Capacity development for agricultural biotechnology in developing countries: concepts, contexts, case studies and operational challenges of a systems perspective

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CAPACITY DEVELOPMENT FOR AGRICULTURAL BIOTECHNOLOGY IN DEVELOPING COUNTRIES: CONCEPTS, CONTEXTS, CASE STUDIES AND OPERATIONAL CHALLENGES OF A SYSTEMS PERSPECTIVE[1]

Andy Hall[*] and Jeroen Dijkman[#]

Abstract

There are divergent views on what capacity development might mean in relation to agricultural biotechnology. The core of this debate is whether this should involve the development of human capital and research infrastructure, or whether it should encompass a wider range of activities which also include developing the capacity to use knowledge productively. This paper uses the innovation systems concept to shed light on this discussion, arguing that it is *innovation capacity* rather than science and technology capacity that has to be developed. The context of deploying biotechnology in developing countries is illustrated with an over view of Uganda and Ethiopia. The then presents 6 examples of different capacity development approaches. It concludes by suggesting that policy needs to take a multidimensional approach to capacity development in line with an innovation systems perspective. But it also argues that policy needs to recognise the need to develop the capacity of diversity of innovation systems and that a key part of the capacity development task is to bring about the integration of these different systems at strategic points in time. The paper concludes with a tentative typology of the main types of agricultural innovation systems that are likely to be important in developing countries.

Key words: agriculture; Ethiopia; Uganda; innovation systems; biotechnology; capacity development; innovation capacity; policy

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1. INTRODUCTION

There is no doubt that if developing countries are to prosper they must build the capacity to take advantage of new technological paradigms such as biotechnology. However what is much less clear is what capacity development might actually mean in a contemporary sense. Building skills in frontier areas of science will of course be part of this process. However it is now becoming increasingly apparent that there is a generic problem with capacity development approaches that focus solely on competencies to produce knowledge – i.e. research. The failure to develop complementary competencies and structures to put that knowledge into use and the need to take account of how scientific resources integrate with the rest of the economy and respond to society as a whole is now a major concern in the science, technology and innovation debate (Hall, 2002, Chataway et al 2005).

In the case of agriculture much of this problem relates to historical patterns of capacity develop in science and technology and the concepts that informed good practice 40 – 50 years ago. At that time is thought desirable to create specialist agricultural research organisations that would produce scientifically validated technologies that farmers and others would subsequently use. Of course what is now realised is that while these "centres of excellence" are important, what is equally crucial is the way the work of these organisations integrates and interacts with other sources of knowledge in a sector or country.

The required process of integration goes much beyond the often rhetorical calls for scientists to work with farmers. Instead it involves the intricate web of interactions through which knowledge is shared and exchanged in different arenas – task, sector, state, and region. This is the process through which individuals and organisations learn and put into use new ways of working and new methods of production. It is this process that leads to innovation in a technological, institutional and organisational sense. In the past working practices, routines, norms, policies (referred to here as institutions) that governed the extent of interaction and learning where not thought to be connected to the question of the effective deployment of S&T resources. However contemporary thinking on the production and use of knowledge suggests that institutional factors are a central component of capacity (Edquist, 1997; Oyelaran-Oyeyinka 2005). To make the same point differently, the suggestion is that capacity is an embedded concept that can neither be understood, nor developed, without an understanding of contextual settings and particularly the institutional dimensions that these imply. A related observation is that since these contextual settings evolve over time, capacity and what it might entail is an ever-changing entity.

These sorts of perspective are emerging from a large body of literature dealing with the way countries and firms have developed and sustained the ability to innovate. Grounded in an evolutionary economics tradition (Nelson and Winter, 1982) and building on empirical observations at the national level (Freeman 1989, Lundvall 1991) and at the firm and sector level (Bell and Albu, 1999) these ideas have found coherence in the concept of an innovation system. (The transition to a new, more embedded mode of knowledge production put forward by Gibbons et al 199? makes a similar point). This concept is increasingly being used to tackle policy questions related to agriculture in developing countries (Hall et al 2001). The purpose of this paper is to use this perspective to explain what the nature of capacity and capacity development might be in this contemporary sense and its implications for biotechnology. The central message of the paper is that policy should recognise that capacity development in a contemporary sense is a multidimensional concept. It requires skills or competencies of both a scientific and non-scientific kind; it requires linkages between producers and users of knowledge; it requires the types of relationships and institutional setting conducive to knowledge sharing and interactive learning; and it requires a policy environment that is sensitive to the need to create the conditions needed to make productive use of knowledge rather than focusing solely on the creation of that knowledge. The paper illustrates this with some examples of the challenges developing countries face and a critique of recent capacity development approaches.

The rest of the paper begins by briefly reviewing the concept of capacity development in agricultural and then presents the innovation systems perspective on this. The remainder of the paper presents recent empirical cases from East Africa and India.

2. CAPACITY DEVELOPMENT IN AGRICULTURAL SCIENCE AND TECHNOLOGY: FROM RESEARCH CAPACITY TO INNOVATION CAPACITY

For the last 40 to 50 years agricultural science and technology has been viewed as a critical driver of technological and socio-economic transformation in the predominantly agrarian economies of most developing countries. Building national and regional capabilities to conduct agricultural research has been has been at the forefront of these efforts. This has included training scientists and the establishment of research infrastructure to create national public sector research programmes. It has also included providing operational funds to conduct research and technology development, often in collaboration with the international centres of the CGIAR.

Yet despite the fact that financial support for agricultural research has declined and the mechanisms for sustaining support have failed to materialise (Rakuni *et al*, 1998; Echier 1989) there are more serious concerns about the appropriateness of traditional agricultural research arrangements and the apparent inability of these to adapt to the changing agricultural scenario (Hall et al 2000; Byerlee and Alex 2002). In many senses the contemporary scenario is markedly different to earlier eras. The agenda has shifted from increasing crop (usually) food productivity, to explicit attempts to reduce poverty and protect the environment. The private sector has emerged as a much more important player in the sector – both in terms of research and product and service delivery. The role of the State has altered, often radically and new trends in governance – participation, decentralisation, consensus building, and intellectual property protection -- are impacting on many areas of research and development practice. Globalisation (of markets, of knowledge, of regulatory and trade regimes) has also had major implications for agricultural research. Defining features include the following:

- New technological paradigms -- biotech, ITC
- Increased private investment in R&D
- Increasing knowledge intensity of production and competition
- New modes of professional behaviour in development practice -- participation, professional self reflection, partnership
- New patterns of accountability to society (egg biotech public debate, but also more consensual processes generally)

- Changing patterns of ownership of knowledge and the technological and institutional changes that have supported this.
- Incremental learning about the nature of knowledge production and use.
- Changing views on the proper role of the state vs. private sector vs. civil society
- Changing views on the value of local knowledge, but also knowledge systems more generally – particularly in health sector.
- Opportunities and threats arising out of globalisation (for both knowledge and trade systems)
- Changes in rates of change and stability of economic systems

The emergence of biotechnology has been a typical example of recent trends whereby the broader framework conditions in which agricultural science and technology sit has been altered in fundamental ways. The critical features of biotechnology are discussed in length in the specialist literature, but these include:

- Technological paradigm shifts whereby whole new trajectories of technological possibilities exist.
- Institutional changes, including: a greater degree of proprietary ownership of knowledge and materials; and new patterns of partnership between scientific disciples and between public and private sectors.
- Science society controversies surrounding ethical, environmental and health risks and uncertainty particularly with regard to genetically modified organisms.

This raises important questions for biotechnology capacity development. Is it just a case of providing technical assistance to developing countries in the old sense -- i.e. mainly as a matter of training and the development of human resources. Or as some have argued, is it a case that capacity building has to address instrumental issues such as the development of procedures, management, organizational structures, or strategy formulation (Biotechnology and Development Monitor, 1999).

While there is an apparently inescapable logic to the view that capacity development in frontier technical field such as biotechnology should focus on training scientists, contemporary views on the production and use of knowledge suggest that this is only part of a larger task. There are increasingly calls for capacity development in Southern countries to be concerned with strengthening the systems that interface between research and society and which can promote learning and innovation (Hall 2002) and the important of institutional development in this process (Fukuda-Parr et al 2002). This contrasts with the earlier knowledge transfer perspective that left unquestioned the way new knowledge or new skills would fit into existing systems and agendas in national settings and how these settings would impinge on the effectiveness and outcome of these transfers. Underpinning this contemporary view is the growing appreciation that in agriculture and economic development innovation is the central ingredient to transformation and that innovation concerns both the production of knowledge and putting that knowledge into use.

This suggests that in areas like agricultural biotechnology it is not science and technology research capacity that is required alone, but instead a more broadly conceived notion of *innovation capacity*. To understand what this concept might mean it is useful to revisit the concept of an innovation system and explore what its implication is for building the capacity to innovate.

3. INNOVATION SYSTEMS

The origins of the innovation systems concept lie in the concept of a national innovation system (Freeman, 1987; Lundvall, 1992). This concept emerged because conventional economic models had limited power to explain innovation, which was viewed conventionally as a linear process driven by research. The innovation systems framework sees innovation in a more - systemic, interactive and evolutionary way, whereby networks of organizations, together with the institutions and policies that affect their innovative behavior and performance, bring new products and processes into economic and social use (Freeman, 1987; Lundvall, 1991, Edquist, 1997 and many others). The framework is now being used to understand and strengthen innovation at national, regional, and sectoral levels (OECD, 1997; Mytelka, 2000), including agriculture (Hall et al., 2001).

The concept provides a number of key policy and analytical insight that have relevance to the nature of capacity development.

3.1 Focus on innovation

In contrast to most economic frameworks, which focus on production (output), the framework focuses on innovation processes. Innovation is often confused with research and measured in terms of scientific or technical outputs. However, the innovation systems framework stresses that innovation is neither research nor science and technology, but rather the application of knowledge (of all types) to achieve desired social and/or economic outcomes. This knowledge may be acquired through learning, research or experience, but until applied it cannot be considered innovation. These processes of learning and acquiring knowledge are interactive, often requiring extensive links among different sources of knowledge. The implication is that capacity development needs to focus not just on enhancing the ability to produce knowledge, but also the ability to put it into productive use.

3.2 The role of institutions

Institutional settings play a central role in shaping the processes critical to innovation: interacting, learning, and sharing knowledge. Again, the meaning of institutions is often misunderstood. The innovation systems framework distinguishes institutions from organizations. Organizations are bodies such as enterprises, research institutes, farmer cooperatives, and government or non-government organizations (NGOs), whilst institutions are the sets of common habits, routines, practices, rules or laws that regulate the relationships and interactions between individuals and groups (Edquist, 1997). Because institutions shape innovation, institutional change is a large element of capacity development.

3.3 The role of policies

Policies are also important in determining how people behave. However, an environment that supports or encourages innovation is not the outcome of a single policy but rather of a set of policies that work together to shape innovative behavior. Furthermore, habits and practices interact with polices: so to design effective policies it is necessary to take into account the habits and practices of the people affected (Mytelka, 2000). For example, the introduction of more participatory approaches to research is often ineffective unless the habits and practices of scientists are also changed. Capacity development therefore needs to both the clusters of policies need to support innovation, but also the interaction of these with institutions also needs to be considered. This hints at the embedded context specific nature of capacity.

3.4 Stakeholder involvement and demands

The framework stresses the importance of including stakeholders and of making organizations and policies sensitive to their agendas and demands. Demand shapes the focus and direction of innovation. It is articulated not simply by the market but also by non-market drivers, such as collaborative relationships between the users and producers of knowledge. Demand for certain sorts of innovation can also be stimulated by policy, for instance by providing incentives to adopt a certain technology or management practice. This can be especially important where key stakeholders are poor and have limited social and economic power or where the negative environmental impact of development needs to be addressed. Skills and institutional setting needed to create stakeholder involvement are thus part of capacity.

3.5 The dynamic nature of innovation systems

The habits and practices that are critical to innovation are learnt behaviors that may change either gradually or suddenly. They are often enshrined in institutional innovations, such as farmer field schools or participatory plant breeding that emerge through scientists' experimentation and learning. These new approaches to research and development often require not only new ways of working but also new partners. Thus capacities develop in incremental ways through learning. But a key element of capacity is the ability to reconfigure approaches and patterns of partnership to deal with changing circumstances.

3.6 Changing to cope with change

One of the characteristics of successful innovation systems is that their component organizations tend to create new partnerships and alliances in the face of external shocks. Examples of such shocks might be: a new pest problem, requiring collaboration between a different set of scientific disciplines; the advent of a new technology, such as GM crop varieties, requiring the formation of partnerships between the public and private sectors; or changing trade rules and competitive pressure in international markets, leading to a need for new relationships between local companies and research organizations. It is not possible to determine the kinds of networks, links and partnerships that will be needed in the future, as the nature of future shocks is by definition unknown. The way to deal with this is to develop capacity that creates the flexibility in working habits and institutions that allows dynamic and rapid responses to changing circumstances.

This as yet no accepted definition of the term *innovation capacity*, but it captures the creative and non-linear events that sustain the change process. In a similar vein, more than a decade ago Bell and Pavitt, (1993) used the narrower term *technological capacity*. They contrasted research capacity and technological capacity stating that the former concerns the resources needed to conduct scientific research. In contrast technological capacity concerns the resources needed to manage technical change including skills, knowledge and experience (scientific, but also entrepreneurial), institutional structures and linkages or networks connecting science, consumers, entrepreneurs, intermediary organisations and policy bodies.

The innovation capacity concept recognises these same broad set of skills, links and structures, but in relation to the total process of producing accessing, diffusing and, most importantly, putting into use knowledge in socio-economically useful ways. It stresses that institutional settings (including the policy environment) are a critical part of this capacity and that capacity development is often an issue of institutional and policy change. Innovation capacity is thus an embedded capacity that can not be understood or development without considering its contextual setting. Furthermore innovation capacity is a dynamic capacity not just concerned with systems, linkages and institutions as they exist today, but also about the ability to reconfigure these arrangements in response to changing demands and circumstances. As Clark 1995 points out, the need is to understand capacity in terms of holistic evolutionary systems of learning and change, where future states were unknown and unknowable. The differences between research capacity, technological capacity and innovation capacity are summarised in Table 1.

The nature of biotechnology is such that its utilisation is embedded large range of institutional and other factors which are themselves evolving rapidly. The innovation capacity perspective therefore seems to have much to offer.

Table 1. *Contrasting concepts of capacity*

	Research capacity	**Technological capacity**	**Innovation capacity**
Nature of capacity	• Resources needed to conduct scientific research	• Resources needed to manage technical change	• Resources needed to continuously innovate in dynamic environments
Main actors	• Research scientists and mangers	• Potentially all scientific, entrepreneurial, policy and training actors related to technical change.	• Potentially all scientific, entrepreneurial, policy and training actors related to innovation.
Defining processes	• Knowledge creation	• Knowledge search and acquisition.	• Knowledge creation acquisition and use.
Key variables	• Number of scientists, research infrastructure and research expenditure	• Scientific, managerial and scientific skills and experience. • Patterns of linkage between actors	• Diversity of sources of knowledge in a network. • Pattern of interactions in networks. • Extent to which institutional settings promote interaction and learning.
Nature of arrangements / structures	• Static	• Static	• Dynamic
Modes of capacity strengthening	• Training, research and infrastructure investments.	• Training, research and infrastructure investments. • Networking and cluster development	• Training, research and infrastructure investments. • Networking and cluster development • Development of enabling environment • Institutional change

4. SETTING THE SCENE FOR CAPACITY DEVELOPMENT: THE CONTEMPORARY CONTEXT OF AGRICULTURAL BIOTECHNOLOGY

4.1 The case of agricultural research systems in Uganda[2]

Using Uganda as an illustrative case this section explores some of the contemporary challenges that agricultural research systems need to tackle in order to make effective use of modern science and technology. The case illustrates that capacity to exploit biotechnology goes beyond scientific competence and requires other forms of skills, new types of relationship including with non-scientific actors, supportive regulatory frameworks as well as a policy process that can tackle capacity development in this more holistic and embedded sense.

Like many countries Uganda's expertise in the area of biotechnology began with tissue culture in the early 1990's. This involved 3 major crops: Sweet potato, a food crop important for poor households; Banana, an important staple food crop widely traded in the domestic market; and coffee, Uganda's main export crop. In the case of the first two crops efforts have focused on the development of disease free planting material and the in the case of coffee the clonal planting material of improved cultivars. Work on banana is now proceeding towards genetic transformation techniques (for female sterility). Much of this work has been supported by donors, often through the centres of Consultative Group on International Agricultural Research.

Technologically much of this work has been successful, but has encountered problems in relating to wider systems that could make effective use of the technologies. The clonal coffee programme was originally set up under EU funding in 1991. Scientists were training in the UK. A laboratory was built at Kwanda Research Station near Kampala but the cloning protocols did not work for the Uganda material and new techniques had to be devised. Material was eventually produced and distributed through various public networks. However plans for the commercialisation of the clonal coffee production facility failed to take place.

In a related development, a link with a German coffee company began promisingly but later fell apart. Initially the company was just buying coffee, but then went into its own production and approached Kwanda for clones. The company's technicians were trained in the production of clones. However the company wanted to take (clonal) material out of the country for evaluation. Under regulations in place at the time this could not be allowed. However, the company felt compelled to do this and smuggled out material. This led to a break down in the relationship between the company and its public research counterpart in Uganda.

The banana programme at Kwanda Research Station faced similar problems. It has difficulties in producing the amount of material that is potentially required in the country (as it is obviously a research facility not a production unit). However, even through a private tissue culture organisation exists, a workable form of collaboration has yet to be found.

A recently established biotechnology facility at Kwanda will continue to build technical capability in the area of biotechnology. It will focus on four areas: diagnostics; marker assisted selection and genetic modification. At the time of writing a draft policy on bio-safety was waiting to be approved. However it was anticipated that this would be cleared and that this would open the way to the use of GMOs. There has been concern voiced by consumer groups about GMOs in Uganda, but there has not been an extensive process public debate on these issues. Currently GMO material can not be brought into the country even for testing. Uganda certainly has the technical capabilities for transformation work, but currently not the legal framework

These points illustrate the way countries like Uganda are moving into an era where the use and application of agricultural science is having to deal with wider issues than biology alone. In this case the need (and difficulty) of building relationships with the private sector, but also the need to engage constructively with the issue of public perceptions of safety if indeed GMOs become a major strategy in Uganda. Part of the challenge in the case of Uganda concerns the way scientists are trained. Scientists at the programmes at Kwanda Agricultural Research Organisation had been trained in straight biotechnology. Clearly frontier scientific skills and disciplinary excellence are important, but the evidence suggests that complementary skills to help scientist related to other agencies and the wider context of their work i.e. skills relating to building partnerships, IPR, participation.

A further issue concerns the wider environment in which scientists are operating as this also needs to be considered in a more holistic way. Take for example the challenge facing the Ugandan National Council of Science and Technology. NCST staff have a clear understanding that innovation needs the support of a number of policies across different ministries and departments. However NCST recognises that existing bureaucracies create difficulties for this integration. So for example the national plan for the modernisation (PMA), suggests dealing agriculture in a more holistic sense. However as it falls under the Ministry of Agriculture support is mainly to National Agricultural Research Organisation and National Agricultural Advisory and Development Service and not to health and transport infrastructure that would be needed to build the agricultural sector in a more general sense. S&T is viewed as one component of the each sectoral responsibility rather than a cross cutting issue where there is both technical convergence across different sectors and where there could be a complementarity

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[2] Based on author interviews August 2004

between different policy instruments under different ministerial mandates to provides the incentives and capabilities to promote innovation.

One could argue that it is bureaucratic arrangements which prevent a more holistic treatment of science, technology and innovation. However the problem is really at a more fundamental level because with the exception of those in the NCST there is limited understanding of the need to deal with STIP in a more holistic way. To address this, policy actors at both operational and strategic levels need to be equipped with practical analytical tools that will allow then to understand their sectoral responsibilities in a wider context. This does not mean that ministerial or sectoral distinctions should be removed. Rather that policy actors should have the analytical tools to recognise the scope of policy instruments needed to make the most of science, technology and innovation in achieving the policy goals in different sectors. Such perspectives would feed through into bureaucratic and other institutional changes in the policy making process in the long term.

The point of the Uganda story is not to pick holes in the way its has gone about building agricultural biotechnology capacity. As a Wafula and Clark (2005) point out, Uganda has actually got much to be congratulated on. The purpose here is merely to illustrate that innovation capacity is multifaceted. It involves scientific skills and facilities; it involves relationships with new partners such as the private sector – a major challenge in this case; it involves the nature of the institutional set up of government bureaucracies and the support structures they give rise; and relatedly it concerns the policy frameworks in use and the skills that key policy actors have to tackle the promotion of innovation as a systemic phenomena.

4.2 The case of agricultural research systems in Ethiopia

Agriculture science and technology have a particularly important role in Ethiopia due to five reasons. Firstly the unique nature of major crops found in the country, e.g. teff, cultivated nowhere else. Secondly, Ethiopia high degree of biodiversity is the centre of origin for major commodities of economic importance, notably coffee and barely; And thirdly the economic value of germplasm in a general sense due to property right protection. But also the specific interest of developing countries in accessing traits and commodities to address lifestyle concerns of the Western World, teff for gluten free diets and decaffeinated coffee. Accompanying these interests are the much greater involvement of private sector companies. Fourthly the continuing need to improve crop and livestock production in ways that ensure both food and livelihood security and the realisation that poverty reduction in inextricably linked to upgrading of the agricultural sector. And fifthly the opportunities presented by the temperate nature of the

Ethiopian climate for export crops including vegetables fruits and cut flowers. This last area of export development has been given considerable emphasis by the government.

The post-Mengistu government decentralised the research systems to each region of the country. There are currently 13 federal research centres coordinated by Ethiopian Agricultural Research Organisation (EARO). In addition there are 5 regional research Institutes. EARO organised into 5 directorates Crops, livestock, Natural Resource management, dryland and forestry. Major support for the development of EARO has come from the World Bank as well as assistance channelled through NEPAD. Notably the World Bank the Agricultural Research Training Programme between 1997 and 2005. This programme trained large numbers of scientists in classic agricultural science disciplines by sending them to India and Thailand for short course and masters and PhD degrees. It is worth noting that training had to take place in other developing countries because in cases where students are sent to UK or USA, 80% do not return.

Contrasting to this pattern of capacity development the director of EARO related a number of challenges that clearly were pushing the boundaries of what traditionally trained agricultural scientists were prepared to deal with. Three interesting examples were as follows.

The arguments over the ownership of decaffeinated coffee germplasm which the Brazilians were trying to claim, but which were a naturally occurring part of Ethiopian biodiversity. IPR were unclear and the EARO scientists were unprepared for dealing with this. Furthermore the Ethiopian expert on these issues was located in another organisation, the Ethiopian Environmental Protection Agency.

The government position towards GMOs was relatively moderate and open mainly because the major GMOs on the international market were not native species to Ethiopia so chances of inserted genes spreading to wild relatives was perceived to be quite low. Public perceptions of GMOs were thought to be generally positive, but was not clear the extent to which a public debate about this topic had been conducted. EARO suggestion that it wanted to demonstrate the advantages of using GMOs suggests that this was seen as a technical issue.

The negotiation of an agreement with a Dutch company for the supply of teff of a specific variety for the production of gluten free bread in Europe. This case was particularly interesting as the agreement gave the company exclusive rights to buy this specific variety (developed by EARO) form farmers. For this concession the company had to pay the government of Ethiopia 10 Euros per hectare.

All of these illustration are typical of the way the utilisation of agricultural science is becomes embedded in a range of new relationships and policy and institutional contexts. While IPR and underpinning biological skills for the development of regimes and biosafety protocols are almost certainly available with in Ethiopia, understanding these in the boarder sense understood in contemporary science technology and innovation policy sense are not so apparent.

The interesting part of these illustrations is that EARO is starting to recognise that it needs to engage directly a series of activities that go beyond the normal remit of a classic agricultural research organisation. For example it is working with commercial organisations to sensitise them to the suitability of locally bred durum wheat for food processing thus creating a market for the products of wheat EARO breeding programme. Scientist indicated that if they did not undertake this technology promotion activity, there was no other effective agency to do it and as a result their research would be wasted. But paradoxically this perspective has not reached the agenda for staff training and instead seems to be the pragmatic response of some scientist to systems failure in the institutional setting in which the work.

5. EXAMPLES OF DIFFERENT FORMS OF CAPACITY DEVELOPMENT

Given the complexity of the capacity development task and recognising that there are divergent views about how it should be achieved, it is hardly surprising that it has been tackled in different ways by different agencies and different countries. The following examples illustrate some of these different approaches. Not all of these examples have been designed specifically with capacity development in mind, although many have. Similarly not all of these examples have had the outcomes that where intended. All these cases, however, have been included to illustrate what on the one hand innovation capacity might mean in operational terms and on the other the short comings of some existing interventions. (Table 3 at the end of this section summarises the key elements of these different capacity development approaches.)

5. 1. Building capacities in basic sciences: The Millennium Science Initiative in Uganda

The Millennium Science Initiative (MSI) is a joint project of the Ugandan Ministry of Finance Planning and Economic Development and the World Bank. The project, which is yet to enter full implementation, is based on diagnosis of the state of science and technology in Uganda which highlights.

- A sociological bias against science which is viewed as "useless and irrelevant"
- Poor science education at primary and secondary levels.
- Low investments in science disciplines in both public and private universities.
- Static or obsolete university science curricula
- Few career opportunities for scientists in Uganda
- Low critical mass of entrepreneurs able to turn science talent into business ventures

Despite the absence of a strong and coherent policy to develop S&T capability, Uganda has managed to create pockets of high quality S&T often with funding made available through donors. Agricultural science has been a good example of this. Recent developments at the main public university referred to as the Innovations at Makerere programme have made strenuous efforts to re-establish the relevance of academic work as a key quality criteria. The MSI is an attempt to build on these advances, recognising the need for capabilities in both basic and applied, responsive research.

The proposed project has two main components:

Component One (85% of project cost). The core of the project is a competitive grant fund (the "MSI Fund"). The MSI Fund would have three "windows" to support (i) advance research connected to graduate training. This is aimed at the top research groups in the country in the hope of giving theme the ability to work at similar levels to richer countries of the OECD; (ii) strengthening or creation of undergraduate degree programs in S&T disciplines; (iii) research activities defined by the private sector.

Component Two (15% of project cost). This component will support involvement of the science and technology community in policymaking and related activities. A main set of activities would involve "social marketing" of science by high profile researchers to primary and secondary school students. The goal would be to catalyze greater attention to and action for improvements in primary and secondary level science education (curriculum reform, strengthen teacher qualifications). The social marketing of science would seek to overcome the anti-science biases that have developed in the education system after years of neglect and underinvestment.

In a sense the MSI is a combination of old ways of developing scientific capacity (i.e. providing funds for research to be carried out) and contemporary thinking about the need to integrate this capacity into the rest of the economy and society. The initiative clearly recognises the needs to build an acceptance of science and a scientific orientation through its focus on primary and secondary education curricula. It also recognises that resources need to be spent to increase interaction with the private sector.

However what is telling about the initiative is that focus is still pre-dominantly on developing capacity of the science and technology system and not the wider innovation system. So for example the issue of integration with the private sector us given relatively minor attention and is discussed in terms of "……..very small initial grants would be given to industry associations/ entrepreneurs to create problem-focused research agendas in collaboration with researchers. Follow-on money would be available for researchers to pursue solutions to these problems that would be directly applicable to the needs of industry." The development of relevant policy capabilities seems to be absent form the project.

5.2. Creating and strengthening regulatory frameworks

USAID has a supported a series of programmes to assit countries in Africa to develop biosafety arrangements. These programme include the African Biosafety Programme I managed by Michigan State University and ABSP II managed by the Cornell University Programme for Biosafety. More recently USAID has launched a global programme on biosafety -- the *Program for Biosafety Systems (PBS*). This programme is managed by the International Food Policy Research Institute. PBS focuses on the development of regulation protocols for biotechnology-related activities through stakeholder consultations, technical training in environmental and food risk assessment, communication and outreach, as well as providing grants for research into environmental risk issues. In 2003 and 2004, PBS focused on enabling the authorization and safe conduct of confined field trials of genetically modified organisms in a number of countries.

This type of approach is clearly important in developing capacity in developing countries in risk assessment and risk management. It is an important element of innovation capacity helping create the necessary institutional framework needed for the deployment of biotechnology. However it is less clear how these efforts relate to creating relevant policy capacity as many of these programmes seem to focus on protocols rather than policy per se. Also unclear is the way these programmes link with the policy process and this will certainly be required if bio-safety is to becomes an integrated part of science and technology and innovation policy.

A more broad based approach has been *East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN).* BIO-EARN was launched in 1999 with support from the Swedish International Development Cooperation Agency (SIDA) and the Biotechnology Advisory Centre of the Stockholm Environment Institute. It aims to build capacity in biotechnology research and policy in Ethiopia, Kenya, Tanzania and Uganda. BIO-EARN has three programme areas: 1.) Biotechnology 2.) Biosafety 3.) Biotechnology Policy Development BIO-EARN capacity building activities target scientists, regulators, the private sector, special interest groups and policy-makers and include training through short courses and workshops, for instance, in:

- Biosafety (biosafety assessment and risk management, field evaluation of transgenic crops, case studies of industrialised country experiences)
- Policy (biotechnology policy formulation, analysis and implementation, intellectual property rights, technology transfer, technology assessment, public-private partnerships)

BIO-EARN also aims to facilitate greater dialogue amongst these actors through its training activities. Examples of courses that BIO-EARN has been involved in include “Biotechnology and Public Policy” and “Building National Biotechnology Innovation Systems: New Forms of Institutional Arrangements and Financial Mechanisms”. This focus of policy capacity development is an important feature of this programme.

5.3 Networked centres of excellence

In 2000 John Mugabe the then director of the African Centre for Technology Studies prepared a strategic document for the United Nations Conference on Trade and Development (UNCTAD) outlining capacity development consideration relation to biotechnology in developing countries (Mugabe 2000). He argued that on the one hand the capacity to search, assess, acquire or develop and utilize new technologies and new knowledge for science and technology policy making is one of the most important prerequisites for sustainable development. But that on the other hand international science and technology organisations under the UN and the Consultative Group on International Agricultural Research (CGIAR) had neither satisfactorily addressed the needs of developed countries nor build adequate linkages with research organisations and research within these countries. The remedy for this it was suggested was to create networked centres of excellence, replacing the trend towards concentration of resources in single locations. Instead the idea would be to build the capacity of a number of centres that would collectively constitute a centre of excellence. These could then be linked to regional and international public research institutes. The logic behind this was that by creating capacity in locally based units of the network, opportunities for local involvement in agenda setting, for local outreach activities and for a stronger scientific base for policy are created (Mytelka 2001).

This vision of networked centres of excellence is being operationalised through the establishment of Bioscience for Eastern and Central Africa (BECA). The concept was developed in 2002, through collaboration between the New Partnerships for African Development (NEPAD) and the International Livestock Research Institute (ILRI), and the Doyle Foundation, who facilitated consultations within Africa and with potential partners internationally. The concept identified capacity building as a key component in any biosciences initiatives in Africa. The focus is on biosciences as they relate to health and agriculture with the recognition that research focus at the gene level has allowed much scientific convergence between the two sectors, including the following areas.

- Marker assisted selection as an aid to breeding programs

- Genomics as an aid to gene discovery
- Plant transformation
- Molecular diagnostics
- Bioinformatics

There are three key elements in operationalising the initiative. The first is the creation of scientific infrastructure hosted at the ILRI Nairobi. This has involved updating laboratory facilities, mainly in the ILRI Nairobi campus with the financial support of the International Development Research Centre (IDRC) of Canada.. The second is mobilisation of further operational funds to ensure that African scientists have access to research funds on a competitive basis. The third element is the establishment of a governance/partnership structure. This is particularly critical for a shared and networked facility. For the facility to operate effectively it needs to partner with key scientific and developmental stakeholder in the region. It is important that different stakeholder groups are involved in priority setting and foresight exercises. There are also issues about the ownership of facilities and how recurrent costs will be paid. In addition there is a need to address the integration of the initiative into other capacity development initiatives in the bioscience in the region needs to be addressed. And perhaps most fundamentally of all, the question remains as to how the scientific agenda and outputs can be linked to those who are going to need to use these technologies particular poor rural communities. Only if the latter can be successfully resolved will the initiative be able to succeed where so many others have failed to fulfil the promised of science delivering equitable and sustainable development in Africa.

The initiative is at an early stage of development and it is probably fair to say that the governance/ partnership element of the initiative is proving by far the most difficult to operationalise. But this is an important part of the process of capacity development as it will create skills and lessons on how to establish and operationalise this type of networked biosciences facility in the context of Sub Saharan Africa. As Carlos Sere, the Director of ILRI pointed out, lessons from the establishment of the BECA facility will provide lessons about how capacities can be created to use science more effectively in the development process. This will not only provide lessons for how to establish biosciences centres of this type in other regions of Africa. But it will also provide lessons on how capacities can be built to exploit the technological paradigms that succeeds biotechnology, for example nano-technology (personal communication 2004)

5.4 Partnerships

Two forms of partnerships are widely discussed in relation to capacity development in biotechnology. The first is North-South partnerships and the second is public private sector partnerships. In both cases the logic is that partnerships give developing country research organisations access to materials and advanced techniques that these organisations can then master. Even if developed county research organisations can not master new techniques because of, for example, infrastructure reasons tit can take advantage of its networked capacity which would include that of its new partner. Another additional benefit arising out of these partnerships is that it exposes research organisations to new ways of working particularly when working with organisations with contrasting cultures such as private firms. Organisation like the International Service for the Acquisition of Agri Biotechnology Applications (ISAAA) have played an important role in brokering partnerships between developing country research organisation and both public and private organisation from Europe and North America. (Verástegui, J. 1999, and Velho 2004 provide useful summaries of examples in Latin America and East Africa respectively)

Table 2. *Examples of capacity development biotechnology partnerships*

Focus	**Private sector partner(s)**	**Public sector partner(s)**	**Observations**
Bt maize (insect resistance	Pioneer Hi-Bred (USA)	Agricultural genetic engineering Institute (AGERI), Egypt	Training for AGERI scientist. Gave pioneer access to evaluate Bt proteins and genes patented by AGERI). IPRs provide for market segmentation
Papaya ring spot virus	Monsanto (USA) Zenica plant science (now part of Syngeta)	Research organizations in South East Asia Universities in USA and UK	Network of public and private partners. Arrangement brokered by ISAAA. License is free for production for local domestic markets.
Golden rice (vitamin a enhanced)	Many including Greenovation, Zeneca (now part of Syngenta)		Involved 70 patents belonging to 32 companies and universities and difficult IPR negotiations Board established to help deliver to developing countries
Virus resistant sweet potato	Monsanto (USA)	USAID's ABSP Kenyan Agricultural Research Organization and Vegetable and Ornamental Plants Institute (South Africa)	Brokered by ISAAA. IPR allow unrestricted use in Africa. Yet to be commercialized and concerns exists about weak links to local private sector, NGO's and farmers.
Apomixis	Pioneer Hi-bred (USA) Syngenta (Switzerland) Limagrain (France)	CIMMYT L'Institut de Recherche pour le Development (France)	
Insect resistant maize for Africa	Novartis (Switzerland))	Syngenta foundation (Switzerland) Kenyan agricultural research institute, CIMMYT	Use limited to Africa

In general the partnership approaches have often been quite successful in developing clusters of organisations capable of developing new technology – examples are presented in table 2. However as Velho (2004) points out a generic weakness, particularly for North-South partnerships is the failure of the Southern research organisation build local partnerships and networks with firms, NGO's and other stakeholders. Without these the uptake of new technologies becomes difficult and identification of priorities becomes skewed.

Perhaps the most graphic example of this is the much cited case of the partnership between the Kenyan Agricultural Research Institute and Monsanto in the development of virus resistant sweet potato (see Ikiara 2004). This was a very effective scientific collaboration. Monsanto had the virus resistant gene and trained Kenyan scientists in genetic transformation techniques. The gene was then transferred into Kenyan sweet potato germplasm. However this virus free material is facing the same struggle of getting out to farmers fields as any new technology coming from the Kenyan public agricultural research system. That is to say that commercialisation and dissemination has been weak. Without down stream partners the capacity to bring about innovation in farmers fields is compromised. More worrying in this case is that the lack of connection with farm reality may have been responsible for selection of a gene conferring resistance to the wrong virus -- it appears that the gene does not give protection against the commonly occurring sweet potato virus in Kenya.

This is clear a case of an intervention that has helped develop important technological capacities, but has not fully addressed the need to strengthen the capacity of the innovation system as a whole. Ikiara (2004) argues that this wider systems failure in Kenya includes a lack of a bio-safety framework, lack of effective intellectual property rights regime; lack of trust between public and private sectors; poor political and economic governance; lack of coordination between the national agricultural research organisation, donor agendas, farmers and national and international research collaborators

5.5 Building policy capacity in innovation systems perspectives

Despite the growing recognition of the importance in development of biotechnology and science and technology more generally in the development process, efforts to build science technology and innovation policy (STIP) skills have been extremely limited. A recent review (Clark 2005) of the demand for STIP training in relation specifically to agricultural biotechnology in Africa highlighted not only the clear need for policy skills with an innovation systems perspective, but also the almost complete absence of organisations providing this training in the region. Exceptions include the African Technology Policy Network (ATPS) which has been active in promoting these policy perspectives. Similarly The African Centre for Technology Studies (ACTS) in Nairobi pioneered a capacity development programme for policy actors using a systems perspective (for details see Clark and Mugabe, 2004). ACTS has recently renewed its efforts in policy capacity development, piloting a new course in 2005.

In the international arena CTA[3] of the Netherlands and the United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology (UNU-MERIT) have been running a regular annual training programme on Agricultural Systems of Science and Technology Innovation (ASTI) for researchers and policy-makers since 2003/2004. The purpose of this programme is to provide policy makers practical tools to analyse and plan with in a framework of a system of innovation. In a related development UNU/MERIT has proposed the establishment East African and South Asia Regional Hubs in partnership with the International Livestock Research Institute.[4] These hubs will act as focal points to link policy research relating to innovation in agriculture and rural development with researchers and policy actors. Underpinning this is the desire to contribute to building the capacity of policy-makers to tackle issues such as the deployment of biotechnology in a more holistic, systems of innovation sense. The International Food Policy Research Institute is also pursuing capacity development activities in this area of policy.

Although these efforts at building policy capacity are rather thin on the ground there does seem to be a growing recognition that building better integrated capacities to deploy technical advances such as biotechnology will require policy capacities that embrace these perspectives (Clark 2005). This is important because it is these policy perspectives that will create the enabling environment to allow innovation take place. The donor community should note that policy capacity of this sort is part and parcel of innovation capacity and therefore must be an integral part of capacity development approaches that seek to exploit science and technology.

[3] The full form of CTA is The ACP-EU Technical Centre for Agricultural and Rural Cooperation

[4] Beginning in April 2004 UNU-MERIT began a programme of work addressing the question of the nature of agricultural innovation system capacity and how, within the framework of sustainable and equitable development this capacity can be developed to cope with changing technological, institutional, policy and social contexts.

5.6 Pro-poor biotechnology capacity development through institutional innovation

The Andhra Pradesh Netherlands Biotechnology programme is a donor assisted programme in India designed to develop biotechnology capacity[5]. Unlike many programmes it recognised that this task was as much about institutional change as it was frontier skills. This perspective was particularly relevant in the case of India because the country already had well trained scientists and scientific infrastructure. The programme therefore viewed the capacity development task not as one of creating disciplinary excellence in science, but as one requiring the integration of conventional laboratory-centric research arrangements with farm-centric activities and process. This required both alliances between the scientific and NGO communities as well as a process of learning to work in new ways.

In essence the programme which had two 5 year operational phases was a series of collaborative research and development projects related to initially traditional biotechnology (tissue culture, microbial inoculants and bio-control of pest) and latter advanced biotechnology (including genetic transformation, for example Bt castor). While at one level the core of the programme was the provision of research funding to help build biotechnology capacity, the project was organised in such a way that it was tackling a much bigger set of issues than research funding alone. Important features were as follows:

- The programme made a conscious decision to focus on using biotechnology to create solutions to real problems faced by poor farmers in the rain fed areas of Andhra Pradesh. This was embodied in an approach called an integrated bottom up approach (IBU). The IBU involved undertaking detailed needs assessment exercises with farmers to set overall guiding priorities for the programme. Later on the IBU meant that farmers were active participant in research and development projects.
- NGO's rather than research organisations were chosen to under take the needs assessment work because of their greater familiarity with rural communities. As part of the IBU, the NGO then became partners with research organisations in the projects that the programme sponsored.
- Right from the start the Dutch donor gave control of the programme to an Indian steering committee and programme office. This was critical because it was recognised that as a

[5] See Clark et al 2002 for comprehensive review of this programme.

capacity development programme it needed local ownership and needed to be shaped by locally appropriate ways of doing things.

- The programme office was hosted by part of a public university, but one which was totally unrelated to biotechnology. The logic behind this was that since the programme recognised that a large element of the capacity development was changing the culture of scientific research (making more client focused, learning to work with NGO's), it need to have the autonomy to provide the institutional space for scientists to experiment in different ways of working. This would have been much more difficult if it had been a classic research programme house in an agricultural research organisation.

This last point is critical as a defining feature of this programme was its attempt to put in place a process which would allow scientists and developmentalists to create and experience the institutional innovations necessary to allow biotechnology to be brought to bear on the problems of poor farmers. By definition this process has to be a very contextually specific and so the approach of allowing this capacity development programme to be locally owned and embed in local systems was very important.

It would be wrong to portray the APNBP as an un-reserved success. There are, however, two points about the nature of capacity that this case highlights. The first as already mentioned is the idea of institutional innovations as part of capacity development. To be specific, in this case what this meant was that it started to become both acceptable and desirable for scientific research organisations to work interactively with NGO's and farmers. This clit about through a long process of collaborative projects in which it became apparent to scientists that they had much to gain from working in these ways. This was particularly in terms of seeing the uptake and use of their research findings. In India where strong hierarchies tend to separate scientists from farmers, this is a significant institutional innovation.

The second point that emerges from this case is the way that social capital emerges as an important element of capacity. In this regard social capital refers to the ability to form relationships of trust, cooperation and common purpose. One of the outcomes of this programme is that social capital has been built up between the scientific and the NGO community. This does not mean that permanent linkages have been formed. But rather it is the case that once having worked together a relationship exists which can be used as the foundation in the future should the need to collaborate arise. This type of capital not only increases the likelihood of linkages forming, but it also increases the rate at with new patterns of linkage can be established in response to changing challenges and opportunities.

Table 3 *Key features of different capacity development approaches*

	Investments in scientific capability	**Investments in research**	**Investments in non-scientific skills**	**Creation of an enabling environment for the creation and application of knowledge**	**Development of linkages**	**Strengthening the policy process**	**Strengthening stakeholding of the poor**	**Institutional change/ learning new ways of working**
1. Strengthening basic sciences: The Millennium Science Initiative in Uganda	Graduate training, and development of new under - graduate course in science	Fund for advanced			Limited attempt to involve private sector			Social marketing of research to dispel anti science bias in society and in policy making
2. Creating and strengthening regulatory frameworks		Funds for research into environmental risk. And biotechnology policy	Risk assessment and risk management. IPR Science, technology and innovation policy.	Protocols for field trials of GMOs. IPR		Better science, technology and innovation policy skills		Public debates on the use of biotechnology
3. Networked centres of excellence	Decentralised scientific expertise and infrastructure	Competitive research funds.						Decentralised research facilities with arrangements designed to respond to local networks of stakeholders

Table 3 (Cont.) Key features of different capacity development approaches.

4. Partnerships					Strong focus on linking research expertise together. Insufficient emphasis on linking research to local and regional enterprises				Starting to develop a tradition of public private sector collaboration
5. Building Policy capacity			Science and technology and innovation policy.	Underpins creation of more effective enabling environment.		Proposals to link policy research more closely with policy actors.			Better integration of science and policy making
6 Pro-poor biotechnology capacity		Research projects as a mechanisms to experiment with partnership and different ways of working			Strong focus on linking research organisations with NGOs			Introduced specific measures to strengthen the participation of the poor in priority setting and implementation.	Introduced partnership and integrated bottom up approach as institutional innovations to more effectively deploy biotechnology in pro-poor ways

6. TOWARDS AN UNDERSTANDING OF INNOVATION CAPACITY

The conceptualisation innovation capacity as developed in the early part of this paper refers to the understanding of knowledge production and use in a systems sense where innovation is embedded in and shaped by contexts, relationships and actor groupings that include but go beyond formal scientific organisations. While the capacity development efforts discussed above had varying degrees of success in addressing this broader task, one senses a lingering tendency to compartmentalise the capacity development task. To make the same point differently, capacity development perspectives which tackle biotechnology in a piecemeal fashion (human capital and research infrastructure; bio-safety; public private sector partnerships; IPR;) without understanding the need to deal with (and often strengthen) the overall system for producing and using knowledge are going to continue to encounter "second order problems" .

Having said that, the examples presented above do provide insights into the range of components that would encompass the concept of innovation capacity. This capacity could be defined as *the context specific range of skills, actors, practices, routines, institutions and policies needed to put knowledge into productive use in response to an evolving set of challenges, opportunities and technical and institutional contexts*. While it is impossible to be definitive about what a context specific and adaptive capacity would entail, the broad elements of agricultural biotechnology innovation capacity may include the following elements, arrangements and skills.

1. National culture appreciative of the value of the scientific knowledge in enterprise and development;
2. A critical mass of scientists trained in frontier area of biology and the scientific infrastructure and funds to productively employ them in research and development roles in the public and private sectors. (This would include the training organizations needs to create this human capital);
3. A range of actors with different types of agricultural knowledge, codified and tacit, in the public, private and NGO sectors;
4. Linkages between key sources of knowledge and the social capital need to allow new linkages to be brought into play when needed;

5. Relationships and institutions (including habits and practices) that support dialogue, knowledge access, sharing, and learning between different sources of knowledge; between different interest groups including the poor; and between policy actors, practitioners and researchers;

6. A range of skills in research, entrepreneurial organizations including: scientific, technical, managerial entrepreneurial skills and skills and routines related to partnering, negotiating, consensus and learning;

7. Clusters of supportive policies that allow both the production of knowledge (i.e. science and technology policy) as well as the productive use of that knowledge (i.e. market and trade policy, investment incentives, regulatory regimes, bio-safety protocols; IPR);

8. Change management competencies and mechanism to help predict and cope with evolving innovation environments (i.e. technology foresight). This will include the ability to link scientific knowledge to policy, problem solving and long-term planning;

9. Coordination and facilitation mechanisms (i.e. sector associations, development authorities or boards) and incentive and support structures (i.e. subsidies, credit) to strengthen systems coherence in the absence of market signals;

10. Policy capacity to plan and promote innovation as a systemic phenomenon.

7. POLICY TOOLS FOR CAPACITY DEVELOPMENT -- MULTIPLE EVOLVING INNOVATION SYSTEMS

The innovation systems concept certainly does help reveal the breath of the capacity development task in the contemporary sense. However the discussion of an innovation systems and ways of building its capacity seems to suffer from precisely the flaw that its critics level at it: namely that is a theory of every body working with everybody on everything. In other words is it sufficiently policy relevant to be operationalised in science, technology and innovation planning? Also at this level of conceptual discussion one senses something counter intuitive about it. So for example we can see that farmer participatory research with local grouping of actors will be necessary to develop innovations in complex agro-ecological environments. But we can also see that the development of biotechnology solutions is going to require quite different grouping of actors, where scientific agencies and perhaps the private sector are going to have to play a lead role. Furthermore these different innovation systems can not be thought of as static entities as they are all embedded in evolving contexts with which they interact and respond to.

To address this short coming it is perhaps more useful to further develop the innovation systems concept and recognize that there are in fact families of connected but distinct innovation systems. These would involve clusters of organizations producing and using knowledge in ways that are appropriate to specific agendas and goals, technological settings, and competencies and of course specific contextual settings.

The empirical cases that have been presented seem to support this in a number of ways. For example it seems quite correct that the capacity of biotechnology innovation systems needs to be developed around clusters of scientific organizations. The examples of the networked biotechnology capacity concept and the partnership model of capacity development are probably of this type. Despite the critique of these, particularly the partnership model, of having failed to build the linkages with local and down stream actors, one can not detract from the fact that these sorts of capacities are important when viewed as part of a bigger endeavor. Similarly, and perhaps at the other end of the spectrum, the APNBP in India was a case of developing and innovation capacity that was more participatory and farmer centric.

A key theme that is common to all these types of cases is that a major task is not just about creating the linkages in the particular innovation system, but about integrating different groupings of linkages. The APNBP chiefly concerned integrating the scientific network of Indian agricultural research organizations with the NGO's and farmer networks working in rural development. The short coming of the Kenyan sweet potato virus case was again about the need to better integrate the scientific network developing new varieties with the commercial, NGO and farmer networks involved in diffusing and using the technologies. It was also not that these clusters all had to be working together all the time, but that there needed to be interaction at strategic points in time, such as problem identification.

The innovation systems concept predicts that these different systems will both emerge spontaneously around new themes, or will evolve through incremental change as systems interact with their changing contexts. Some of these systems already exist while others, it is probably safe to predict, are likely to emerge (or need to be put in place) in coming years. This would include the following agricultural innovation systems typologies

These major typologies include:

Old CGIAR: Network of international centres of scientific excellence linked to national agricultural centres of excellence. Little integration with clients or other actors in the agricultural/ rural sector. **Mission:** increase agricultural productivity.

New CGIAR: Network of international centres acting as brokers of science for development linked to national agricultural research organisations, private companies and civil society organisations. Increasingly strong integration with other actors in the agricultural / rural sector **Mission**: contribute to poverty reduction and sustainable development.

Entrepreneurial led Agri-businesses: Nation and international companies with strong links to markets and farmers, and increasingly strong linkages to both public and private sources of technical expertise. **Mission:** exploit existing trade comparative advantage.

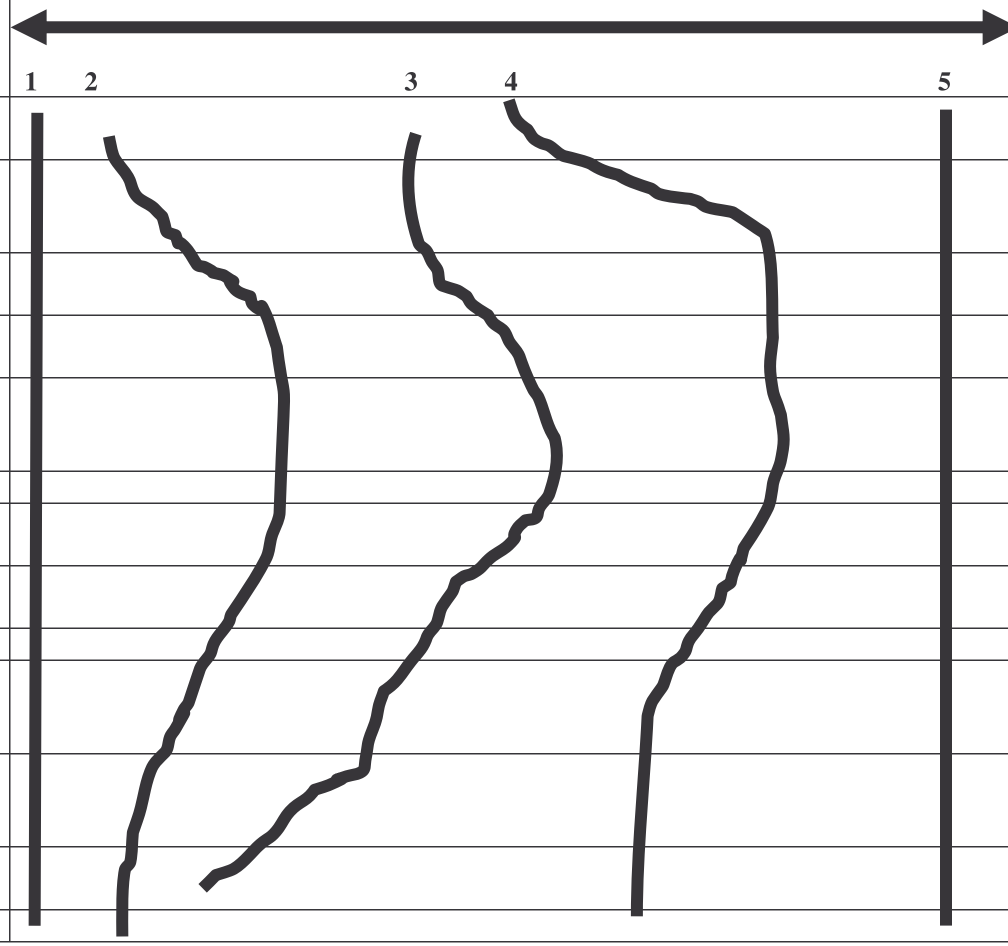
R&D led agribusiness: National and international companies with advanced R&D capability. Strongly linked to markets and advanced research organisations internationally often involving alliance between national and international agribusiness partners. **Mission:** commercial exploitation of advances in (usually) biological sciences

Public private sector partnerships: Alliances of public research organisations to gain access to advanced and complementary expertise and proprietary methods and materials or to gain access to private manufacturing and distribution capacity. **Mission:** development and delivery of products with high social returns.

Coping and competing in international agricultural commodity and product markets: Sector based groupings of farmer, agric-business and public and private research organisations. Strong patterns of interaction throughout the sector and particularly with research organisation and sources of market knowledge. **Mission**: Equitable economic growth by to proactively respond to changing demand, norms and standards in international markets.

Pro-poor participatory innovation for complex agro-ecologies: Localised and well integrated groupings of farmers, agri-business and government and non-government development agencies with strategic links to research organisations. **Mission:** Poverty reduction through improvements in agriculture related livelihoods.

Figure 1. *Typology of agricultural innovation systems*

Defining characteristics[6]	**Indicators of transfer of technology paradigm**		**Indicators of interactive innovation paradigm**
Organising principle/ scope of task	Scientific research		Innovation/ socio-economic change
Responsiveness to different stakeholder agendas	Low		High
Accountability for outcomes	Low		High
Knowledge types used	few/ codified		Many, codified and tacit inc indigenous
Degree of integration of different knowledge types	Low		High
Use of policy incentives	Low		High
Defining processes	Linear, reductionism		Reflective/ learning evolutionary systems
Ability to cope with change	Low		High
Scale	global		Multiple scales
Priority setting	Prescriptive by scientist and economists		Consultative with different interest groups
Policy regimes	Narrow, S&T policy to guide research		Clusters of policy working together to promote innovations
Power / relationships	Unequal / hierarchical		Equal / flat
Knowledge flows	Top down		Multi-directional

Notes 1 Old CGIAR; 2 New CGIAR; 3 R&D led Agri-business; 4 Public private sector partnership; 5 Pro-poor participatory innovation for complex agro-ecologies.

Figure 1 presents these different typologies, describing them by placing them at different points along a continuum between two innovation paradigms. The first on the left is the technology transfer paradigm and the second on the right is the interactive and iterative innovation paradigm. Institutional characteristics of each paradigm are given in the left and right hand columns. The lines representing the different typologies are shaped to map the different institutional features which characterise them.

Figure 1 is not intended to indicate an evolutionary progression from the technology transfer paradigm to the interactive iterative paradigm. Rather it represents a branching genealogy where new types of innovation system emerge through adaptation in response to new tasks and other changes in the research and development environment. It is not that one is better than another, rather than different systems are suited to achieving certain outcomes.

This recognition of diversity is important for a number of reasons. Firstly it allows policy and capacity development activities to recognize and support the co-existence of different types of innovation capacity. This helps break out of the false dichotomy whereby old practices are vilified at the expense of new without recognizing synergy. Secondly, it allows emphasis to be given to ways of strengthening the strategic, purpose-oriented interaction of these systems at various points of intersection. This shifts attention to complementing and integrating different ways of producing and using knowledge rather than arguing for homogeny and, for example, insisting that all approaches having to become participatory or partnership based or that all approaches have to be science-led. Clearly neither of these propositions is workable and could undermine well intentioned capacity development efforts. This perspective is important for biotechnology as it helps understand how agriculture biotechnology innovation systems might be situated and integrated with respect to other systems or indeed whether biotechnology is not a new innovation system in itself but an aspect that has to be integrated into other systems. This might be particularly important with generic technologies as knowledge and expertise major be located in apparently unrelated research and development sectors such health.

8. CAPACITY DEVELOPMENT: WAYS FORWARD

This paper has a number of messages about the ways biotechnology and other innovation capacity can be developed in developing countries. The first is that policy should recognise that capacity development in a contemporary sense is a multidimensional concept. It requires skills or competencies of both a scientific and non-scientific kind; it requires linkages between producers and users of knowledge and between scientist and policy makers; it requires the types of relationships and institutional setting conducive to knowledge sharing and interactive learning; it requires a policy environment that is sensitive to the need to create the conditions required to make productive use of knowledge rather than focusing solely on the creation of that knowledge; and it needs a policy capacity with the perspectives to deal with innovation as a systemic phenomenon.

Secondly, at a general level the innovation systems approach is a useful policy tool for thinking about how capacities can be developed. However, this alone maybe too simplistic an analysis to be policy-relevant. Nor indeed does it reflect the diversity of knowledge production arrangements that already exist, only one of which might be focused on biotechnology. Instead policy should recognise that there are in fact multiple innovation systems operating in the agricultural sector; all have different rules and different players appropriate to the themes and incentives to which these are responding to. Agricultural biotechnology capacity has to been seen in both this broader innovation systems sense, as well as recognising that it is only one in a series of related innovation systems. The corollary to this is the importance capacity development in a diversity of these systems.

Thirdly, policy should look at ways of strategically integrating different innovation systems; for example how can biotechnology innovation systems be brought to bear on farmer participatory innovation systems. And fourthly, it is noted that these sorts of perspectives are yet to penetrate the policy community dealing with developmental aspects of agricultural science technology and innovation in national and international organisations. Building the skills of policy actors to conceptualize innovation capacity in this way will be essential for putting in place supportive frameworks for capacity development in this broader embedded sense. Only when this happens will biotechnology start to significantly impinge on the development process in the poorest countries and deliver the potential that its advocates have promised for so long.

REFERENCES

Bell M, Albu, M. 1999. "Knowledge systems and technical dynamism in industrialised clusters in developing countries. *World Development* 27:9, pp. 1715-1734.

Bell RM, Pavitt KLR. 1993. Technological accumulation and industrial growth: contrasts between developed and developing countries. *Industrial and Corporate Change* **2**(2): 157–210. Biotechnology and Development Monitor. 1999. Editorial: Capacity building for biotechnology and beyond. Biotechnology and Development Monitor 39: 2-3.

Byerlee D, Alex GE. 1998. *Strengthening National Agricultural Research Systems: Policy Issues and Good Practice.* World Bank, Washington DC.

Chataway J, Smith, J. and Wield, D. 2005. Partnerships for building science and technology capacity in Africa: Canadian and UK Experience. Paper prepared for the Africa-Canada-UK Exploration: Building Science and Technology Capacity with African Partners 30 January – 1 February 2005 Canada House, London.

Clark NG. 1995. The interactive nature of knowledge systems: some implications for the Third World. *Science and Public Policy,* 22(August).

Clark NG. 2004. Science policy and agricultural research in Africa: a capacity building needs assessment. Report to the Science and Technology Commission of NEPAD.

Clark N, Yoganand, B and Hall AJ. 2002. New science, capacity development and institutional change: the case of the Andhra Pradesh-Netherlands Biotechnology Programme (APNLBP). *The International Journal of Technology Management and Sustainable Development*. 1:3, pp.195- 212.

Clark NG. Mugabe J. 2004. Strengthening science and technology policy in the field of environment and development: The case of the African Centre for Technology Studies Capacity Development Programme in *Innovations in Innovation: Reflections on Partnership and Learning.* Hall AJ, Yoganand B, Rasheed Sulaiman, Raina R, Prasad S, Niak G, Clark NG. (Eds) ICRISAT, Patancheru, India and NCAP New Delhi.

Eicher CK. 1989. Sustainable institutions for African agricultural development. Working Paper No 16. The Hague, The Netherlands: International Service for National Agricultural Research (ISNAR).

Edquist C. (ed.). 1997. *Systems of Innovation Approaches: Technologies, Institutions and Organizations*. Pinter, Casell Academic, London.

Freeman C. 1987. *Technology and Economic Performance: Lessons from Japan.* Pinter, London.

Fukuda-Parr S, Lopes C, Malik K. (Eds.) 2002. Capacity for Development: New Solutions to old Problems. UNDP, New York and Earthscan, London.

Gibbons M, Limoges C, Nowotny H, Troww M, Scott P, Schartzman T. 1994. *The New Production of Knowledge.* Sage: London.

Hall AJ. 2002. Innovation systems and capacity development: agenda for North-South research collaboration. *The International Journal of Technology Management and Sustainable Development* 1:3, pp.146-152.

Hall AJ, Clark NG. Rasheed Sulaiman V, Sivamohan MVK, Yoganand B. 2000. New agendas for agricultural research in developing countries: policy analysis and institutional implications. *Knowledge, Policy and Technology* 13:1, pp. 70-91.

Hall AJ, Sivamohan MVK, Clark N, Taylor S, Bockett G. 2001. Why Research Partnerships Really Matter: Innovation Theory, Institutional Arrangements and Implications for the Developing New Technology for the Poor. *World Development* 29:5, pp. 783-797.

Horton D. 2003. Evaluating capacity development: experiences from research and development organisations around the world. The Netherlands: International Service for National Agricultural Research (ISNAR); Canada: International Development Research Centre; The Netherlands: ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA) 170pp

Ikiara M. 2004. Agricultural biotechnology partnerships in Kenya. In Velho, L *Agricultural Biotechnology Research Partnerships in Sub-Saharan Africa. Achievements, Challenges and Policy Issues, Velho L.* UNU-MERIT Technology Policy Briefs 3:1, pp. 3-4

Lundvall BA. (ed.). 1992. National S*ystems of Innovation and Interactive Learning*. Pinter, London.

Nelson RR, Winter SG. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge.

Mytelka LK. 2000. Local systems of innovation in a globalized world economy. *Industry and Innovation* 7:1, pp.15-32.

Mytelka LK. 2001 Promoting scientific and technological knowledge for sustainable development. Prepared for the Third UN Conference on Least Developed Countries, Round Table: Education for all and Sustainable Development in LDC, 16 May 2001.

Mugabe J. 2000. Biotechnology in developing countries and countries with economies in transition: strategic capacity building consideration. Prepared for the United Nations Conference on Trade and Development (UNCTAD), Geneva, 23 March 2000.

Oyelaran-Oyeyinka B. 2005. Systems of innovationa and underdevelopment: an institutional perspective. UNU-MERIT Discussion Paper Series in press. United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology: Maastricht.

OECD. 1997. National innovation systems. Paris: Organization for Economic Co-operation and Development (OECD).

Rukuni M, Blackie MJ, Eicher CK. 1998. Crafting smallholder-driven agricultural research systems in southern Africa. *World Development* 26:6, pp.1073–1087.

Velho L. 2004. Agricultural biotechnology research partnerships in sub-Saharan Africa. Achievements, challenges and policy issues. UNU-MERIT Technology Policy Briefs 3:1, pp. 1-6.

Verástegui J. 1999. Transferring expertise and building capacities in agro-biotechnology: the experience of CamBioTec. *Biotechnology and Development Monitor* 39, pp. 2-7.

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