Technological Initiatives to Promote Science Growth in Mozambique

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Abstract. Deploying NREN infrastructures is considered a crucial step for fostering Science and Technology in Africa as it will allow to support advanced services for sharing science. For managing science components and players, the Current Research Information System (CRIS) has been proposed and adopted internationally. Understanding these concepts and applying them in the science ecosystem of developing countries will allow to foster science management in these countries, saving years of progress.

Facing the above, this paper discusses the challenges and strategies for the implementation of technological platforms for accessing science, taking Mozambique and its NREN as the primary goal. Answering questions such as "What is the current state of Science and Technology in Mozambique? What are the challenges and strategies to put Mozambique a step forward in science development?" is the aim of this research work. The proposals envisioned in this paper are sustained by the analysis of worldwide initiatives and recommendations regarding open access to science, CRIS inputs, the Portuguese and African context, and the Mozambican science and education ecosystem. This work also aims to provide insights for other developing countries by identifying good practices and international cooperation opportunities.

1 Introduction

Sharing knowledge in the information age is seen as a vehicle for the development of societies, being technological platforms and infrastructures for managing science used as a way of promoting the growth and dissemination of scientific production. In this context, it is important that the academic and scientific community take advantage of the benefits of advanced services provided by National Research and Education Networks (NRENs), with emphasis on Open Access (OA), since it allows to freely access academic or scientific literature using the Internet. Another aspect that should be highlighted in the knowledge management supporting service is the Current Research Information System (CRIS) concept, which should be considered to manage the scientific production of any institution. CRIS allows to provide evidence to funders and other entities, and

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allows to measure the impact of the research carried out in the different research areas in an intelligent way.

Facing the above, it is important to look at international directives and the experience of countries which are at the forefront in terms of provision of connectivity and advanced services to the research and academic community. Portugal is recognized as a success case, due to the implementation of the national scientific OA repository (*Repositório Científico de Acesso Aberto de Portugal* - RCAAP) and the Online Knowledge Library (B-on). RCAAP and B-on are services supported by *Fundação para a Ciência ê a Tecnologia* - FCT (through *Fundação para a Computação Científica Nacional* - FCCN unit), the national entity responsible for managing the NREN, which provides high-speed connectivity and advanced services to academic and research institutions. These services have proved to be relevant to the production, sharing and dissemination of scientific production.

The challenges for deploying high-speed network infrastructures in Africa, including advanced services dedicated to the academic and scientific community, are still prominent compared to developed countries. The need for improving the quality in the higher education and research system also involves surveying the governmental strategies for science and technology, their funding and implementation. In view of the above, a careful study of the national repository of Mozambique, known as SABER, and the Mozambique Research and Education Network (MoRENet), the NREN of the country, is crucial as they will effectively support the work of the academic and scientific community of Mozambique.

The analysis of technological and scientific issues involving developing countries implies understanding science dimensions applied to each reality, the worldwide initiatives and potential cooperation synergies. Therefore, the present work discusses: (i) international initiatives for science sharing and success cases, such as the Portuguese experience on digital libraries and OA; (ii) CRIS directives and new trends; (iii) research and education network associations, with special emphasis to the UbuntuNet Alliance and AfricaConnect projects; and (iv) Mozambican strategy for science and technology. By interrelating these aspects and proposing an evolutive service model for open science in Mozambique, this work presents new perspectives to support the growth of science in this country, which can be extended to other developing countries.

The present article is structured as follows: Sect. 2 discusses the concepts related to the open access to scientific literature and research management issues, with emphasis on CRIS; Sect. 3 describes the Portuguese case study and Sect. 4 debates the African context; Sect. 5 discusses the technological guidelines for the evolution of open science in Mozambique; and conclusions are provided in Sect. 6.

2 International Initiatives for Science Sharing

The access to academic and scientific literature through digital libraries and open access repositories involves the storage of data in information systems and their access via NRENs. NRENs, providing either application and operational

supporting services, represent the current trend of collaboration and sharing of scientific knowledge among various communities spread throughout the world, with emphasis on higher education institutions (HEIs), libraries, schools and, in some cases, government institutions.

2.1 Policies and Mandates

The definition of policies and mandates in the last years has been an important effort to foster OA adoption. In 2004, 34 countries members of the Organization for Economic Cooperation and Development (OECD) legitimized a Declaration on Access to Research Data From Public Funding, acknowledged the importance of OA to return the value resulting from public funding, and stressed that constraints imposed on the access to research data can influence negatively the quality of the results of science and innovation projects. With respect to the United States, the government of this country launched in 2013 a guideline through the Office of Science and Technological Policy recommending that federal agencies should organize their strategic plans of OA, i.e., that the results of research funded by public funds, including the research data, involving more than 100 million dollars should be made available in OA [1].

At European level, the European Union (EU) through the European Council (EC), continuing the 2008 FP7 Open Access Pilot project, instituted guidelines for EC funded projects regarding the improved access and re-use of data resulting from research. These guidelines stress the need for: (i) depositing research articles after peer-reviewing or manuscripts resulting from their projects in an online OA repository; (ii) effective actions to ensure free access to the same articles within 6 or 12 months (in case of publications in social and human sciences) after publication. These periods allow the scientific editors to ensure a return on investment and OA after the interdiction period has expired [2]. The Horizon 2020 Framework Program, being a recent funding program for research and innovation, highlights all the recommendations set out in previous programs concerning data and metadata in OA [3].

2.2 Research Management

Current Research Information System (CRIS) emerged as an information system of science and technology in which individual and professional information of researchers and professors, funding agencies, projects and scholarships, patents, data and products, equipment and services, are stored. CRIS is intended to assist users in registering, disseminating their work and making decisions in the course of the research [4,5]. The management of science based on CRIS can lead to multiple benefits, such as: (i) to provide administrators and science managers with tools to enable a better evaluation and report of scientific activity; (ii) to provide the academic and scientific community with means to manage their activities; (iii) to support professionals in the media, technology companies, civil society organizations and people in finding innovative ideas and interests that favor the fusion of science and society. It is within the scope of CRIS to make

possible to obtain information on the results of the scientific production carried out in a given institution and its authors, and to know the ongoing activities, projects, departments, funds and portals, as a way of improving the visibility of the research outcome produced in the participant institutions. In this context, the CRIS components are depicted in Fig. 1(Left) [6].

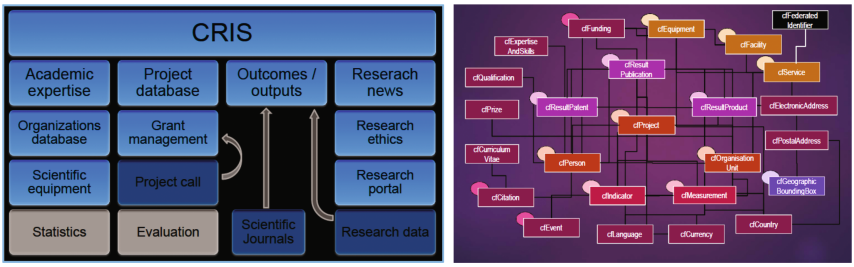

Fig. 1. CRIS ecosystem (Left) and CERIF model (Right). (Color figure online)

2.3 CRIS Evolution

The evolution of information systems for managing scientific activity has evolved, mostly in developing countries with a vast human resource capacity in ICT. Currently, the European Union (EU) has been a major engine of the debate on the development, integration and interoperability of services and platforms for managing science.

OpenAire - OpenAIRE represents an effort for the implementation of sustainable open communication technologies, assuming responsibility for the management and operation of all processes associated with the storage of research results. This involves storing and linking research results with scientific datasets and financing details in existing or future repositories, including the analysis, manipulation, monitoring and other tasks related to research results handling. In the context of Horizon 2020, OpenAIRE2020 represents a new phase in implementing and reinforcing the impact of the EC long-term OA policies, based on previous projects [7].

EuroCris, CERIF - In the European context, euroCRIS is an international non-profit organization whose aim is to promote cooperation among members for the sharing of knowledge in the areas of research and interoperability based on the use of the Common European Information Format (CERIF), the international format model for information in the context of scientific research [8]. In this perspective, CERIF encompasses several areas of interest related to knowledge management and OA, including CRIS scientific datasets and institutional OA repositories, covering the guidelines and best practices for CRIS relations between entities that are semantically defined [5,9]. In this context emerged

CERIF-XML, a language that sustains the exchange of information according to the recommendations of the EU Member States. The CERIF model, presented in Fig. 1(Right) [10], evinces the quality and robustness achieved in this model, since complex roles and relationships between the three main entities (in orange) may be defined, and other entities can be linked by role/date relationships to any or all of these three major entities. As an example, it is possible to obtain useful information, namely: "How many researchers participated in national research projects?"; "In which countries did they obtained the PhD degree?"; "How many scientific papers were published by the same researchers in year Y?".

3 NRENs and OA: The Portuguese Experience

In Portugal, FCT through FCCN unit, the managing body of the Portuguese NREN, is responsible for providing high-speed connectivity and advanced services to academic institutions and research centers. The Portuguese NREN was founded in 1987 and the evolution of its network infrastructure enabled the creation of projects supporting research and education services, especially in the last 10 years, including the access to scientific contents. With the creation of the "*Biblioteca do Conhecimento Online* (B-on)", in 2004, the digital library, supported by FCT, the national academic and scientific community can access a large number of scientific publications and electronic services. Before the creation of B-on, each Portuguese institution acquired its own scientific contents, being the contents only available to the users of the institution. Attending to this situation, the Ministry of Science and Education (then Ministry of Science of Technology) decided to centralize the budget for buying scientific publications and mandate the FCCN (currently FCT) to acquire and manage the access to information. The decision of purchasing access rights through a joint consortium proved to be advantageous as it allowed a stronger ability to negotiate with publishers. For the fulfilment of B-on mission, several entities have been working together, as represented in Fig. 2(left). B-on services are based on contents, which undergo processes of acquisition, access, support, management, evaluation and monitoring, as illustrated in Fig. 2(right).

Another service provided by FCT to NREN community is the RCAAP, the national OA repository created in 2009, available to increase the visibility, accessibility and dissemination of results from national scientific and academic activity. RCAAP is a meta-repository aggregating institutional repositories and journals, allowing free access to a vast number of scientific national publications. In 2010, to enhance the visibility of scientific contents in Portuguese idiom, a Luso-Brazilian memorandum was established, aggregating OA sources from Portugal and Brazil, and the annual CONFOA conference was created.

Currently, RCAAP has available the Institutional Repositories Hosting Service (*Serviço de Alojamento de Repositórios Institucionais* - SARI). SARI is a cloud-based repository service for institutions that do not want to assure technical aspects related to the implementation of repositories, such as servers, connectivity, maintenance, backups, upgrades and monitoring. This service is provided

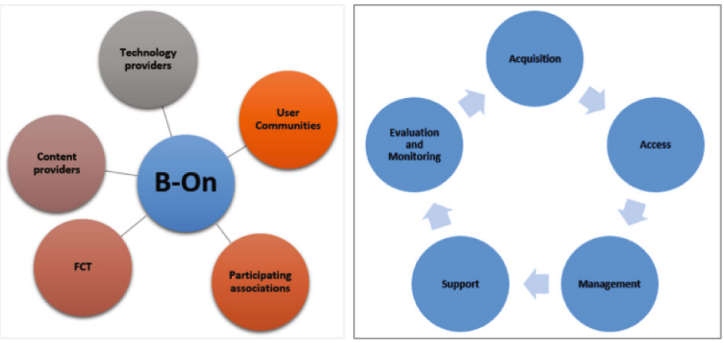

Fig. 2. B-on: (left) service entities; (right) a cycle of five processes

centrally, and institutions only have to worry with administrative aspects. From the 73 repositories participant in RCAAP, 22 are aggregated and 51 are hosted in SARI. Another service associated with SARI is the common repository, available for institutions that do not have their own repository due to their small size or low publications volume. Later on, institutions taking part of the common repository may evolve to a hosted repository, according to RCAAP policies. Apart from SARI, RCAAP supports a hosting service for scientific journals, available for institutions who want to create a journal and undergo its life-cycle, including the release of call for papers, peer reviewing and editing process.

In May 2016, FCT and Mozambique National Research Fund (NRF) signed the first protocol for cooperation between the two countries in the areas of science, technology and innovation. This protocol has resulted from the need to develop joint scientific and technological relations, which will bring mutual benefits to both institutions and their countries. This agreement recognizes the importance of science, technology and innovation in promoting the growth and competitiveness of the national economy, therefore, FCT and NRF aim to promote cooperation in these fields on the basis of equality and mutual benefit. This memorandum of understanding will operationalize the following key areas of collaboration: exchange of staff, scientists, researchers and experts; exchange of scientific and technological information, teaching and learning materials resulting from cooperation; conduct joint activities, including scientific conferences, symposia, workshops and other meetings; support joint research and technological development projects; facilitate scientific exchange among research institutions; exchange experience and expertise in information and communication technology for development; and promote the transfer of appropriate technology [11].

4 The African Context

Generically, NRENs have appeared many years ago with the aim of providing dedicated, high-speed networks to the academic and scientific community as a way to respond to the high communications costs and the lack of specific services of commercial operators. In the African context, NRENs began

to be implemented just over 10 years ago, with South Africa at the forefront. However, a number of factors have pushed the African continent to the bottom regarding communication and services infrastructures, as well as on the sharing of global knowledge at both national and regional levels. The high cost of broadband access and the lack of fiber-based infrastructures at both national and international levels, have made it difficult to fulfill NRNs implementation phase, a situation that is changing due to the recent projects of international connectivity through submarines and terrestrial fiber optics cable connections. At a regional level, associations of NRENs have emerged, such as TERENA in Europe, Internet2 in the United States, and RedClara in Latin America.

In order to extend the network infrastructure to all African countries, two main regional NRENs have been created, namely the UbuntuNet Alliance in Eastern and Southern Africa, and WACREN in Western and Central Africa, which aim to provide a higher quality Internet with reduced costs, and to foster the sharing of knowledge among members, wherever they may be. The UbuntuNet Alliance currently has 15 members, and its creation in 2005 has enabled the community of member countries to share the challenges and experiences, considering their different contexts, and connect them to existing NRENs in the world. The TENET in South Africa, the KENET in Kenya and the MAREN in Malawi are success cases of NRENs operating in Africa. Regarding specific projects:

(i) the AfricaConnect project - The UbuntuNet Alliance Network was the first of its kind in Africa and was implemented between 2011 and 2015, supported by the European Commission. The AfricaConnect project expanded the existing network managed by the UbuntuNet Alliance. This network, presently, has 10 points of presence (PoPs), two of which delivering traffic in Europe (London, Amsterdam) and 8 PoPs within the regional backbone covering 7 countries members of the UbuntuNet Alliance area.
(ii) the AfricaConnect2 project - The plan defined for this project is to extend the network to all African countries and this initiative will serve to stimulate research in the global region. The social and economic differences of the involved countries is pointing out as a challenge in the execution of the project. AfricaConnect2 aims to support the development of high-capacity Internet networks for research and education across Africa. It builds on existing networks in East and Southern Africa and North Africa, and will extend connectivity to West and Central Africa. As a result, AfricaConnect2 will encompass the 3 geographical clusters and their respective regional networking organizations in coordination with Geant, UbuntuNet Alliance, WACREN and, in the North Africa, the Arab States Research and Education Network (ASREN), which operates for the League of Arab States in north. The budget for the AfricaConnect2 project will amount to e26.6m, e20m co-funded by the EC [12].

The higher education and research in Africa still needs external support for researchers and research centers to develop their projects to the level of the best that is done in the world. In this context, open access repositories and digital

libraries allow researchers, even from isolated locations, as long as they have connectivity and available services, to access and share their knowledge on a global level. This is a reality that breaks down many barriers, allowing the involvement and the development of science in Africa at an equal level considering developed countries. For a long time, the access to information on the continent was scarce and, currently, the aim is to face the challenges of implementing OA platforms and associated policies so that the future looks more promising. Issues related to magazines and repositories, institutions and their departments, non-governmental organizations, national initiatives, editors, professional associations and research groups should also be considered. The production of OA Journals in Africa is still insufficient, according to the data available at the Open Access Journals (DOAJ) directory. African Journals Online (AJOL), the African directory of OA journals, created in 1998, is a non-profit organization based in South Africa, targeting health and agriculture as the most prevalent areas of research. In terms of free access to information, the Association of African Universities (AAU), the International Network for the Availability of Scientific Publications (INASP), the Research4Life and the Electronic Information for Libraries (EIFL) are organizations that have led the OA initiatives between the academic and research community. These organizations seek to create sustainable conditions to provide free or low cost scientific literature through agreements and partnerships with commercial publishers, and to establish or enhance the consortia of national libraries, the open access repositories, and the discussion and resolution of issues related to intellectual property rights.

5 Promoting Science in Mozambique

In Mozambique, ICT policies and strategies are recent, only started in 2000, focusing on solving local problems to improve the living conditions of citizens and the development of the country. In this context, the access to information and to scientific/academic production are also defined as relevant issues to frame the country in the global information society. The Science, Technology and Innovation Strategy of Mozambique(STISM) deserves a special attention in this developing scenario.

5.1 Open Access and the Repository SABER

Although it is recognized that the science academy plays a fundamental role in stimulating and disseminating the scientific production carried out in a country, the path to access the scientific literature in Mozambique is focused on the University Eduardo Mondlane (UEM). UEM was chosen to coordinate a consortium of universities (not officially created) to benefit from the support of the INASP project, managing the budget available for paying the access to scientific literature for all public and private higher education institutions in the country. Using this approach, Mozambique got the support of INASP to access 90% of publications having to pay only 10% of the real cost. From the relative analysis

on the use of scientific publications, about 23,000 titles were accessed, totaling 3000 American dollars per year, which leads to a very low access rate, with downloads ranging from 5–10% per year. Thus, although having scientific information available, there are some challenges that need to be addressed, namely: (i) the investment in the training of technical staff in the libraries field; (ii) the creation of a common system that facilitates the integrated research in all databases, or where scientific literature is available; (iii) the inclusion of disciplines that encourage research culture throughout academic and scientific education; and (iv) the lack of a consortium of libraries where technicians and communities with similar interests could discuss the challenges of the access to scientific information. In particular, this last issue has led UEM to began in 2015 the creation of a consortium of HEIs and libraries but this initiative is still in its initial phase of registration of the member institutions. It should be noticed that there are particular areas of interest in which there was also the need to resort to other organizations to support the access to scientific literature in Africa, more specifically HINARI for biomedical, OARE for environment and AGORA for agriculture.

OA initiatives in Mozambique are recent and are the result of a major effort of UEM to promote access and knowledge sharing, and to make the academic and scientific production of the country's institutions visible. In this context, the first multi-institutional repository SABER was launched with the aim of collecting, preserving, aggregating and indexing the academic and scientific production carried out in higher education and research institutions in Mozambique. The SABER repository integrates six HEIs, including UEM. From the analysis carried out after 6 years of its creation, the repository contains about three thousand documents, of various types, including scientific articles, didactic materials, monographs and dissertations. From the analysis concerning the scientific contribution of each member institution, UEM is the institution with the largest number of documents deposited (98%), with the particularity that 78% documents deposited correspond to a period prior to the creation of SABER. Given these numbers and the lack of national policies on OA, it is crucial to understand and fight the existing obstacles that undermine the OA success in Mozambique.

5.2 Research Infrastructures and MoRENet

Within the scope of science and technology policies and strategies defined for Mozambique, the MoRENet project (the Mozambican NREN) was launched in 2006 in order to boost the evolution of the national science, technology and innovation system. In practice, the MoRENet project only started in 2008 after obtaining external financial support and went through several phases of implementation. At present, MoRENet deployment is as follows: (i) in terms of *network infrastructure*, MoRENet is based on fiber optic and SDH-STM technology with 5 Point of Presences (PoPs), 155 Mbps for the backbone as well as 34 Mbps for connecting institutions. It also adds 2 international links of 155 Mbps for shared Internet traffic, one for SEACOM and the other connecting the UbuntuNet Alliance network; (ii) in terms of *interconnected institutions and supported*

services, at the beginning of 2016, 77 higher education institutions had been included all over the country, and the Internet was the main service provided. Presently, the efforts have been targeting the inclusion of other institutions and research centers, the analysis of the type of services to be provided, and the evaluation of the quality of service of the network.

During the different phases of MoRENet implementation, some challenges had to be overcome, namely: (i) the unavailability of operational equipment in the national market involved their external acquisition and corresponding delays; (ii) the metropolitan fiber optic infrastructure coverage was insufficient, which entailed carrying out engineering works to bring connectivity to the institutions; (iii) the cases of electric power failure in the country are frequent, as well as natural catastrophes, and it was necessary to carry out an adequate study and to implement emergency plans to improve network reliability.

5.3 Proposed Model for Science Growth in Mozambique

This section is devoted to present a model for fostering science growth in Mozambique which considers the multiple dimensions of science and takes into account specific challenges in the country that impairs science growth. In particular: (i) the lack of governmental and institutional policies covering OA and management issues, ranging from science to human resources and their qualification, is a reality in Mozambique; (ii) the need for a comprehensive metropolitan fiber optical network throughout the country is urging, as well as the creation of strategies to early respond to the acquisition of network equipment facing the country financial and technological dependence; (iii) regarding higher education and research institutions, the lack of national and institutional mandates and strategic policies for OA end up being factors that prevent the promotion of science in the country.

In this way, inspired by the OA project in Portugal RCAAP [13], an open science model and recommendations to respond to the lack of OA services and to take advantage of the existing NREN infrastructure in Mozambique are here proposed:

(i) the creation of a repository service, or the migration of SABER, into MoRENet, available to all the institutions of this NREN and being centrally managed. This brings innumerable benefits in technical and operational terms, leaving to the member institutions the tasks of documental and workflow management; (ii) for institutions with a reduced volume of publications, the creation of a common repository integrated in this repository service will be advisable; (iii) the ministry of science and technology still lacks specific guidelines regarding OA, as only recommendations for scientific knowledge dissemination were provided. Therefore, it is important that the census of rectors and the academy of sciences are involved in the actions carried out by higher education institutions, the Ministry of Science and Technology, and MoRENet; (iv) in the case of MoRENet, the QoS analysis and continuous performance monitoring is crucial to ensure that, in the future, the institutions can discard the existing connectivity services through commercial operators and that they can contribute to

the economic sustainability of MoRENet. The implementation of new services, the increase of the national and international Internet access bandwidth and the reliable connectivity of the member institutions depends on a sustainable NREN; (v) the lack of technical librarians is another reality in the country and the training of specialized personal in this area to support the academic and scientific community, and content management is mandatory; (vi) a national database of researchers, similarly to Lattes in Brazil and DeGois in Portugal, should be implemented. In addition, the new trends of CRIS should be followed in the science management information system; (vii) as regards research data, in the African context, South Africa is at the frontline, with the largest number of OA repositories, being the only country with a data repository, the South African Data Archive (SADA) [14]. To consider this case study and sharing experiences is also crucial to understand and foster science in developing countries.

6 Conclusions

To efficiently manage scientific activity in developing countries and gain a global and consistent view of science participants and outcomes, the approach for NRENs, OA and CRIS needs to be rethought. In this context, this paper discussed the issues related to the evolution of science in developing countries, with emphasis on the implementation of NRENs, CRIS and OA at a global level of democratization of information access. Portugal represents a success case in terms of efforts in these areas, being here detailed and serving as a guide for this study, which had Mozambique as the main focus. For this purpose, recommendations for promoting scientific production, the sharing and disseminating of the research carried out in Mozambique were pointed out through an evolutive model for science growth in this country. This paper has also discussed the challenges and main resources for accessing information in Mozambique, to guide the proposal of recommendations for the adequate growth of science in Mozambique. These recommendations may serve as a basis for application in other developing countries, aiming at promoting their economic, scientific and social development.

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