumps to draw water from shovel-dug ditches. A traditional method of irrigation, these shallow wells are now many times the size they used to be

as farmers replace hand-held cans with pumps to scale up their operations. Where they used to grow collard greens, tomatoes and onions on small areas of a few yards, they now plant hectares of winter cash crops traditionally monopolised by white commercial farmers – potatoes and early maize, for example[4] (Wuta, Nyamadzawo, Mlambo and Nyamugafata 2016). Research shows that artisan–craftsmen are critical suppliers of agricultural and other tools used daily (Bennell 1993; Mupinga, Burnett and Redmann 2005), and that rural areas are a potential site of grassroots-driven beneficiation of crops, milk, fruits and so forth (Bertelsmann Stiftung 2014; Popov and Manuel 2016). Specific examples include fruits, vegetables and grains that could be processed into juices, dried products and extracts like oil, as well as organic waste (like cattle, goat and chicken manure) that could be processed into fertiliser and fuel (Mvumi, Matsikira and Mutambara 2016; Rusinamhodzi, Corbeels, Zingore, Nyamangara and Giller 2013). We have to start reimagining the homestead, the village, as laboratory and factory.

To do this, programmes must be initiated to make value-adding tools available to rural and urban sites of informal economic activity and to turn them into venues of vocational–entrepreneurial education. Non-pedagogical ingredients are already present in some countries. For example, the leading German company Bosch Group supplies artisans with hand and machine tools (and user training) in Ghana and Nigeria under its Bosch Power Box programme of value-addition through improving product quality (Agbugah 2016). Another example is Hello Tractor,[5] an app-based tractor rental for the poor, started by Jehiel Oliver, an African American. The social enterprise is currently operating in Nigeria. Marketing, too, is increasingly being linked via information and communication technology (ICT)-based platforms, which build upon and respond to the needs of farming and add value to their activities. Platforms like eSoko, iCow, Rural eMarket, and M-Shamba (Fripp 2013) offer services like market information, weather forecasts, farming tips, business strategies, market monitoring, supplying, and sourcing. Studies of ICT use often stress how they could be used to improve the lives of the poor, especially by governments and non-governmental organisations. They talk of computers, printers, telephones, television, the internet and fax machines (Mugwisi, Mostert and Ocholla 2015), yet ordinary people use the cheapest cellphones as long as they have one function: WhatsApp. Thus, such studies miss, for instance, how villagers in Chihota strategically deploy WhatsApp to sell their crops, inquire about prices and arrange pick-up of their commodities for transport to city markets after ascertaining that they are not flooded with

the same products.[6] Our higher education system is still 'too academic and distant from the developmental challenges of African local communities' to capture and collaborate with innovator–entrepreneurs like these (Kaya and Seleti 2013:30).

The language of research, engineering, science, innovation, and entrepreneurship has no space for the real-life problem-solving, value-generating activities happening at the grassroots level. The usual colonial languages (English, French, Portuguese and German) are still the official academic and research languages, except in Tanzania, which returned to kiSwahili. Scholars who see this as undermining the serious development of research and theory based on indigenous conceptual frameworks and paradigms are right. Our failure to develop indigenous modes of theory to meet the needs of the African people has robbed us of the opportunity to engage African people as partners in, not recipients of, solutions. Languages die if they are not used (Divala 2016; Hountondji 2002; Gudhlanga and Makaudze 2012).

An Entrepreneurial University

Research has shown that about 60 per cent of Zimbabwe's start-ups (called SMEs locally) fail in the first year, 25 per cent fail within three years, and just 15 per cent survive. This translates into an 85 per cent start-up failure rate (Mudavanhu, Bindu, Chigusiwa and Muchabaiwa 2011).

Africa has already embraced entrepreneurship education (EE), but not entrepreneurship. On paper, the mandate of EE is to educate entrepreneurs who are also innovators, to instil 'an entrepreneurial attitude' or 'spirit' and expunge 'risk-averseness'. EE is supposed to equip students with techniques to analyse and synthesise, and create risk-takers who initiate innovative start-ups and see them to success (Fayolle and Gailly 2008; Griffiths, Kickul, Bacq and Terjesen 2012; Woollard, Zhang and Jones 2007). Sceptics, however, differ: a certificate does not make one an entrepreneur, and entrepreneurship does not exist without innovation (Walt and Walt 2008).

EE is expanding in Africa at a rapid pace; the demand is 'overwhelming' (Robb et al. 2014). Since 1997, entrepreneurship has been a compulsory subject in Kenya's technical vocational education and training (Farstard 2002), even though at Jomo Kenyatta University of Agriculture and Technology (JKUAT) engineering students were 'encouraged' to 'audit or attend' entrepreneurship courses, but they were not a requirement for graduation (Marangu 1997). JKUAT and Kenyatta University offer entrepreneurship specialisation at

doctoral level; other universities offer undergraduate programmes (Robb et al. 2014). Since 2008, EE programmes have been established at Mozambique's three public and two private HEIs: Universidade Eduardo Mondlane, Universidade Pedagógica, Instituto Superior Politecnico, Universidade Católica de Moçambique and Instituto Superior de Gestão, Comercio e Finanças. Under the National Agenda to Combat Poverty, these HEIs are the nation's vehicles for driving the economy forward through entrepreneurial education, start-up incubators and leveraging overseas partnerships (Libombo and Dinis 2015). Thus far success stories are scarce (Libombo and Dinis 2015).

In general, EE curricula focus more on theory and business plans rather than exposing students to real-life business situations. Entrepreneurship is about taking risks, yet students graduate without ever having taken any (Robb et al. 2014). Their instructors are themselves risk-averse; few have ever been entrepreneurs (Kirby 2006). The institutions that train them have no support structures for start-ups or ties to, let alone collaboration with, industry or the informal sector (Shambare 2013). EE slavishly teaches the Schumpeterian principles of a linear correlation between entrepreneurship and economic development. African entrepreneurship is highly informal, creative, irregular and often hardship-driven, with no access to lines of credit (Libombo and Dinis 2015; Robb et al. 2014; Sautet 2013). Despite supporting the majority in a continent of limited formal jobs, the informal sector does not feature as a space for students to acquire practical skills.

This is where vocational education becomes key to any research university: to not just research but turn our findings into products. Vocational education is supposed to train people in hands-on, practical, basic reading and mathematical skills. Empirical research shows that the courses are quite poorly developed, offer limited practical training and depend on donors for funding and equipment. Usually the programmes do not build on predominant activities and local resources that sustain the informal sector. For example, in Mozambique, despite loud political declarations about non-formal vocational education, few programmes are devoted to agriculture, which supports 75 per cent of Mozambican livelihoods. Furthermore, small-scale farmers contribute 95 per cent of agricultural production and 70 per cent of the population lives in the countryside. There are similar problems in Botswana and South Africa (Mayombe 2016; Moswela and Chiparo 2015; Oladiran, Pezzotta, Uziak and Gizejowski 2013).

Our science does not usher in anything tangible due to the specific circumstances in which it originated, and the notions that technology is an outcome of scientific research and that white men determine what is considered scientific. Since our independence, we have voluntarily chained ourselves to the Haldane principle that emerged in the UK in 1904, which states that researchers, not politicians, should make decisions about research funding allocations. In 1918, Richard Haldane recommended that government-supported research be placed in a special department and more general research in autonomous research councils. Classical political science designated technology as residual to factors of production (land, labour and capital); everything starts with research in basic sciences, is applied by engineers, which ushers in technological application, innovation and diffusion. Thomas Kuhn (1962) further cemented the Haldane principle in *The Structure of Scientific Revolutions*.

The African Union's Science, Technology and Innovation Strategy for Africa (STISA-2024) is the latest iteration of the Haldane principle, on a continent where many innovations are 'neither based on nor the result of basic science research' (Marjoram 2010:173), but in informal activity. STISA-2024 derived from the 'Frascati family' of manuals that OECD National Experts on Science and Technology Indicators have developed since 1960: the Frascati Manual in 1963 (on R&D), the Oslo Manual in 1991 (innovation) and the Canberra Manual in 1995 (human resources in science and technology) (OECD 2002, 2005).

The argument is not that R&D is not important; the issue is what ingredients ought to constitute it so that it works for us. Everything else – who, where, with what – depends on critically addressing that question. Marjoram (2010) points out that promoting the development and application of science, engineering and innovation must take precedence over education, capacity-building and infrastructure, which the UN Conference on Trade and Development (UNCTAD 2007) emphasises. Yet both are further downstream of establishing an identity for science and engineering in Africa defined by and for African priorities, as Latin American science, technology and innovation strategists did when crafting their own Bogota Manual (RICYT/OAS/CYTED 2001). Instead of top-down (science-intensive) R&D, these scholars emphasise the role of 'social innovation', 'inclusive innovation', 'innovation at the bottom of the pyramid', 'grassroots innovation', 'innovation for development', '*jugaad* innovation', 'reverse innovation' and 'community innovation' (Globelics 2012).

Our designs 'must reflect local conditions, use local resources in response to local problems. Anything from the outside must be complementary to this' (Mamdani 2010).

Conclusion: An Interdisciplinary, Cross-Cultural and Anticipative University

In a world that demands interdisciplinary, cross-cultural and out-of-the-box thinking, we have ministers of higher education and vice-chancellors who are taking us where we should be fleeing from. Disciplinary rigidity and the separation of the engineering sciences into electrical, civil, mechanical or agricultural engineering impedes an integrated approach and leaves no room for productive floor-crossing and collaboration. The physical architectures of the university are such that the humanities, arts and social sciences are aloof from the science and engineering departments. Internal engagement across lines is non-existent, to say nothing of interdisciplinary research and teaching. These structural and pedagogic rigidities are a serious obstacle to a multi-optic problem-solving research university. But we are building more of these.

For countries like Nigeria, the path lies in modelling new science and engineering institutions around very specific services and products – energy, materials, chemical and leather technology, industrial research, various types of incubators, biotechnology, remote sensing, etc. (FG Plans 2016). The danger is that STEM will create a vast pool of mono-skilled technicians (what I call 'glorified mechanics' of bodies, cars and the soil, with no historical and identity consciousness), whereas the informal economies that dominate Africa thrive on multi-skilled competence. For Ethiopia, the route to a developed nation lies in quintupling the current public universities to thirty-four (Rayner and Ashcroft 2011). For Rwanda, it lies not in numbers but in merged universities with concentrated researchers and resources (Iizuka, Mawoko and Gault 2015). Private universities and colleges are sprouting in every African country, absorbing high school graduates in large numbers. There is much money to be made. For example, by 2012, Uganda had twenty-seven private universities compared to just seven public; Ethiopia had thirty private and twenty-two public; Nigeria, forty-five private, thirty-seven state and thirty-six federal; while South Africa had a whopping eighty-seven private compared to just twenty-three public (Mashininga 2012). The number of PhDs every country is producing is also increasing – for example, Burkina Faso has been lauded for having

one PhD for every twenty graduates (UNESCO 2015). However, Africa's problem is no longer one of quantity but rather the quality of degrees. Engineering professors need to be doers, not just by-the-book 'lecturers'; then, students will also be doers.

Notes

1. Personal Communication with Chikoko Nyamayemusoro, WhatsApp Chat, 16 October 2016.
2. https://www.dangote.com/foundation/
3. Mavhunga Field Notes, Mbare, Mupedzanhamo, Gazaland (Harare), Chikwanha and Makoni (Chitungwiza), Zimbabwe, 20–30 January 2017.
4. Mavhunga Field Notes, Mavhunga Village, Chihota, 14 July–26 August 2016.
5. www.hellotractor.com
6. Mavhunga Field Notes, Chihota District, Zimbabwe, 25 June to 30 August 30 2016.

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