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Synergizing E-infrastructures Initiatives to Foster e-Research in Higher Education Institutions in Africa

Simon M. KARUME[1], Kelvin K. OMIENO[2]
[1]*Faculty of Science, Masinde Muliro University of Science & Technology, P.O. Box 190, Kakamega 50100, Kenya*
Tel: + 254 722499397 Email: karumesm@yahoo.com
[2]*Faculty of Science, Masinde Muliro University of Science & Technology, P.O. Box 190, Kakamega 50100, Kenya*
Tel: + 254 726849197, Email: komieno@acm.org

ABSTRACT

It is expected that improved connectivity will enable African Tertiary education and research institutions to generate a proportionate amount of intellectual property goods to achieve parity with the rest of the world. Nevertheless this vision can only be attained through intensive collaborative activities. The emergence of large-scale e-infrastructure projects in Africa reflects a trend toward more complex configurations of scientific collaboration. This paper investigates the concepts of *synergizing* which denote the active processes of creating and managing relationships among people, organizations, and technologies in the creation of e-infrastructure. The paper also explores how embeddedness is not only an important result of infrastructure development, but is also a precursor that can act as both a constraint and a resource for development activities. The researchers are more interested with the process of creating and maintaining productive socio-technical relationships, which they refer to as synergizing. Human infrastructure posits that complex infrastructures come about through complex interactions among networks, place-based organizations, groups, and consortia. Through a multiple case study approach and integrated literature survey, the research examines how two e-infrastructure initiatives; UNESCO-HP brain gain and HP catalyst projects attempts to make use of these concepts to foster e-research and draws specific lessons for African HEIs. The study revealed that the two dominant e-research projects have adopted approaches that favor synergizing and embeddedness in e-research however despite funding of 24 projects in 21 HEIs, visibility of Africa in e-research world map is still wanting.

Keywords: *E-research, e-infrastructure, synergizing, embeddedness, higher education institutions (HEIs)*

1. INTRODUCTION

Information and Communication Technology (ICT) together with Internet is making it possible to share vast amount of knowledge and information and is driving all round socio-economic changes and growth. The growth of large-scale e-infrastructure projects reflects a trend toward more complex configurations of scientific collaboration [1] including: i) a movement towards large scale enterprises such as those for physicists [2], ii). the rise of interdisciplinary research which is related to the growth of big science but is also strongly associated with changes in funding for science and the sites and contexts of knowledge production [3].The gap between disciplines in modern day science is perceived as a natural place for new disciplines to evolve: “The real-world research problems that scientists address rarely arise within orderly disciplinary categories, and neither do their solutions. Thus, the information needed to solve complex research problems is distributed across disciplines and takes many different forms, physically and intellectually”[4]. As noted by Wulf (1993) [5] , scientists and policy makers acknowledged early the potential of networked computing for scientific practice, and envisioned the collaboratory (a blend of the words collaboration and laboratory) as a “center without walls” enabled by highspeed computer networks in support of distributed science. A significant body of research and development work grew up around the concepts of collaboratories, e-research, and virtual laboratories [6] [7] [8].

2. BACKGROUND

A. E-infrastructure

E-infrastructure is the integration of technology and organizations that support research undertaken through distributed regional, national and global collaborations enabled by the Internet. It comprises of grid computing software, which can provide researchers with shared access to large data collections, advanced ICT tools for data analysis, large scale computing resources, and high performance visualisation, among other examples. It embraces networks, grids, data centres and collaborative environments, and can include supporting operations centres, service registries, single-sign on, certificate authorities, training and help-desk services[9]. In view of this definition, e-infrastructures are composed of multitudes of heterogeneous entities and relationships. Thus as noted by Matthew J. Bietz et al. (2010) [10], they are the result of interactions among many and varied individuals, organizations, and other entities. They employ ultramodern information technologies that enable large research endeavors with potentially far-reaching impacts that could not be otherwise realized to be conducted. An example of such research is unifying functional brain imaging scans from multiple distributed work sites [11]. They represent a shift toward technologically-supported collaborative research approach that provides a unique dimension from which to gain insights about the process of infrastructure development [12].

B. Embeddedness in Infrustructuring

As noted by Star (1999) [13], Infrastructures materialize through use and over time across great physical distances. Often, they are embedded in other infrastructures and have other infrastructures embedded in them, resulting to a complex set of relationships embedded in and constrained by other systems. This makes it unfeasible to envisage rightly beforehand what the infrastructure will be or how it will be used. Due to its complexity, big size and layered structure, it cannot be changed from above. Since nobody is really in charge of infrastructure [13], and changes involve adjustments with other systems' aspects, change implementation requires negotiation and takes time. From this perspective, embeddedness of infrastructure can be seen as constraining ongoing development by limiting the autonomy of the systems and their developers. On the other hand, embeddedness may be viewed as a vital resource that can be used by infrastructure developers to accomplish work by drawing from existing arrangements of relationships to build new infrastructure. Figure 1 demonstrates the complexity resulting from embeddedness during the emergence of an e-infrastructure.

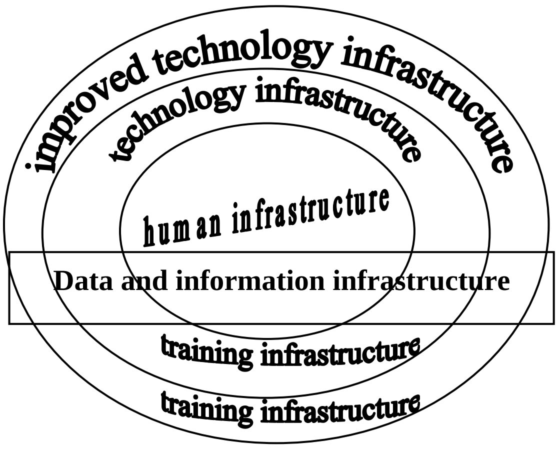

Figure 1: investigators perception of e-infrastructure complexity as a result of embeddedness

As illustrated in figure 1 technology infrastructure is embedded within a human infrastructure while new technologies are embedded within existing ones. Further to facilitate use of technologies, training infrastructures are necessary and are embedded within technology and human infrastructures. As informed users start using technology they generate data and information giving rise to a data and information infrastructure layer which is further embedded in the other infrastructures.

C. **Synergizing in E-infrastructure**

The concept of embeddedness smoothly links up to the concept of synergizing that is used in this paper to highlight the collaborative work that need to be done in the course of developing an e-infrastructure so as to build and maintain productive relationships among people, organizations, and technologies. The Oxford English Dictionary 1989 defines synergy as increased effectiveness produced as a result of combined action or co-operation [14]. In the context of research powered by e-infrastructure, synergizing constitutes strategic collaborative activities seeking to produce superior combined effects that cannot be realized independently by individuals, groups, or organizations. As noted by Matthew J. Bietz et al (2010) [10], Synergy can arise from bringing two groups together in a collaborative relationship (human infrastructure), or it can come from the linking together of two pieces of software to produce a more capable system (technology infrastructure) [15]. Synergy arises from bringing together already-existing entities, rather than "from scratch" development of new entities or growth of a single entity. However, something new may be created as a result of the synergy [3].

3. RESEARCH DESIGN

Multiple case study and integrated literature survey was adopted in this study. The researchers examined the evolution of the pan-European research network by scrutinizing artifacts such as project websites, research papers and reports. In addition UNESCO-HP brain gain and HP catalyst projects were examined to understand the project models adopted and how they foster synergy and embeddedness. To obtain summaries of projects and HEIs funded the projects reports were scrutinized. So as to understand the project models artifacts including request for proposal documents were examined to identify specific funding constrains that favored collaborations and application of ICT.

A. The power of Synergy in E-infrastructuring: Lessons From the Pan-European research Network

The evolution of the Pan-European research network summarized in table 1 is a good example of how the two concepts can work together to give rise to a cohesive and productive e-infrastructure.

Table 1: Summary of evolution of the pan European research network.

Year	Network and Technologies
From 1993 to 1997	EuropaNET was developed. It connected 18 countries at speeds of 2Mbps and used IP technology.
From 1997 to 1998	TEN-34 was developed, again connecting 18 countries, but now at speeds of 34Mbps and using both IP and ATM technology.
From 1998 to 2001	TEN-155 was developed, connecting 19 countries at speeds of between 155 and 622 Mbps, again using IP and ATM technologies.
From 2001 to 2005	The GÉANT network connected 30 countries at speeds of between 2.5 and 10Gbps. It too used IP and ATM technologies.
Since 2005	The GÉANT2 network has been gradually taking on Europe's research and education network traffic, as the network has been rolled out. At completion, it will connect 34 countries at speeds of up to 10Gbps.

As can be observed from this table each generation of network was developed from the previous by upgrading certain technology aspects such as protocols and speeds alongside expanding the coverage. According to DANTE, the coordinating organization, development of each network has been undertaken as a project involving a consortium of National Research and Education Networks (NRENs). Clearly from this illustration each new network was embedded in the previous via synergetic activities involving a consortium of NRENs. This has catapulted Europe to the centre of global research networking as illustrated in figure 2.

Figure 2: Geant at the Heart of global Research Networking (source DANTE website)

Apart from synergetic efforts via NRENS to build technology infrastructure, another notable area that the European e-infrastructure projects have sought synergies is in capacity building. Through the Exchange Programme to advance e-Infrastructure Know-How" (EPIKH). Participants of the exchange program are concentrated in Europe as can be seen in figure 3

Figure 3: Source Geocentre consulting MapLink, Tele Atlas, Whereis(R), Sensis Pty Ltd

4. UNESCO AND HP INITIATIVES

A. UNESCO-HP Brain Gain Initiative: Mobilizing the Africa Diaspora Using E-Infrastructures

Through the deployment of advanced information and distributed computing technologies (IDCT), The UNESCO-HP Brain Gain Initiative addresses the effects of human migration, especially the emigration of highly skilled people that is having a significant impact on education and economic development in less developed countries [16]. The project uses IDCT to enable students to run innovative technology-based projects in their home countries aided by interaction with experts in the Diaspora [4]. The Initiative seeks to make each participating university a "digital hub," developing its research capacity to address local priorities and linking young scientists and other talented local individuals to university resources abroad, funding opportunities and international partnerships. The UNESCO-HP partnership provides equipment, including servers for grid-enabling and cloud computing technologies, training and support, as well as operational funds.

B. Embeddedness and synergy in The UNESCO-HP brain gain project model

As can be construed from a UNESCO project paper presented in the world conference for higher education [4], The UNESCO-HP brain gain project model posses certain distinguishing characteristics that promote embeddedness and synergetic inter and intra university collaborations. These characteristics include:

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(i) Leveraging existing relationship with grantees to develop new collaboration through project phases. This happens in two ways i.e. inter project phases where participants of one project phase are linked up to participants of another project phase and intra project collaborations where participants within a specific project phase are linked up. In both cases relationships are embedded within existing relationships and synergetic collaborations sprout out of this project model trait as illustrated in figure 4.

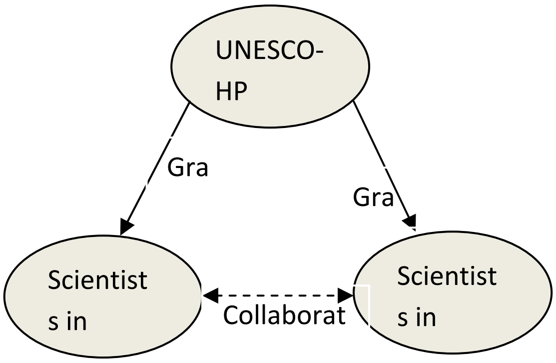

Figure 4: embedded relationships and synergetic collaborations (adopted from Matthew J. Bietz et al (2010)[10])

This strategy takes advantage of embeddedness by drawing on existing relationships to develop new relationships, and creates synergy by facilitating new collaborations. This is an inter university synergetic approach.

(ii) Leveraging the Diaspora link to local universities to create an inter scientist's collaboration that reverses brain drain to gain: this trait of the project model has resulted to synergetic collaboration between local scientists and scientists in the Africa Diasporas as depicted in figure 5.

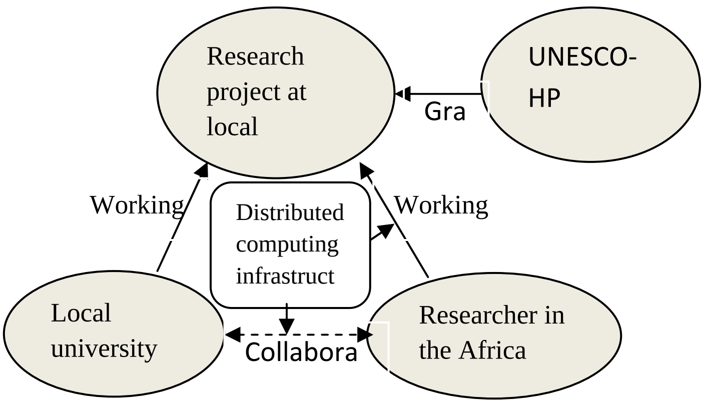

Figure 5: synergetic collaborations between local and Diaspora scientists powered by distributed computing infrastructure

(iii) Utilizing a Multidisciplinarity to facilitate intra university collaboration among disciplines. Particularly domain scientists and technologists. As depicted in figure 6, so as to access advanced technology, a life science project partners with a technology project developing high performance computing infrastructure in the same university resulting to inter discipline synergy that enables the life scientists to seek further collaboration with other domain scientists outside the university using the advanced technology.

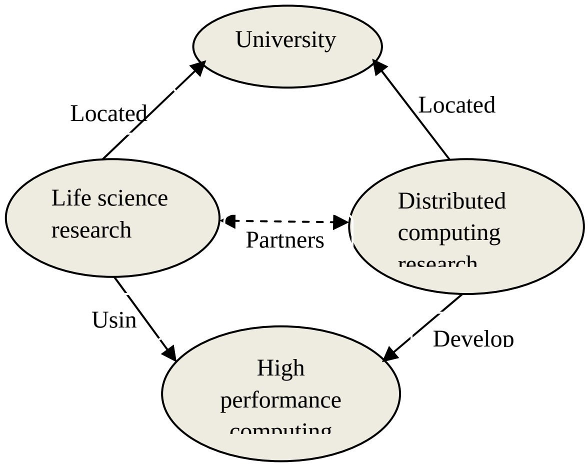

Figure 6: intra university synergetic collaboration between disciplines (adopted from Matthew J. Bietz et al. (2010)[10])

An example of this is the brain gain project at Masinde Muliro University of Science and Technology that involves a computational chemistry project partnering with a high performance computing project.

(iv) Seeking synergies and cooperation with existing e-infrastructure projects: this project trait enables UNESCO-HP brain gain e-infrastructure projects to leverage existing e-infrastructure projects and become assimilated in them. By so doing the project encourages synergetic effort through embeddednes. Notable examples in Africa include: (i) linking the grid node at the University Cheikh Anta Diop (UCAD) in Dakar, Senegal to the European Grid for E-science (EGEE). The UCAD grid node is the first sub-Saharan African component of the grid infrastructure created in 2004 by the European Union through the UNESCO-HP project to develop cooperation on a global scale for many scientific applications [4]. (ii) Linking the High performance computing node at Masinde Muniversity of Science and Technology Kenya to the South African grid through University of Cape Town (UCT), South Africa.

C. HP Catalyst project: Innovating approaches to STEM education

The HP Catalyst project combines technology with expertise to explore innovative approaches to science, technology, engineering, and math (STEM) education by establishing a network of leading

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educators, education institutions, and key stakeholders in selected countries [17].

Embeddedness and synergy in The UNESCO-HP brain gain project model

As can be construed from the project website [5] and the 2011 request for proposal document [18], the project model adopts the following approaches that promote embeddedness and synergy.

(1). Organizing grantees along consortia focusing on specific themes: this brings together organizations that work independently to create a global network of consortia and community of practices in the identified themes. This model is depicted in figure 7

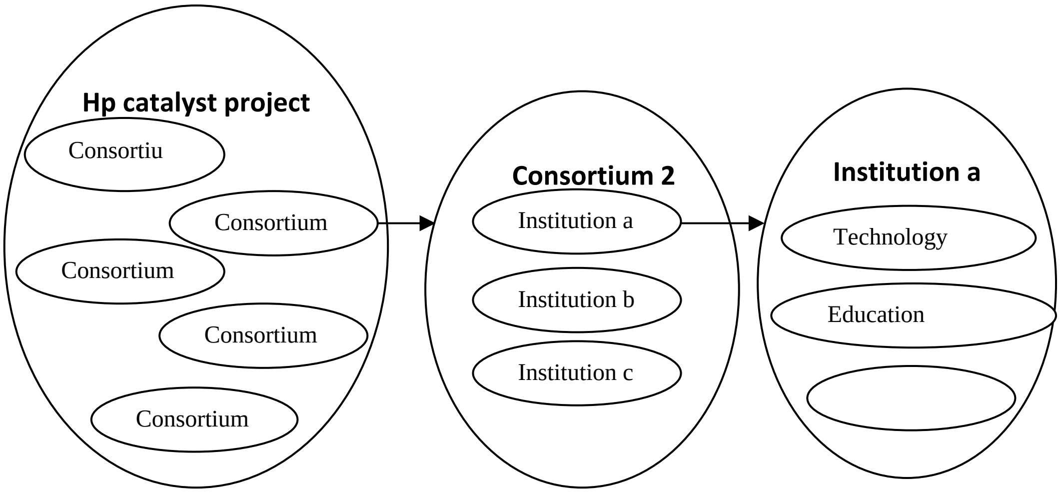

Figure 7: HP catalyst initiative project model

(2). Multidisciplinary approach: the project model requires that within the grantee institutions, the project team adopt a multidisciplinary arrangement constituting of technologists, scientists and educationists in some consortium.

(3). Collaborative approach: this approach is reinforced by placing specific funding constraints that prefers institutions that:

- Are actively engaged in other networks or partnerships that are related to one or more HP Catalyst Initiative themes.
- Are engaged in currently funded projects which could be enhanced by their participation in an HP Catalyst Initiative consortium.

This requirements seeks synergies from existing projects

(4). Minimum infrastructure requirements to support the use of the technology awarded as part of the HP grant: this requirements include

• Adequate infrastructure (electricity, buildings, Internet access, etc.)

• Existing or planned high-speed wireless computing environment

• IT resources that will be committed to support the use of the granted equipment

This grantee constraint technology support is incorporated in existing technology.

(5). Integrating participants into a global HP Catalyst Network a professional community of practice whose benefits include:

- Access to an exclusive online community of former and current HP grant recipients through an online social media platform
- Potential opportunities for visibility, such as speaking, guest blogging, participation in webinars where recipients showcase their solutions, and possible invitations to showcase best practices at education conferences and tradeshows

D. Towards Promotion of Sustainable E-research in Africa

Synergizing Existing E-infrastructure Initiatives

A notable aspect of the Brain gain and the HP catalyst initiatives is focus in e-Research. This can be construed from the emphasis placed on the minimum technology infrastructure requirement for a grantee in both projects. E-Research, can be defined as research conducted in virtual communities across the academic and industrial sectors using specially designed online technical facilities and services [19]. The virtual community research members have the ability to share, federate and exploit the collective power of global scientific facilities, supported by a technical framework that allows participation regardless of geographic location. Table 2 summarizes the number of higher education institutions and the number of projects involved in the UNESCO-HP brain gain and HP catalyst initiatives.

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Table 2: Summary of number of higher education institutions and the number of e-research projects involved in the UNESCO-HP brain gain and HP catalyst initiatives.

Country	No. of HEIs	No. of projects	
		Brain Gain	HP-Catalyst
Algeria	1	1	
Ghana	1	1	
Nigeria	1	1	1
Senegal	1	1	
Zimbabwe	1	1	
Côte d'Ivoire	1	1	
Ethiopia	1	1	
Morocco	1	1	
Tunisia	1	1	
Burkina Faso	1	2	-
Cameroon	2	2	-
Kenya	3	2	2
Uganda	2	2	-
South africa	3	-	3
Egypt	1	-	1
Total	**21**	**17**	**7**

Despite the fact that 24 e-research projects powered by distributed computing infrastructure are supposedly taking place in 21 institutions of higher learning in Africa, feasibility of Africa in the e-research world map is wanting as evidenced by figure 8. Three major concerns from this scenario are:

i) How can this efforts be consolidated to improves Africa's feasibility in the e-research world map
ii) How can the projects manage to be sustainable after the funding phase?
iii) How can the HEIs involved incorporate more researchers and HEIs?

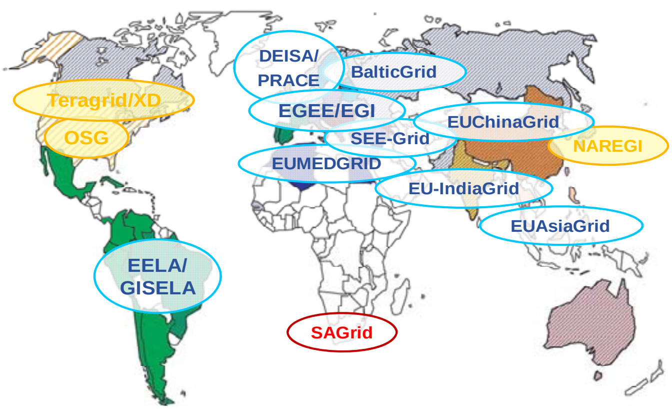

Figure 8: grid infrastructure world map

Cleary out of the 24 e-research projects founded on collaborative project models discussed in sections 4.1 and 4.2, none can be sustainable in isolation. Taking into account the amount of resources invested by donors and the respective institutions, it is worth looking beyond the funding phase. To sustain the research momentum after the funding phase the institutions involved will have to seek synergies from each other and establish new relationships with other HEIs and research institutions. To attain this goal we propose a synergetic triple model that advances embedding of technical infrastructures in a human infrastructure so as to attain sustainable e-research.

5. SUSTAINABLE E-RESEARCH SYNERGETIC TRIPLE MODEL: A CONCEPTUAL FRAMEWORK

From a sustainability perspective we look at the concepts of synergizing and embeddedness from three perspectives namely 1) technology 2) human and 3) training infrustructures. The human and training perspectives constitute capacity building to enhance collaborative work with the aid of synergy drawn from technologies so as to generate sufficient data and information that will give rise to new knowledge. As new technologies are embedded in existing ones training modules to be disseminated via the training infrastructure need to be developed. Through the training infrastructure, users are empowered to apply the technologies in research. The envisioned conceptual framework is summarized in figure 9.

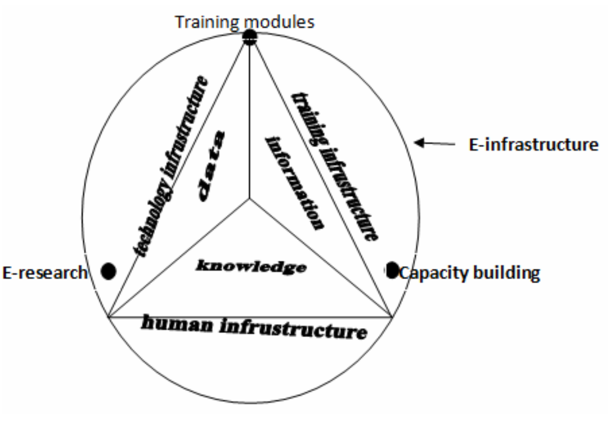

Figure 9: conceptual framework of a sustainable e-infrastructure synergetic triple model

A. Synergy in Training

As noted by A,Voss & M, Asgari-Targhi (2009)[20], Researchers are often not aware of the potential of distributed systems or of the issues involved in developing and using them. This means that they find it difficult to make sense of the e-Infrastructure services

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or to relate them to their own work and come up with possible ways of using them. While training material exists that provides instructions for the use of advanced ICT systems, there is a lack of material that teaches the underlying principles of e-Research and helps researchers to engage creatively and critically with these technologies. Thus the training modules proposed should incorporate materials that emphasize the underlying principles of e-Research. The training infrastructure could incorporate various approaches including: Exchange programs similar to the EPIKH project model in Europe, expertise sharing, internships to address capacity deficits etc.

B. Synergy in Technical Infrastructure

Although much has been done in this respect via NRENS in Africa under the coordination of ubuntuNet alliance, there is still a long way to go. The issue of high speed networks seems almost conquered but synergies in other technical facilities need to be encouraged too. Such equipments include high performance computing (HPC) facilities that are required to support e-research and in particular e-science. For instance the brain gain project grantees have in their custody 34 HP G6 ProLiant servers which can be pooled together to form a network of high performance computing nodes. A clustering approach can be used to progressively build a network of African HPC nodes. The clusters can be organized from bottom up i.e institutional national, regional then continental. E.g. at institutional level departments/faculties form infra grids, faculty/department grids combine to form institutional intra-grids, institutions e.g in Kenya Nairobi University HPC team up with Masinde Muliro University HPC to start a national HPC network or an extra-grid which can then be extended to Uganda since there are HEIs in Uganda with brain Gain HPC to form an inter-grid. This scenario is depicted in figure 10.

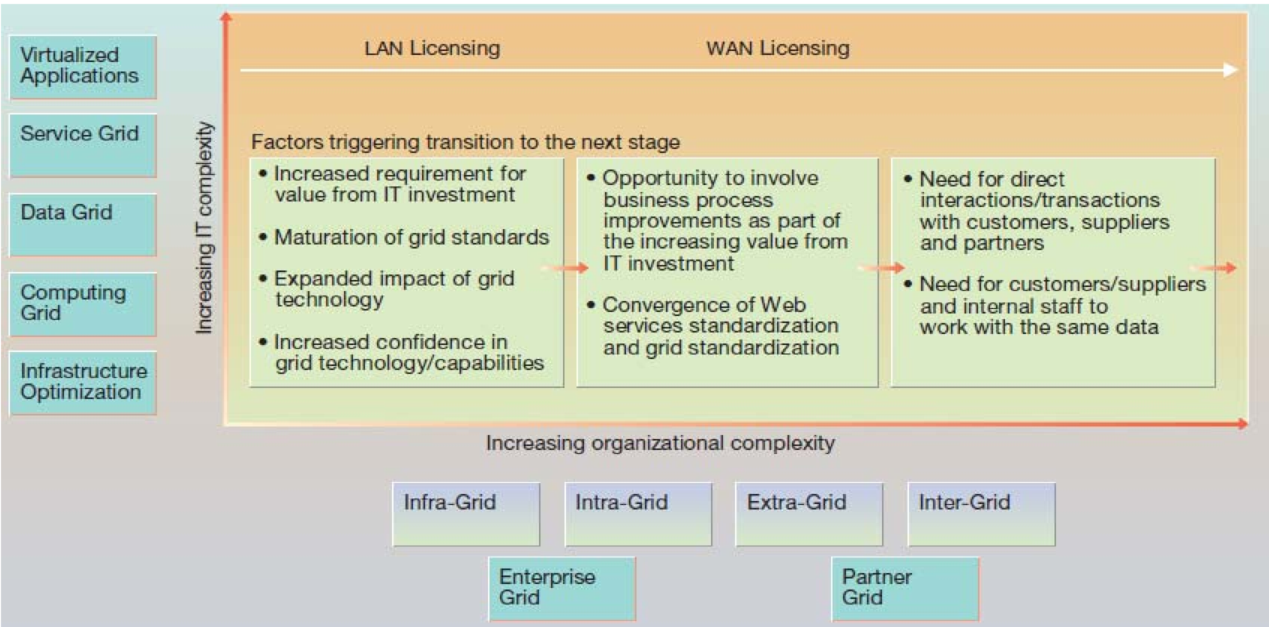

Figure 10: Figure 2 Grid adaption factors [21]

C. Synergy in Human Infrastructure

A report on accelerating transition to virtual research organization in social sciences notes that e-Infrastructure uptake is as often hindered by human and organizational issues as it is by technical ones [22]. The report recommends continued technical innovation in e-Research, but at the same time improving the social framework that would allow research communities to better exploit these technical assets. In view of this we propose a synergetic model in which the technical research framework is embedded in a human infrastructure.

A viable approach to this is organizing the researchers and technologists into consortia like in the HP catalyst initiative project model. The consortia may be clustered along research themes members of which will form a community of practice. Since the participants are likely to be dispersed a community building approach similar to the one adopted by open source software project teams can be helpful since they are similarly distributed and virtual. As noted by Moon & Sproull (2000), distributed teams have been effectively applied to manage some very complex, large, and non-routine activities [23]. As noted by Gabriel, H. (2010) Building a sustainable product largely depends on forging an environment in which users and developers share a culture of mutual support and a sense of following a common goal. Similarly success in e-research is dependent on users and developers of the supporting e-infrastructure sharing a culture of mutual

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support and a sense of following a common goal. This can be achieved through effective communication between researchers and the technical team as well as removing barriers that could prevent users' involvement in the community i.e. adopt an open approach to the project. This approach to community building is depicted in figure 11 adopted from the open source community building paper by Matthias et al. (2010)[24]

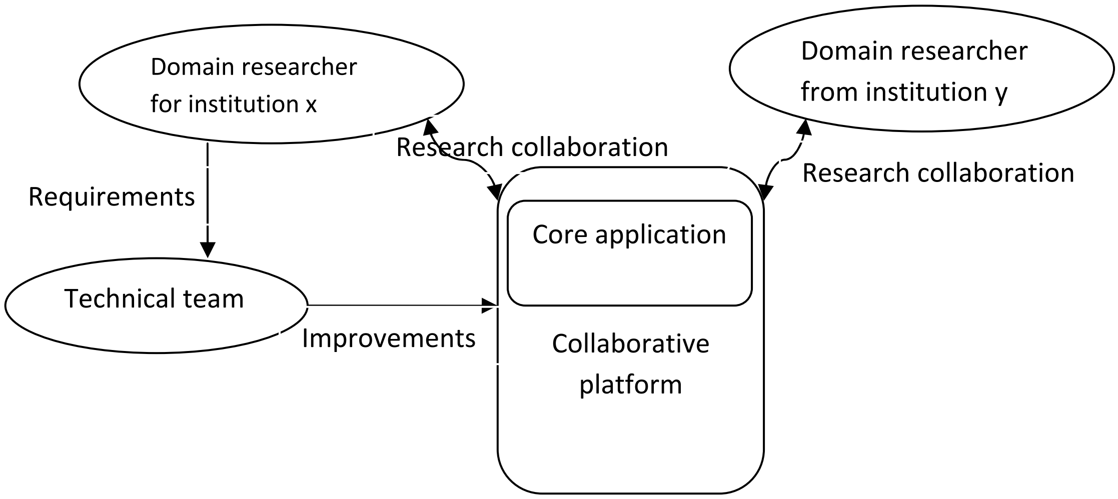

Figure 11: e-research community building approach

6. CONCLUSION

Coordination is key to achieving the proposed synergies. However the concern is who is going to take up the task of coordinating HEIs to pool together in the three dimensions represented in the proposed synergetic triple model. As noted by R.J.Osazuwa 2010[25], research and educational Networks are platforms of synergy, growth and development for increased collaboration, cost effective application of resources, improved infrastructure and capacity building. It enables institutions to collectively own and achieve what would have been impossible for a single institution to attain, as result of expertise and cost. Just like African RENS have pooled together to conquer the bandwidth challenge through ubuntuNet alliance, they can similarly come up with a mechanism to coordinate HEIs to synergize their e-infrusturctures in the three dimensions proposed to foster e-research in Africa.

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