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Abstract

The question of how to build science and technology capacity in developing countries has been on (and often off) the agenda for decades, as has the issue of how to use partnerships to accelerate capacity building. There is, however, currently an explosion of interest in science and technology (S&T) in Africa. A plethora of reports and policy documents have argued for an expansion of S&T but to a far lesser extent for a rigorous rethink about how science, technology and innovation can be better organized for development. This paper aims to assess the importance of 'new' theories and practices based on the role of innovation and knowledge systems. The paper argues that lessons can be learned from transformations in research policy and from practices that better integrate new ideas from innovation, knowledge and development Such lessons exist not only from North America and Europe, but especially from developing countries including from Africa itself. The paper uses a range of evidence from recent cases of successful science and technological capacity development and capability enhancement in Africa, to assess the implications for future development of science technology and innovation capabilities. It has been argued that science and technology in the poorest developing countries is being held back by a single minded, short-term focus on poverty alleviation. This focus is seen as a constraint on gaining resources for medium and longer-term programmes, including in science and technology. However, an alternative argument would be to ask what changes are required for science, technology and innovation to be accepted as key for the alleviation of poverty. This alternative would also lead to transformations in research policy.

Keywords: science, technology, innovation, development; capacity building; Africa

1 Introduction

In recent years, a number of high-profile initiatives have signaled renewed interest and concern about science and technology capacity-building in Africa. A series of influential reports and interventions has highlighted both the importance of science and technology in achieving development goals, and the role of capacity building in that process. Africa is particularly needy - not only is it the poorest continent; it is also the one with the weakest science and technology institutions.

At the same time, there has been a modest contemporary increase in initiatives and resources, albeit sitting uncomfortably against a backdrop of static or worse science and technology baseline capacity and overall low national levels of national support for science and technology. New initiatives include modest local efforts in some countries to increase local resources for research, emphasis on setting up science and technology ministries, and a range of public-private partnerships to tackle new science (like biotechnology) and rampant diseases (like HIV/AIDS, malaria and tuberculosis).

The United Nations Millennium Project Task Force on science, technology, and innovation emphasizes the need to harness science and technology to accelerate development, pointing to low productivity agriculture, the burden of infectious disease, environmental pressures on production and tourism, increasingly urban environments, and weak transport infrastructure. The report underscores the need for enabling and innovative policy as crucial in this regard:

> A nation's ability to solve problems and initiate and sustain economic growth depends partly on its capabilities in science, technology, and innovation. Science and technology are linked to economic growth; scientific and technical capabilities determine the ability to provide clean water, good health care, adequate infrastructure, and safe food. Development trends around the world need to be reviewed to evaluate the role that science, technology, and innovation play in economic transformation in particular and sustainable development in general (Juma and Yee-Cheong, 2005, p. 20).

The role of learning, and by extension capacity and capabilities, is fundamental to generate maximum benefits from enabling technologies, emerging knowledge bases, and concrete technologies. The October 2004 UK House of Commons Science and Technology Committee report on The Use of Science in UK International Development Policy underlined the importance of generating real capacity through development, partnerships, and science and technological innovation. Building capacity is seen as a lever to draw together the 'yawning divide between north and

south' (House of Commons 2004, p. 44). The importance of capacity building is drawn through the Science and Technology Committee document. Recently too, the UK Royal Society has shown its support by arguing for more Department for International Development (DFID) support for science and technology, though it focuses on UK based expertise:

> It is essential that [DFID] builds sufficient in-house expertise so that science can play a central role in developing long-term, sustainable solutions, such as robust vaccination programmes and drought resistant crops … DFID must invest in building up the science and technology capabilities of developing countries (Royal Society, 2004)

The flurry of reports from 2004 highlights the importance of first, science and technology, and second, capacity building. But the issue of how best to enable the sustainable development of capacity in developing countries with respect to new knowledge is not a brand new endeavour. Historically, much effort has gone into attempts to diagnose the problem of the weak science and technology base of the "South" and its weak integration with production (Bell and Pavitt, 1993; Garrett and Granqvist 1998; Ernst et al, 1998; Forbes and Wield, 2002; Lall, 1990). The seemingly increasingly intractable paradox of a globalizing, integrating world within which asymmetries of information, knowledge, and wealth continue to grow, signals the need for new and innovative approaches in this area.

As the very need for a Commission for Africa (2005) demonstrates, in Africa these issues are further amplified, and new approaches must be firmly embedded within an understanding of the African context if suitable and sustainable progress is to be made.

For decades now, the simple idea that science leads to technology and S&T leads to industrialization and development has been critiqued and more complex notions substituted. However, science and research capacity building has continued to be emphasized by those few agencies willing to support science, technology and innovation (ST&I) against the prevailing wisdom that investment in the state and the long term must take second or third place to more formulaic neo-liberal approaches. The continued emphasis may be because science and research capabilities were so weak in the poorest countries that support for S&T was linked to a basic survival strategy for secondary and tertiary education. It may also have been because much support has been bilateral donor support to governments and public sector institutions, rather than to productive enterprises. Whatever the reasons much of the support provided has created a defence of use of 'old theories' of ST&I by prioritizing 'S' and research over 'T' and innovation. Thus, this focus on longer term (science

first) over shorter-term possibilities may have weakened the chances of successful innovation, and therefore weakened the argument concerning the key role of ST&I in confronting poverty. Or perhaps, as the New Partnership for Africa's Development (NEPAD) might argue, the key variable is just the absolute weakness of investment in ST&I. In any case, it has led to science being seen either as a cultural and educational necessity worthy of support to avoid complete collapse, or as a complete waste of time and money.

Critiques of 'linear' assumptions about science leading to development, certainly as they emphasize innovation theory and practice, cluster around mode1/mode 2 debates (Gibbons et al, 1994, Nowotny et al, 2001) and the rise of systems of innovation conceptualisations of how innovation occurs (Edquist, 1997; Lundvall, 1992)

Gibbons et al. (1994) and Nowotny et al (2001) argue that a shift is taking place in modes of knowledge creation from mostly mode 1 towards mode 2. They characterized Mode-1 knowledge, produced in institutions like universities and research institutes and companies, as disciplinary, usually peer reviewed and written down — codified. They did not suggest that mode-1 knowledge was not important, but suggested that mode-2 knowledge was growing in importance. Mode-2 knowledge was characterized as practice based, transdisciplinary and context-bound, and involving groups joining together with different skills to solve problems. It tends to be more practice-based than theoretical, and has a greater ability to draw on local knowledge and expertise. Some have argued that the science base in many developing countries has not shifted as quickly as in other countries.

These concepts are closely allied to idea that processes of innovation can better to analyzed in systemic ways. For Metcalfe, systems of innovation are defined in terms of institutional connectedness:

> That set of institutions which jointly and individually contribute to create, store and transfer the knowledge, skills and artifacts, which define new technologies. (Metcalfe, 1995)

For Hall et al:

> At its heart lies the contention that change — or innovation — results from and is shaped by the system of organizations and institutions (in the rules, norms and conventions sense) in particular locations and points in time. An innovation system includes organizations involved with research and the application and adaptation of research findings, as well as intermediary organizations that promote knowledge transfer (2001, p. 794)

Increasingly these ‘newer theories’ can face the ‘old theories’ as equals though their theoretical acceptance may prove more straightforward than the implied institutional transformation. Indeed reforms are often accompanied by ferocious conflict and debate. Conflicts occur between institutions that may lose out from transformation and also because the ‘old’ is deeply embedded at organizational, institutional and individual levels. This affects north-south research partnerships just as much as it does research practices everywhere else. Maureen O’Neil, Director of the International Development Research Centre (IDRC) which supports innovative research led from the south, notes that development related research is often not considered wholly legitimate:

> Too often IDRC hears stories — especially from younger faculty — that they get little or no credit towards career promotion and tenure for the research they do on IDRC and CIDA-funded projects. This is considered “research for development” or research that is worthy but not “excellent.” (O’Neil, 2004, p. 2)

Conflict can also be subtle because mode1 and mode 2 are not mutually exclusive - the balance between support for science, research, technology and innovation is important.

Such ‘new’ approaches highlight the need for a re-evaluation of notions of research ‘excellence’ and ‘good practice’. O’Neil argues:

> Hedging and risk averse approaches must not trap Canadian researchers within one definition of research excellence, blinding them to other less familiar approaches to knowledge creation and capacity building while blunting the potential to create new knowledge (O’Neil, 2004, p. 2)

O’Neil goes on to offer an alternative version of excellence which she sees as more appropriate for judging research carried out in partnership with developing countries:

> By “excellence”, we may mean “urgently needed and challenging research” - that which is problem oriented, multi-disciplinary (preferably comparative) and carried out by teams networking internationally across research sites and policy jurisdictions. By “innovative”, we may value co-production of knowledge through innovations only made possible by bringing together the experience of experts in Canada and other countries and applying that knowledge to solve real problems. (O’Neil, 2004, p. 2)

From a systems of innovation perspective, innovation evolves from networks of actors, public and private:

> Interaction is critical because organizations do not innovate alone. The system is dynamic and evolving and can stimulate change in complex relationships. The framework places emphasis on interactive learning between producers and their suppliers, buyers, and organizations that support them (Oyelaran-Oyeyinka, 2005, p. 10).

Unfortunately, these subtleties are 'academic' in much of Africa since there are few examples of newer approaches in practice – still many more examples exist of disintegration of 'older systems' in universities and public sector research establishments (PSREs) as neo-liberal policies inexorably eat away at the fragile systems built up to the 1970s. IDRC is one of just a few exceptions of institutions that have continued coherently to fund research capacity building in Africa over the longer term.

At the level of ST&I capabilities, the most important fact is that Africa has an extremely weak base in each. For example, only South Africa and the Seychelles – two obvious anomalies – spend more than one per cent of gross national produce on R&D (UNESCO, 1998). A situation where little sustainable state support exists is further exacerbated by rather weak integration between research centres, universities and firms. Much research around the world depends on the creative tension between on the one hand public core support; for labs, training, baseline expenditure; and on the other hand project support for new initiatives, from public and private sources. This creative divide is not there in much of sub-Saharan Africa. Other divides substitute and in practice they seem less benign. Donor support plays a major role in project support but this has led to a series of negative impacts. First, governments have tended to give less support that in the past so there is very little 'core' support and thus tremendous pressure on donors to support both the 'core' and the 'project' components. Second, 'projectisation has led to short-term priorities often taking over from medium and longer term ones. Third, donor priorities can subsume local priorities, especially if donor support is primarily given in the form of people. Biggs describes one such situation where interests can conflict:

> There sometimes exist conflicts between the goals and rewards for UK researchers working in Nepal and the current needs for strengthening national and local level innovation systems in Nepal. For example publishing an article a UK/International respected journal at the end of a research project may be a major goal for the UK (and Nepali) researchers. However, the process by which the research was carried out in Nepal may or may not have made much contribution to strengthening local capabilities (Biggs, in HoC, 2004, p. Ev291).

The evidence for our arguments comes from the cases set out below of relatively successful S&T capacity enhancement in Africa where innovative partnership activity may bring lessons of new approaches to knowledge creation (Chataway et al, 2005). The cases allow examination of issues, some overlapping, some unique. The cases all differ, each in their own way, from 'normal' S&T capacity building[1]. They all, in different ways, exhibit aspects of 'new' knowledge forms linked to 'old', within a more systems of innovation approach. Together, they allow a deeper appreciation of what is happening and what could improve in the future.

2 Concentrating knowledge, focusing research, and institutionalizing innovation in centres of excellence: Biosciences East and Central Africa (BECA)

There are debates around how capacity coalesces, and is encouraged to coalesce, within and around particular institutional structures. One model supported by NEPAD, and funded with start-up money from the Canadian International Development Agency (CIDA), is a centre of excellence model.

Biosciences East and Central Africa (BECA) is a recently launched African centre of excellence focusing on the biological sciences. The vision for BECA is that it will enable African scientists and institutions to become significant technological innovators. It will become one of a network of similar facilities serving each region of Africa. The remit of these centres of excellence is to encourage African scientists to stay in the African continent and enable them to undertake cutting-edge research targeted at priorities identified in the region by Africa's broader research and development architecture. In the case of BECA, partners include the National Agricultural Research Systems (NARS) including its universities and research organizations, and other institutions such as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), the East African Community (EAC), the Forum for Agricultural Research in Africa (FARA), and NEPAD. Moves are also being made to engage the private sector.

A key aspect of BECA is that it is an attempt to build 'new' institutional arrangements within the 'old'. The facilities will be hosted by the International Livestock Research Institute (ILRI) in Nairobi, Kenya. The Canadian grant will be used initially to refurbish existing laboratory facilities, provide new facilities and equipment (including additional biosafety containment facilities) necessary for the centre of excellence, and develop capacity in biosciences among African scientists (through fellowships, educational

[1] Which have tended to focus on:masters and doctoral training; project funding; departmental strengthening; support to national research institutes.

and training activities that complement existing programs at national, regional, and international levels). An important additional aspect of BECA's development that sets it apart from the normal re-equipping of a research institution is a focus on developing BECA as a central node of a regional network of research institutions. Consequently, resources will also be channeled toward facilitating the generation of a knowledge network.

The idea of instituting a revitalized concept of centres of excellence within the African context are very much born out of critiques of more traditional agricultural research and its institutional framing in developing countries (Hall et al. 2001; 2003).

There are many examples of initiatives in Africa that have focused primarily on the supply-side, infrastructural aspects of institutional building. Technical and financial resources have been steered toward bricks and mortar and equipment, as opposed to perhaps providing the conditions needed for an institution to participate systemically within a given context.

An understanding and acknowledgement of the array of constraints that face institutions in their pursuit of scientific knowledge and innovation has led to an increasing acknowledgement of the importance of building strategic partnerships and alliances to overcome these problems.

Closely related to the issue of partnerships, is the realization that sound management of "knowledge flows" and "technological connections" define the strength and utility of relationships more so than the constituent institutions themselves.

"New model" centres of excellence, then, are a way of avoiding some of the problems that have characterized science and innovation, including in Africa. Centres of excellence can take advantage of economies of scale, of strategic partnerships, of knowledge-sharing and informational networks, and of institutions becoming an integral part of an innovation system. Sound governance is at the heart of creating the conditions where a centre of excellence can flourish. Generating and managing inter-institutional relationships are fundamental to avoiding problems and using institutional structures and networks to integrate them with each other and within systems of innovation (Malkamaki et al. 2001).

BECA is conceived as an institution that can work in partnership with national systems and the CG (multilateral international agricultural research) system to make better use of R&D comparative advantages in Africa. The extent to which BECA will become a *new* model for research and innovation in Africa is unclear, but significant resources have been earmarked to shape the initiative. A clear rationale for the way in which it should be organized, what its priorities should be, and how it builds

capacity has been blueprinted from Canadian, Scandinavian, and Asian models of centres of excellence.

Such a model has potential downsides. First, to what extent will existing institutional inertia, and the constraints that continually characterize agricultural research and development in Africa, constrain or promote new institutional arrangements in African agricultural research. Second, there are issues to be explored with regard to the centre of excellence model and capacity building in the African context. Experience suggests that although partnership activities occur, capacity can be drained to the regional core, denuding national research systems of talent.

3 Building capacity in universities: Swedish International Development Agency Research Department

Sweden's research-support agency for developing countries (SAREC, Sida's Research Division) is one of a very few bilateral institutions (IDRC is another) that support researchers in the South based on local research ideas.

SAREC's support has differed from other donors in one important respect. It has explicitly supported institutional development of research capabilities in African universities, and exhorted others to join it in coordinated support led by the local universities themselves (Olsson, 1992; Wield, 1997).

SAREC's mission statement includes: 'The contribution to strengthening research capacity involves assisting developing countries in their building up of research capacity in the form of functioning research environments' (Sida, 2004). The approach to 'support for research environments' is different to other donors. It does not just fund projects, it also supports institutions. The characteristics of its higher-education research support include:

1 A focus on universities as centres in which research and research training can take place together. The focus is on a few [the single best or a few good] 'more research intensive' universities in each country with a strong attempt to avoid spreading resources for research support too thinly and away from key national universities. 'Sida shall focus on support to research universities with a central position in the national system for research and education'.

2 A focus on support for systems of research (with future inspiration to systems of innovation). Thus, the support includes not only project support but program support, which includes library, internet, and research management support 'coupled with support for activities relevant to the institutional development of faculties or universities as a whole'.

3 There is an emphasis on local research design. ‘The formulation of realistic and constructive poverty reduction strategies relies on local assessment and analysis, underpinned by local research’. Emphasis on local conditions includes support for local research training programs ‘in collaboration with universities abroad that allows university staff under training to continue activities at their home university’, via development of local programs for research training, and the building of research environments, laboratories, libraries, Internet systems, and electronic journals. Projects are supported as a means of building university research environments: in Mozambique, for example, Sida research support has allowed the development of a research decision-making system to prioritize projects.

Recently the idea of clustering institutions has emerged: ‘Clustering is more beneficial than scattering because it builds critical mass and it strikes a better balance between quantity and quality’.

It is important to understand why SAREC support has pinpointed universities as nodes for research-institution building. The decision came from lessons learned over many years. First, support given to national science and technology commissions sometimes did not deliver grounded research environments for working scientists and technologists, but stayed at the national policy level. Second, the decision not to emphasize research institutes, individual scientists outside the national research institutes, and NGO research units is made in an attempt to build longer-term research structures. The thinking is also linked to the idea that research institutions should also be key national cultural centres not short-term ways of responding to particular development problems - although much of the research supported is applied, problem-oriented and strategic. Thus, there is a move within even this university-centred approach in the direction of Mode 2. Finally, support to local universities for development of postgraduate and doctoral programs was important.

This concept in many ways, runs counter to some of the other ‘new’ approaches, in that in many of these African universities are invisible in accounts of African research centres. In some of the other examples given in this paper there is no role for African universities, rather an assumption that ‘freestanding’, post-doctoral trained researchers exist to be plucked for the new research institute model centres or partnerships. There has so far been little appreciation of trends elsewhere towards seeing masters and doctoral training as key parts of a research environment. The next case also gives universities a role.

4 Continent-wide leadership in research for policy – the African Economics Research Consortium

The African Economics Research Consortium (AERC) provides continent-wide leadership in a subject which is important for policy, specifically at present concerning the alleviation of poverty.

AERC is a large scale sub-Saharan Africa-wide network with headquarters in Nairobi and nodes in various sub-Saharan African countries. The donor consortium totals 16 and includes multilaterals, bilaterals, and the large US-based foundations. An annual budget of $10 m. US a year funds about 100 researchers at any one time, plus 140 masters students and 71 doctoral students in its training program.

The AERC was established by senior African economists and a consortium of donors in 1988 for 'the advancement of economic policy research and training'. AERC's mission is to strengthen local capacity for conducting independent rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa. This mission rests on the premise that: development is more likely to happen where there is sound management of the economy; and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

Capabilities in economics in Africa had begun to weaken and fragment in the 1980s, as investment in African universities waned. The idea of AERC was to regain space for research that would strengthen national and regional ability to think about and practice better economic management, focused on macroeconomic management. AERC is generally seen by its main supporters (donors, economists, universities, private sector and governments) as having been incredibly successful. Senior economists have said that the capacity building organized and led over the years by the AERC through its project on poverty was the single most important reason why so many African countries had produced the high-quality poverty reduction strategy papers required by the donor community.

As such, we suggest, it has given 'voice' to a professional grouping so as to increase overall ability to use policy knowledge to address economic issues. It is then a professional voice, but one that acts collectively for an alternative approach to economics that better reflects local realities.

Significantly, AERC's governance separates donor interests from research and capacity-building priority setting. The Board of Directors, constituted by members of the donor consortium, agrees on the 5-year strategic plan. All donors accept a common reporting system, avoiding the normal fragmented constantly changing

systems of each donor. The Programme Committee sets the research and training agenda and has no donor representatives. It is made up of four senior African economists, four senior African policy-makers, and four international resource persons. The committee is responsible for overseeing the research and training programs. The Executive Director and secretariat manages the consortium and the programs. There are just four professional staff in Nairobi, avoiding 'core as magnet' knowledge drain.

The concept of research training in AERC is that it should happen through doing research. Thematic areas are defined (there are four at present) and research-projects proposals invited. At any moment, there are about 100 small projects and a few larger networked projects. Over the last 7–8 years, about 760 projects have been funded, engaging about 1000 researchers. Each proposal is judged, and the researchers who propose the promising proposals attend the bi-annual meetings to discuss and debate their proposals. At this stage, proposals are either agreed on or sent back for further work. Each promising proposal is given attention and feedback. Junior researchers are encouraged to apply, either in groups or with more senior colleagues. Every proposal accepted gets another work session as "work in progress" and is discussed at the final report stage. There is thus a collegial process of quality control. As well as this peer review system AERC provides methodology workshops and literature. At each biannual meeting there are Africa and international resource persons, all world-class economists. AERC says that the workshop process has been central to developing a sense of ownership of AERC activities on the part of researchers and their institutions.

More recently, formal training programmes have been set up in partnership with 21 sub-Saharan African universities in 16 countries, all Anglophone. Nigeria and South Africa are not included because they have well-established Master's programs. All member universities can send students to the 18–24 month courses, but only the seven accredited universities can teach on them. Accreditation is on the basis of capacity to mount a Master's degree in Economics. The programme started with an intake of 58 students in 1993, and the latest intake was 140 in 2004. Most recently, a collaborative doctoral programme has begun with eight teaching node universities and an aim to graduate 400 PhDs in 15 years. This has four sub-regions: Anglophone West Africa; Francophone Africa; Eastern Africa; and Southern Africa. Intake has risen from 19 in 2003, to 25 in 2004, to 27 in 2005, and all are still in the programme. It has demonstrated clearly that African universities can innovate during a period when they have been criticized for not giving a lead.

AERC has several key characteristics that are important for capacity building:

1 It is managed and coordinated from an African base, with strong African leadership and support at the highest levels. It has not turned inward but rather has excellent international relations and resource persons.

2 It has a large set of node points around the continent, and good relations with most of the best universities, research institutes, and governments on the African continent. But it has managed to keep a very tight focus around its research capacity and training initiatives, which are strongly integrated.

3 It has a disciplinary focus for capacity building in economics, but within a strong policy and practice framework on economic policy.

AERC has grappled with the inevitable tensions around direction and focus. Donors, for example, are used to having a major say in the style and direction of the programmes they fund. Similarly, international resource persons could become very powerful in shaping research agendas. The leadership of AERC has worked hard to keep the leadership initiative, to avoid fragmentation of efforts, and to keep a single common reporting system. It has consistently pushed for a particular approach to economics with values related to the problems of poverty alleviation in Africa. It is a high-profile institution with a reputation for international excellence around the world, and it has worked hard to maintain control of AERC's strategy and focus.

5 Developing product networks: the East Coast Fever Vaccine Project

The East Coast Fever (ECF) vaccine project is an initiative to research, design, and disseminate a bio-engineered vaccine for a parasite that affects cattle across Eastern, Central, and Southern Africa. The regional economies lose an estimated £300 million a year from the disease, which is caused by the parasite *Theileria parva*. Analysis led to the identification of several problems with the existing, traditional live attenuated vaccine currently in use. Issues related to poor efficacy, cost, transportation, and refrigeration led to efforts to design a new bio-engineered vaccine.

The project, based at the International Livestock Research Institute (ILRI) in Nairobi, is a model of how to manage a product-focused R&D process in a developing country. DFID has provided £5.1 million as a needs-based public–private partnership, which has ensured that effective systems of vaccine delivery provided by the private sector will be in place when the vaccine comes on stream. In fact, a complex set of partnerships between the public and private sectors across several continents has played an important role in moving the science forward. Private-sector ventures are

involved in producing the vaccine for trial and will be responsible for the delivery of the vaccine in a context where there is little demand (because of a lack of resources) and to create a “pull” where the vaccine is needed most.

There is a high degree of complementarity between the major partners. ILRI has conducted basic research on *T. parva*. The local national agricultural research system, the Kenyan Agricultural Research Institute (KARI), is responsible for conducting trials of the vaccine and for monitoring impacts of cattle. Merial, a French biotechnology company, produces the vaccine candidates and has been working on novel delivery systems with University of Oxford collaborators. This new delivery system has potential spin-offs for the effective delivery of other human and veterinary vaccines. Other potential spin-offs for the private sector include insights into the life cycle of the parasite itself.

The East Coast Fever parasite has properties of great interest to biomedical researchers. Like the organisms that cause malaria, tuberculosis, HIV/AIDS, and many other human diseases, the cattle parasite invades its host’s cells. The East Coast Fever parasite invades the white blood cells of cattle and causes the cells to start dividing endlessly. In this way, the infected white blood cells are immortalized and behave very like cancer cells. The East Coast Fever researchers have gained valuable experience in identifying key molecular components of cell-invading pathogens. This work could allow medical researchers to more readily identify previously unknown antigens from the pathogens causing TB and malaria. This is important, given that no user-friendly, widely deployed, and universally efficacious vaccines are yet available for malaria or HIV/AIDS.

One important element of the project from the perspectives of innovation and capacity building is that it is an example of funding and conceiving a project within the multilateral Consultative Group for International Agricultural Research (CGIAR) system in quite a different way. Furthermore, the way in which DFID prioritized and funded the project is very different from the more traditional, technology-led approach. DFID’s more recent emphasis on the role of partnerships in delivering technological innovation, particularly public–private partnerships, and its focus on how best to achieve “maximum impact” have shaped the rationale of the project (DFID 2004). Aside from recognizing the need to support and generate mechanisms for the delivery of the vaccine once it exists (technological dissemination is generally a key constraint in such ventures), several interesting issues regarding capacity building can be underscored. Encouraging a tight focus on the development of the product, in particular the individual steps needed to develop the product, appears to have generated tangible capacity in several areas (Smith, 2005).

The product-focus itself seems to be more effective in this particular case than a broader, multi-sectoral approach. In particular, playing to the strengths of KARI in coordinating and assessing vaccine trials in cattle has resulted in much needed funding percolating into the national agricultural system at a time when KARI does not have the capacity to attract large amounts of international research funding. Interviews with senior researchers in KARI attest to the important role that attaining some project funding, even for quite low-level science, has played in stocking laboratories and training staff.

In this case, building an institutionally embedded R&D network focused on creating a very particular product appears to have built concrete capacity in a more effective and broadly based way than injecting broadly based funding. This has interesting implications for understanding both of how capacity can be built and of the relationship between capacity building and innovation in an African institutional context.

This product network has tied researchers and research entities together in quite different collaborative structures from the more traditional knowledge-based approaches to collaboration. Building collaborations around products involves understanding the broader system of innovation, and by extension, understanding what capabilities particular partners can bring to product development *outside* of purely cutting-edge academic knowledge. Product networks can incorporate, and gain strength from, academic centres and this broader perspective works to build capacity across the widest possible spread of partners. Support for the resulting networks can then be incorporated into longer-term institution building.

6 Advocacy and voice: the International Aids Vaccine Initiative (IAVI)

IAVI presents an important example of the relationship between research ‘for’ developing countries and research ‘with’ developing country partners, not just ‘in’ developing countries. The need for a preventative vaccine against HIV/AIDS is overwhelmingly evident and the emphasis has to be on the fastest and most effective way of achieving that target. However, a closer look at the main public–private partnership working on a preventative vaccine, the International Aids Vaccine Initiative (IAVI), suggests that even here the distinction between ‘for’ and ‘with’ need not be so clear cut — IAVI has in fact had very positive impacts in terms of capacity building. In this case, political and ethical sensitivities around vaccine development and clinical trails are powerful arguments in favour of local engagement and voice at all levels.

As described earlier, developing a vaccine for East Coast Fever is another example of when top-class international science is required, but also benefits enormously from local engagement. Although a very different case, the combination of research 'for' and research 'with' is brought together in a product-focused initiative that addresses issues of local engagement in a way that adds to the overall outcome of the work.

IAVI was set up in 1996, initially within the Rockefeller Foundation and then as an independent entity. From the outset, IAVI's mission and mandate focused on the creation of an effective preventative AIDS vaccine and the distribution of that vaccine to those in the world who most need and can least afford medication. On the one hand, IAVI acts as a sort of venture capitalist, investing in promising vaccine candidates and offering support for the expensive clinical-trial stage of drug development. It works in a completely untied way, funding on the basis of excellent research.

On the other hand, IAVI engages in high-profile public relations and grass-roots advocacy work to promote the need for a vaccine and to provide insight into technological possibilities. Political support, in the absence of economic demand, is considered crucial if a vaccine is to be distributed. Much of the grass-roots advocacy work takes the form of vaccine preparedness work, which is linked to preparation for clinical trials. IAVI then focuses on three things: awareness, access, and research.

A crucial part of IAVI's work is developing strong links with developing country institutions. Vaccine Development Partnerships (VDPs) have been established with institutions in a number of countries including India, Kenya, and Uganda. VDPs are responsible for running clinical trials and for the vaccine preparedness work. They also engage in planning for vaccine manufacturing and distribution. VDPs create extensive networks with community-based groups and local nongovernmental organizations (NGOs).

IAVI's role in capacity building is paradoxical but successful. Capacity building is not a core priority but it is strategically important, and IAVI has achieved significant capacity building through its VDPs. One senior IAVI manager explains the approach:

> It's not part of IAVI's mission, nor a mandate but it is part of the reason we're funded. The IAVI mission and mandate is clear which is to develop a vaccine. That probably…can't be done without capacity building in the developing countries. In other words, as a strategy it's probably essential in the truer sense, in that without it we probably can't achieve what we want to, but it's not part of the mission nor mandate. (Interview with senior IAVI manager, 2004)

Capacity building has been essential to IAVI for three principle reasons. First, for scientific reasons it is essential that clinical trials be conducted among those populations for whom the drug is intended and in many instances it is more convenient and in some cases acceptable to do those clinical trials locally. Second, and relatedly, building support for a vaccine requires local political support and this is built through active engagement. Third, the majority of IAVI's funding now comes from bilateral and multilateral funding agencies and these agencies clearly favour a capacity-building approach where possible. In this case, capacity building has been possible.

IAVI partners in Kenya, Uganda, and Rwanda have all received very significant investment in training and infrastructure, and have benefited in particular from close and constant communication via phone, internet, and face-to-face meetings with leading scientists and managers. IAVI's African partners say it is the constant focused activity around a boundaried set of tasks associated with vaccine development that has been particularly valuable. For partner organizations in Uganda, Kenya, and Rwanda, new prospects have opened up as a result of this engagement. They are able to interact with IAVI on a broader basis, to assume increased control and responsibility, and to think of engaging with other vaccine development initiatives. They can now aim realistically to be centres of excellence for the development of vaccine clinical trials.

This product-based approach to capacity building seems to have important lessons for those thinking about S&T capacity building policy. Capacity building can result from initiatives that focus on product development rather than on broader and more diffuse initiatives aimed at formal training. The tacit knowledge exchange around the vaccine and vaccine preparedness that has taken place as part of the IAVI work is particularly important to try and build on in other S&T capacity-building initiatives.

7 Discussion

In this paper we have analysed case evidence to support the argument that new initiatives exist in Africa which are informed by the need for new institutional forms to source and create new forms of knowledge. Our argument goes on that ST&I can not only be better organised in systemic ways but that this is essential if poverty alleviation initiatives are to mesh with S&T capacity building ones so that poverty and innovation policy-led initiatives become compatible.

Thus, we argue that to link use of science and technology more closely to poverty and human development requires that 'new forms of knowledge' and systems of

innovation approaches are taken on board and improved. The two go hand in hand. We will summarise the five cases then look at some emergent issues, focusing on context, on time scales and on the need to flesh out the systems approach.

The five cases suggest (Table 1), in varied ways, some positive approaches that are emerging. Evidence suggests that new types of partnerships for capacity building are emerging which encompass signs of 'new forms of knowledge. It suggests that there needs to be strong focus on outcomes. Such a focus seems to work well, which allows better focus on poverty and basic development at the same time as building S&T capacity.

Table 1:Summaries of lessons learned from case studies.

BECA – Concentrating knowledge for research	Research and training centre of excellence focused on building capacity for the continent. Aspires to strengthen other institutional basis rather than undermine. Layering the 'new' institutional forms on top of the 'old' builds notions of networking systems
SAREC University Research Support – African university capacity building	Support to set up some universities as national centres, with support not just for projects but for the whole university research environment. Local research design and management. Builds both scientific and research management knowledge
African Economics Research Consortium (AERC) – Continent-wide leadership in research for policy	Research capacity building on a continental level, with node points in many countries. Research capacity building by "doing research" and creating supportive environments. Avoids danger of core being a magnet for skilled staff by strengthening a large number of centres. Separates funder accountability from decision-making on research priorities. Reaches out to international resource persons without losing local priority setting. Builds scientific knowledge with policy knowledge; and integrates knowledge from institutions involved in economic policy concerning poverty alleviation
East Coast Fever – Developing product networks	Product-based network with '"implicit" research capacity building based on understanding local needs and local capacities to conducting research.

IAVI – Advocacy and voice	Product-focused approach to capacity building. Product is of extreme importance where it would be easy to do the research "for" the people of the continent. But in this case, research is also being done "with" the continent's researchers. Public awareness of science; integrates voice of publics; Builds tacit knowledge about vaccine and vaccine preparedness

What has not happened until recently – and then mostly in policy rather than in practice – is to conceptualise ST&I capability building and development in a more integrated way. This paper suggests that innovation, knowledge and development are intertwined and capabilities are a key element of all three. Surprisingly, at present, there is not much attempt to explicitly link the narrower notions of sci-tech and industrial-innovative capabilities with social development approaches and 'rights-based' approaches to development currently advocated by so many academics, policy-makers and NGOs (Pettit and Wheeler, 2005).

7.1 Two critical issues – space and time

Two factors essential to capacity building efforts and related policy are where and how efforts are conceived and implemented (space) and the time period over which they will be realized and within which results are expected. This section briefly considers these two essentials

7.1.1 Space

Value can only be added with knowledge of the local context, not only in terms of understanding local needs, but also how the local context shapes the ability to find solutions. Studies of innovation strongly emphasise the power of incremental innovation – small improvements often coming from grounded efforts to solve problems as they arise. The S&T capacity literature tends not to focus that much on such local capabilities. Furthermore, not understanding local capabilities can lead to an erosion of local capacity as local capabilities are bypassed by particular activities and funding, and effectively removed from systemic local innovation.

Problem-oriented projects are a good way to build initial capacity, and indeed may do more than this if the project is sufficiently embedded, uses local input in problem identification, and concludes by creating a concrete product that can be efficiently distributed. The key here is to understand how to embed project approaches within

both broader systems of innovation networks and a deep understanding of local capacities, needs, and markets.

The East Coast Fever project is a good example of just such a ‘joined-up’ project; pulling together highly technical scientific knowledge with embedded tacit ideas about what ought to be done, and how it will be done once the technical core has been advanced to a sufficient level. The International Aids Vaccine Initiative (IAVI) is another example where technical knowledge is transferred and accumulated among African partners but is made useful and more lasting by intensive sharing of more tacit knowledge. The focus on both technical and tacit knowledge helps to relate projects to the real world.

Both initiatives illustrate ways in which inter-institutional capacity can be built almost as a by-product of the research and design process. By strategically understanding the local institutional architecture and sets of available capacities and competences, complementarities can be achieved and further capacity built. Both the East Coast Fever Project and IAVI draw on local competences where available, and international competences where necessary. Therefore, understanding the local context enables research and design networks to be effectively extended and stretched over whatever distance and skill sets that are necessary to achieve the aim. From this perspective, understanding both local needs and local capacities allows a fuller, broader and more appropriate innovation system to be developed.

It follows, conversely, that policy making and management supporting large new S,T&I initiatives will need to take careful account of the complex of activity that actually exists and which employs most of the existing skills existing of the continent. There is always a temptation to implement ‘green field’ initiatives. Our evidence suggests that the absorptive capacity of existing organizations and institutions can be significantly and rapidly enhanced by careful layering in of new initiatives and institutions.

7.1.2 Time

There is often a tension between finding suitable interventions that can bring shorter-term and longer-term capacity building. Although short-term approaches may play some role in shaping long-term capacities, they may not be systemic, cost-effective, or appropriate.

Loosely allied in many ways to differing shorter- and longer-term approaches to building capacity are the spectrum of activities such as projects, programs, networks, and institutions. Supporting the correct mix of activities is crucial to building effective capacity in Africa. Short-term initiatives and activities must be understood in the

context of longer-term institutional support and innovation. Projects such as the East Coast Fever vaccine initiative and IAVI are two of the best examples of projects focused on meeting the relatively short-term goals of vaccine production, within the context of local capacities and institutional realities. Despite these apparent successes, the landscape of donor-supported R&D activity in Africa is still dominated by many discrete projects. This “projectization” limits the creation of true capacity in several ways: projects may be replicated, little learning is passed from one project to the next, it is very difficult to prioritize at the regional levels, and it remains difficult to embed individual projects within local realities.

Horstkotte-Wesseler and Byerlee (2000) identify four key things necessary to avoid the negative impacts of “projectization”:

1 Creating systemic learning from project to project;

2 “Hierarchizing” project priorities;

3 Avoiding replication by building projects on the back of one another; and

4 Embedding projects within local realities.

However, focusing on long-term support for institutions such as BECA in no way guarantees that immediate development goals will be met. Networks that stretch beyond the traditional research centre are just one of the prerequisites necessary for that to occur.

The experiences of Sida-SAREC in supporting African universities as hybrid research and learning institutions illustrates that focus on support for the single best institution within a particular resource-poor setting can place universities within national systems of innovation. This approach provides short-term project support and also longer-term infrastructural program support, including library and ICTs, support for research management, laboratory development, and technician training. The model is one way of supporting the short-term within the context of the longer-term — as an institutional approach and potentially as part of a systemic approach. As such it is a much more flexible support system than much other project based, time boundaried bilateral support.

More generally, and not surprisingly, evidence from studies particularly of east Asia, suggests that institutions that work effectively in one time and space, may not be as effective in others (Wade, 1990, Hobday 1995, 2005, Forbes and Wield, 2002). Obviously, learning can take place by transferring policies and activities from one time and space to another but, as Leonard-Barton (1997) and many others have argued, absorptive capacity depends on their flexible and contingent application.

7.2 Systems of Innovation that lead to more value

The five cases, and the ideas and concepts drawn from them, point toward a systemic approach to building capacity and achieving development goals through science and technology. However, systems of innovation approaches provide only a conceptual skeleton that must be fleshed out with elements of best practice, contextual reality and scientific knowledge in varying combinations.

Our understanding of such a systemic approach is a richly networked array of institutions of differing skill sets, and indeed aims, that can build on strengths to identify strategic needs, and collective weaknesses that may necessitate further networking. Such a systemic approach is important in science and technology capacity building. Systems of innovation differ from nation to nation. Some like Japan and Korea demonstrate strengths in industrial technologies (measured in new products rather than new science and citation). Others, like the Scandinavian countries or the UK, are stronger in science. All have relatively strong educational systems, from nursery to university. A system of innovation approach highlights the importance of the interaction of different actors as catalysts of innovation.

Systems of innovation approaches also allow analysis of different industrial and social sectors, since ICT differs dramatically from pharmaceuticals, for example, as does health from transport. Networks that stretch beyond traditional research centres to include industry, health, and education sectors are just one of the prerequisites necessary for enabling centres of excellence to meet development goals. NEPAD's vision of a networked system of centres of excellence is very much in this vein, as is the approach taken by IAVI and AERC. Networks can be seen as the tacit glue that holds projects, and potentially institutions, together:

> Even if single elements of such systems are strong, the system as a whole may be weak. The capability to learn and build new competencies will depend on how well the parts fit together and on the strength of these connections. (UNCTAD 1996, p.387)

The final principle is that systems of innovation must be encouraged and locally contextualized. Innovation is not something that only happens in high technology firms or in sophisticated research laboratories. New discoveries with economic and social significance are rare. More often what emerges are new combinations of existing scientific, technological, and organizational elements. Indeed, innovation need not even mean something that is totally new. It is better taken to mean something that is new to those who are innovating. Therefore, in the context of innovation by firms, Ernst et al. (1998, p. 12) write that innovation should be defined broadly as 'the process by which firms master and implement the design and

production of goods and services that are new to them, irrespective of whether or not they are new to their competitors'.

One limitation of the systems of innovation approach is that it tends to be quite abstract and skeletal, providing a conceptual approach to understanding how organizations and institutions involved in research, R&D, product development and marketing relate to each other. In particular cases, of course, the 'devil is in the detail' and much of the conceptual apparatus around systems of innovations approaches does not provide decision making clarity.

We suggest that one way of grounding the idea of a 'systemic' approach is by adopting some of the perspectives and insights developed in work on value chains and production networks. A value chain describes activities required to take a product from conception to consumer. It includes all of the product's stages of development. McCormick (2001, p106) outlines an important dimension of a value chain as its 'input-output structure'.

> At its simplest, we can think of a chain as having four main sections. A product is first designed, then raw materials are purchased and production takes place; the product if then distributed through wholesalers and retailers. At each stage, services such as transport or finance may be needed to keep the process going.

She goes to say that a value chain also has a less visible input-output structure.

> This is made up of the flow of knowledge and expertise necessary for the physical input-output structure to function. The flow of knowledge generally parallels the material flows, but its intensity may differ. For example, the knowledge inputs at a product's design stage may be much greater than the material inputs; production, on the other hand, needs large quantities of materials, but in many cases requires only standard or routine knowledge (McCormick, 2001:106).

Adopting a value chains perspective can help analysts and policymakers think about where to direct investment in science and technology and innovation in light of local and contextually appropriate production opportunities and limitations.

Finally, firms have been, in general, rather absent from S,T&I policy in Africa. With a few important exceptions (Kaplinsky, 1994, Oyelaran-Oyeyinka, 2004) firm-level innovation has not been seen as particularly important to link to S&T development in Africa. Future policies for ST&I will need to take better account of the fact that much innovation in East Asia is still of the imitiative variety and that more work such as that

of Hobday (2005) on the relationship between research systems and industrial systems is needed

8 Conclusion

There is, at present, a massive expansion of interest in, and plans for, improvement of ST&I in Africa. This paper has used evidence from recent examples of relatively successful S&T capacity development to assess the implications for future ST&I in Africa. What is known from half a century of intensive science and technology policy research is that the translation of research knowledge into economic and social benefit (getting science out of the laboratories) is extremely complex. One simple but often ignored lesson is the need to focus on innovation and the shaping of social and economic need, not on the 'push' of S&T alone.

Our basic argument is that, instead of seeing ST&I as held back by short sighted focus on immediate poverty alleviation measures, focus is required on what changes in ST&I are needed for the alleviation of poverty. One basic change is that ST&I be better organised in systemic ways so that poverty alleviation and ST&I initiatives are compatible. The factors that shape innovation, and its take up within what is both a social and economic value chain, will vary by sector and reflect distinct knowledge bases and networks, organizational structures, and institutional (including regulatory) contexts.

We examined capacity building initiatives that that built on what exists rather than undermining existing institutions. One essential lesson is to try and target ST&I capacity building initiatives in developing countries so as to contribute to local needs and targets and not agendas that are the outcome of geographical or otherwise remote institutional and organizational trajectories. Our research suggests one simple and essential requirement - the need to address the question: How can African expertise be brought to bear, from the earliest stages, on new research initiatives affecting Africa?

The lessons and recommendations from this paper generate other challenging questions for policymakers and those driving the transformations of the next years. The successful cases we have studied have other common attributes. Primarily, project support has been linked to overall research policy and research management capacity development, whether explicit or implicit. One lesson is to take more explicit account of this key factor for success, in big as well as more modest programmes. The policy question arising is: How can ST&I programmes be constructed with clearer regard to ST *&I* capacity building?

More specifically, but importantly, given the massive recent increase in resources for product development initiatives, we have examined global product development based initiatives which have led, again often implicitly, to the enhancement and rebuilding of local capabilities. The policy question arising is: How can product development partnerships be made to work for capacity building at the same time as rapid alleviation of need?

Transformations along these lines are required if science, technology and innovation initiatives such as those advocated by NEPAD and the Commission for Africa are going to make a major, profound contribution to Africa's development in the coming years.

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