Harnessing the Open Science infrastructure for an efficient African response to COVID-19

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To contribute in the collaborative response in some of the work steps and/or financially, please visit https://info.africarxiv.org/contribute/.

Introduction

The international publishing landscape is currently undergoing a drastic shift towards Open Science practices and COVID-19 related research activities are all being made openly accessible for a rapid community driven research and assessment effort (Akligoh et al. 2020; JOGL COVID19 project[1], Open Letter: Contact Tracking and NHSX[2]). In an opinion piece for Financial Times[3], Ethiopian Prime Minister and 2019 Nobel Peace Prize laureate Abiy Ahmed shed a spotlight on the importance of concerted global efforts to fight the pandemic summarizing: "[I]f the virus is not defeated in Africa, it will only bounce back to the rest of the world". The economic and political dimensions which Ahmed focuses on must be grounded in sound scientific research - locally unique, while globally connected. Opening research in developed economies will thus not be enough, we must in addition support, enhance and connect existing pockets of expertise in Open Science on the African continent.

With the current coronavirus pandemic, the urgent need for Open Access to research results will increase scientific public domain knowledge to COVID-19 related literature hence enabling African researchers to develop African-centered solutions towards combating the SARS-CoV 2 virus, while at the same time strengthening the local biomedical resources of African countries and increasing their preparedness for future outbreaks. This applies to both global and regional levels. Previous virus outbreaks, such as the recent Western African Ebola and Zika epidemics, have highlighted the devastating effects of restricted access to data and poorly coordinated dissemination pathways[4]. It is only by removing paywalls, increasing digital access to resources, and fostering individual sharing practices that coordinated attempts to mitigate the effects of the virus can be successful. This is true not only for short-term responses to the health crisis, but also for the longer-term effects on African economies, societal facilities and livelihoods of the people across the continent.

Low and middle income countries' (LMICs) stakeholders have been leading the way with Open Access - particularly the Brasilian searchable full-text journal database network SciELO (Scientific Electronic Library Online) which is also represented in South Africa[5]. We encourage African stakeholders to foreground existing pockets of expertise. It is important to recognize that a coordinated response to information sharing in Africa can rely on a wide range of existing structures supporting openness in research and information sharing. Indeed, what is needed is draw attention to these existing resources, facilitate connections and communication, and address any gaps and shortfalls that such mapping exposes.

To be most effective, African research and innovation stakeholders must work along existing and affordable structures and platforms to ensure that data produced during this pandemic meets FAIR data standards, and that any resultant analyses are published in Open Access platforms and underlying raw data made available on open data repositories.

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[1] https://app.jogl.io/projects/?query=covid
[2] https://medium.com/@rachelcoldicutt/open-letter-contract-tracking-and-nhsx-e503325b2703
[3] https://www.ft.com/content/c12a09c8-6db6-11ea-89df-41bea055720b
[4] https://politica.think.bm/2020/03/covid-19-lessons-from-west-africas-battle-against-ebola/
[5] http://www.scielo.org.za/

Instigating such practices will be beneficial not only for COVID-19 research, but for African research as a whole, and will establish further open and collaborative workflows as well as publishing mechanisms. Enhancing openness within African scholarship is an existing priority on the continent, and a number of key declarations exist to support efforts. These include the Dakar Declaration on Open Access Publishing in Africa and the Global South (2016)[6] and the more recent African Principles for Open Access Scholarly Communication (2019)[7]. These guidelines outline a vision for African open research that addresses the following priorities:

- Federating scholarly ecosystems on the continent from Northern, Central, Eastern, Western and Southern Africa and connecting them to the global research ecosystem.

- Facilitate the amelioration of language barriers esp francophone/anglophone/arabic and also African regional and traditional languages.

- Establish workspaces and sets of technology-enabled tools that are appropriate for use in African research contexts to facilitate faster collaboration and equal opportunity in access to data and services regardless of location, language and other conditions.

- Interconnect with other initiatives, sources, and relevant projects inside and outside Africa both inbound and outbound to maximize Openness and information exchange in a seamless way.

The opportunity that the pandemic offers to research as well as action communities such as makers, (bio) hackers and governments is to reflect upon systemic changes which have been apparent before Corona, and which we now have a real chance to tackle collectively.

An African approach to the COVID-19 pandemic

There is an imperative for a holistic approach to building institutional capacity within the higher education and public funded research centres on the continent. Much like the delivery of the Sustainable Development Goals (SDG), the response to the Covid-19 crisis will need to be brought about through collective action. International response to date is centred around the ability to connect to the populace through media and technology, much of which is concentrated in the metropolises of most African countries. The toll to human life and to African economies is one that requires a globally joint response on how to best utilise and harness resources to support those countries hit the hardest with the specific and diverse realities of everyday lives esp. in urban areas (Adegbeye, 2020).

 Bringing together key stakeholder groups and communities, such as:
- ScienceCommunication & Science Literacy initiatives (PR scientists & journalists)
- Research (biomedical & socio-economical)

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[6] https://www.codesria.org/spip.php?article2595
[7] https://info.africarxiv.org/african-oa-principles/

- Tech & Innovation Hubs (AfriLabs, i4Policy, ASKnet, a.o.)
- Policy makers (municipal, national, regional levels)

On March 18, AfricArXiv launched a decentralized crowdsourcing effort for resources around COVID-19 in a pan-African context[8]. On March 26, 2020, The African Academy of Sciences (AAS) convened a webinar[9] for African and non-African experts to kick-start a common thinking towards defining a research agenda for the COVID19 outbreak & provide a concerted science-based effort for combating this pandemic in Africa. Both initiatives agree that the approach must be inclusive of serving and protecting all Africans, i.e. also vulnerable and marginalized groups such as orphans, Internally displaced people (IDP) and refugees. A theoretical approach of inclusive innovation was described by McPhee et al. (2018) from traditional approach of inclusiveness and be sure that we consider African in its contemporaneity.

Indigenous and traditional knowledge

In most African countries, the use of traditional medicines is commonplace amongst communities. Traditional medicines are often used in conjunction with, or in replacement of, allopathic medicines. Coordinated COVID-19 responses in Africa thus depend on traditional health practitioners, allopathic health practitioners and government guidelines providing a consistent message. In particular, councils for traditional healers must be brought into COVID-19 discussions of national COVID-19 responses.

Research on traditional medicines and indigenous knowledge systems is on the rise in many African institutions, and these expert researchers can act as a valuable conduit between traditional health practitioners, governments and the national health systems (REF).

In a number of African countries, collaboration between health provision communities is already emerging. For example, Traditional Health Practitioners (THPs) in South Africa offer a coordinated position on COVID-19 and discourage false and misleading claims of about powers to cure or knowing how to cure or treat coronavirus (Covid-19)[10]. Examples of such practice should be widely shared for information and best practice.

It is also important that the hard-won protection of indigenous knowledge (as evidenced in the CARE principles) is not overridden by the urgency of the COVID-19 response. In particular, research in areas tangentially connected to COVID-19, health and well-being must continue to be protected. For example, the projects to promote the sustainable production and utilization of African indigenous vegetables for nutrition security and poverty reduction (Abukutsa-Onyango, 2019). African researchers are well-placed to continually scrutinize research in these areas to preserve data protection, ethics and respectful re-use of indiegnous and traditional knowledge.

Importantly, these areas require scrutiny within and between African and international research communities and advocacy organisations (e.g. The Indigenous Peoples of Africa Coordinating Committee, IPACC[11]) on all levels. Many international research units have

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[8] tinyurl.com/COVID19-Africa-Response, twitter.com/AfricArxiv/status/1240208295266304002

[9] (AAS) COVID-19 in Africa: Research and Development Opportunities youtube.com/watch?v=7nyPIS9pcz0

[10] iol.co.za/news/opinion/no-traditional-healer-and-no-traditional-medicine-can-cure-coronavirus-45725864

[11] https://www.ipacc.org.za/

long-standing collaborations with African communities, and such contacts can also be leveraged towards connecting in all areas to facilitate optimal discussion and collaboration, ensuring the implementation of CARE principles[12], adherence to the [UN Declaration on the Rights of Indigenous Peoples](UNDRIP[13]) as well as addressing 'Intellectual Property Issues in Cultural Heritage' (IPinCH project)[14] .

International collaboration

An additional priority of both science governance and funders is to support South-South collaboration. Such collaborations can facilitate best practice sharing and mutual learning so as to identify feasible pathways and operation modes across Africa, and through exchange of knowledge and expertise between Africa, Latin-Amercia, and South-East Asia. There are already good examples of successful practice transfer, such as the adaption of the Latin American Open Access publishing organisation SciELO for South Africa[15].
There has also been considerable support by funders for African-led projects and networks that strengthen research capacity. Such examples include the African Open Science Platform (funded by the National Research Council of South Africa) and the Alliance for Accelerating Excellence in Science in Africa (AESA - partnership of African Academy of Sciences (AAS), New Partnership for Africa's Development (NEPAD) Agency with US$5.5 million in initial seed funding from the Bill & Melinda Gates Foundation, the Wellcome Trust and the UK Department for International Development (DFID)). These funders provide important sources not only of funds for future infrastructural development, but also expertise, and contacts to international expertise and national/regional governance stakeholders.

A range of other stakeholders also exist within the African research ecosystem that already work towards facilitating openness. If properly connected it is possible that these digital tools and stakeholders can already contribute significantly towards achieving the aspirations outlined in the declarations above. Global networks and initiatives such as JOGL[16] or GIG[17] have in recent years gathered tremendous experience in facilitating and managing global communities of practice beyond the provision of databases and repositories.
Nonetheless, for South-South collaborations to flourish, more effort needs to be put into facilitating cultures of openness, sharing and regional collaboration. This has been widely recognized as a priority for African research (REF). Developing mutual trust between community members from different countries, languages, and cultures in addition to developing technical capacities is one of the most pressing challenges for the global open science community right now. Any approach must consider community management, the development of onboarding measures, as well as means to connect the African open science community to other relevant stakeholders. Examples from existing communities, such as H3Africa and MalariaGen, as well as the emerging DELTAS programmes will provide helpful resources and roadmaps towards collaborative research practices.

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[12] https://www.gida-global.org/care

[13] http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf

[14] http://www.sfu.ca/ipinch/

[15] http://www.scielo.org.za/

[16] https://jogl.io/

[17] https://www.globalinnovationgathering.org/

As we are learning from other world regions who are about two weeks ahead with coronavirus incubation times, immediate and directly related research & innovation activities must include the thorough assessment of assessing the current infection rate and statistical analysis on infection, deaths, and recovery on local, national, regional and pan-African levels as well as investigation of socio-economic impacts not only directly related to infection rates but taking into consideration all levels of society and future scenarios.

Table 1: The stakeholders, their expertise and resources
Find a growing list of more than 120 stakeholders at info.africarxiv.org/stakeholders/.

Stakeholders	Expertise / responsibility	Institutions
Policy makers and funding agencies	Ensuring financial sustainability	AfDB, AU, heads of state, research and health ministries, AfDB, African Union Gates Foundation, CZI, World Bank,
Health facilities	medical care	clinics, hospitals, traditional healers
Innovation hubs and makerspaces	Repair, tinker and upcycling of scrap materials and broken equipment, open documentation of work, connecting research and action, creating and utilizing open educational resources (OER)	AfricaOSH, Open Science and Hardware Network - OSHNet (Tanzania), AfriLabs, Impact Hub Network, Jokkolabs Network, RLabs Network, as well as over 400 individual innovation hubs on the African continent such as Vilsquare (Nigeria), MboaLab (Cameroon), KumasiHive (Ghana), STICLab (Tanzania), Robotech Labs (Tanzania), and many more
Journalists	Ensuring Science Literacy	African Science Literacy network
Scientists and researchers	Data collection, viral tests/screens, data analysis	Universities and research Institutions, NRENs
Educational centers and platforms	Capacity building and training on all relevant topics	TCC Africa, OER Africa, INASP, …
General public	Seek information from trusted sources, social distancing	
International communities & organisations (global)	Connecting to global communities of practice, sharing of experience and best practices, connect to overall topics, e.g. infrastructure development	Just One Giant Lab (JOGL), Global Innovation Gathering (GIG), GOSH, ISOC; APC

Most if not all of the stakeholders have already geared up for a thoughtful and dedicated COVID-19 response. It is important that instead of acting in silos we coordinate strategies and approaches across countries, stakeholders, language barriers and sectors of societies.

Collaborating on hardware development for medical supplies

Collaboratively developing hardware internationally has its own specific challenges. These guidelines are designed to help new collaborations avoid common pitfalls. This section is particularly aimed at researchers in the Global North that are looking to help design hardware that can be built and used in Africa

1. Form collaborations between makers, health professionals and end users to understand the environment where the hardware will be used. This is essential for forming appropriate specifications. Local collaborators will likely have experience with similar devices and will know how well they work in the local environment. Consider the availability of supporting infrastructure (does your ventilator require a fixed oxygen supply?), consider the ambient conditions (what is the working temperature range of the hardware?), or the reliability of the local electricity supply. Over the course of the last two years, the Horizon2020 open project Careables[18] has gained much experience in such collaborations between different stakeholders and offers a database of existing solutions as well as support for documentation.

2. Form collaborations for local manufacturing/repair to better understand how much of the design can be built and repaired locally. Local manufacturing and repair is essential to improving the availability and up-time of any hardware. Replacement parts must be sourced or produced locally for local manufacturing and repair to work efficiently. It is worth noting that low-cost/readily-available components in Europe or America does not necessarily correlate with what is low-cost/readily-available locally. For this reason it is essential to involve local collaborators from the first prototyping stages.

3. Consider the speed of international supply chains. Work with local collaborators to understand the lead times for purchasing equipment internationally. The speed and reliability of global supply chains varies significantly by region. Do not assume that because a part can make it from a factory in another continent to your laboratory in a few days that it can reach your collaborators at the same time. Test the supply chains where possible even if a small supply can be sent directly between collaborators. The scarcity or lack of research equipment can partially be compensated by leveraging Open Source Hardware, repair and upcycling of what is available (Maia Chagas et al., 2019).

4. Co-build and collaboratively vet prototypes. While it may seem like a duplication of effort to build prototypes concurrently in multiple locations it allows all relevant partners to be involved with the design. It also allows for early identification issues that may be faced during local production. Collaborative vetting of prototypes, as has
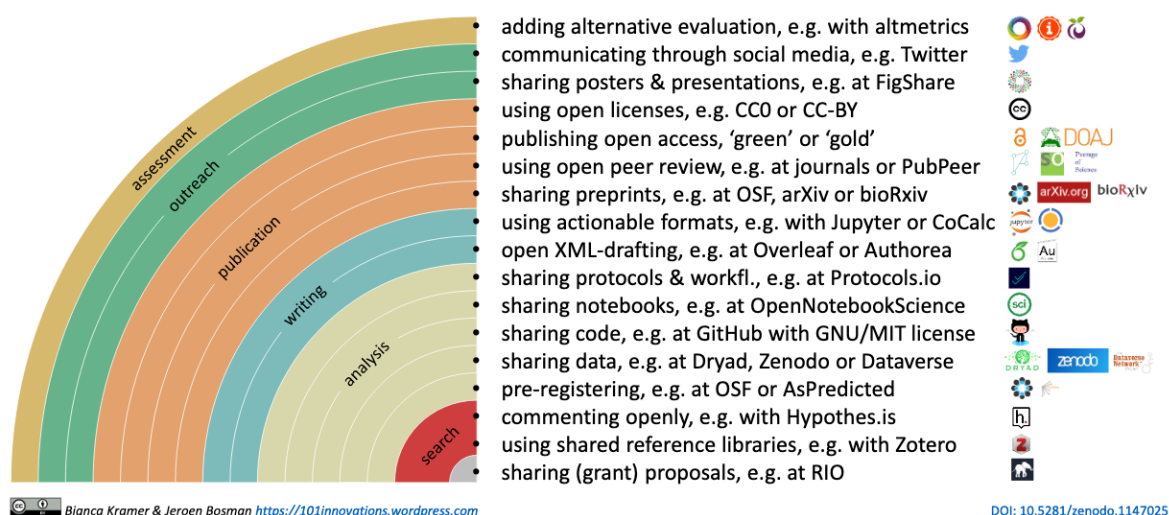
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[18] https://www.careables.org/

been done within the JOGL Covid19 Project, is a useful global endeavor to support local manufacturing of those designs which have proven to be most useful in different contexts.

The Research Workflow in an African context

In the following section, we are breaking down the general research workflow to make specific suggestions to each step from Discovery, Analysis (including project planning, methodology, data generation, results analysis), writing and publishing.

You can make your workflow more open by ...

- adding alternative evaluation, e.g. with altmetrics
- communicating through social media, e.g. Twitter
- sharing posters & presentations, e.g. at FigShare
- using open licenses, e.g. CC0 or CC-BY
- publishing open access, 'green' or 'gold'
- using open peer review, e.g. at journals or PubPeer
- sharing preprints, e.g. at OSF, arXiv or bioRxiv
- using actionable formats, e.g. with Jupyter or CoCalc
- open XML-drafting, e.g. at Overleaf or Authorea
- sharing protocols & workfl., e.g. at Protocols.io
- sharing notebooks, e.g. at OpenNotebookScience
- sharing code, e.g. at GitHub with GNU/MIT license
- sharing data, e.g. at Dryad, Zenodo or Dataverse
- pre-registering, e.g. at OSF or AsPredicted
- commenting openly, e.g. with Hypothes.is
- using shared reference libraries, e.g. with Zotero
- sharing (grant) proposals, e.g. at RIO

Bianca Kramer & Jeroen Bosman https://101innovations.wordpress.com
DOI: 10.5281/zenodo.1147025

Discoverability of relevant research literature

Most academic publishers have made COVID-19 relevant research accessible by (temporarily!) waiving subscription fees.

Web of Science and Scopus are not representing the global bulk research output (Tennant et al., 2019). Unfortunately, ongoing design challenges can mean that literature in English that is published in journals listed in international databases (such as DOAJ) are foregrounded. This is particularly true for small, regional African journals that do not have the capacity to host their full content online. This can mean that African Research outputs are difficult to find and access.

It is recognized that a key means of offsetting the lack of visibility for African research is to strengthen the role that digital repositories play in the African research landscape. To date, the visibility, interconnectivity and searchability of these repositories has varied enormously. Mapping the repository landscape and plotting interconnections is thus vital. A recent

contribution to this has been the publication of a dynamic dataset of African digital research repositories with an interactive visual map (Bezuidenhout, Havemann, Kitchen, De Mutiis, & Owango, 2020). Such resources must be curated and expanded to provide up-to-date information on this important network for data sharing.

It is also important that the emerging African repository ecosystem continue to engage with international experts, such as the Re3data community to ensure that their design and practice meets international standards and facilitates interoperability. In addition to supporting repositories, more effort must be made to build capacity in data sharing and open access amongst the African research community. Support in digital literacy training is thus a vital element of an evolving Open Science landscape. A datasheet of online courses that foster digital literacy should be produced and curated. Efforts should be made to translate content into key languages such as English, French, Swahili and Arabic.

Digital tools for Science that are suitable for low-resourced settings / Based on REF
In recent years there has been a rapid expansion of online tools that facilitate various stages of the research lifecycle. The uptake of these tools in Africa has, however, been limited. It is likely that this is due to a range of different issues, including awareness, research traditions, language, infrastructural challenges and design-related issues. It is important that African researchers actively curate a list of digital tools that are suitable, preferred and sustainable.

Discovery: Digital tools for discovery of relevant scholarly works.
1) = Africa-specific, 2) = global, open source, 3) global, commercial

	Literature search, Repositories	Reference Management
1)	African Journals Online (AJOL), AfricArXiv, DICAMES	- - -
2)	Open Knowledge Maps, BASE Search	Zotero, ReFigure
3)	Google Scholar, The Lens, ScienceOpen SciLit, ResearchGate, Paperhive.org	Mendeley

Methodology & Data analysis

**Analysis: Digital tools for analysis of relevant scholarly works**
1) = Africa-specific, 2) = global, open source, 3) global, commercial

	Methodology	Data repositories	Data visualization
1)		openAfrica, Africa Information Highway Portal, Africa Infrastructure knowledge Program Portal	
2)	Protocols.io	R-OpenSci, Re3Data, Dataverse, Oceanprotocol.com, OSF.io	Gephi, R

3)		Figshare	Kumu,

Agile Remote Collaboration

All collaborative knowledge work benefits from utilizing an agile approach, which offers the added benefit that it is relatively easy to practice with remote teams as well.
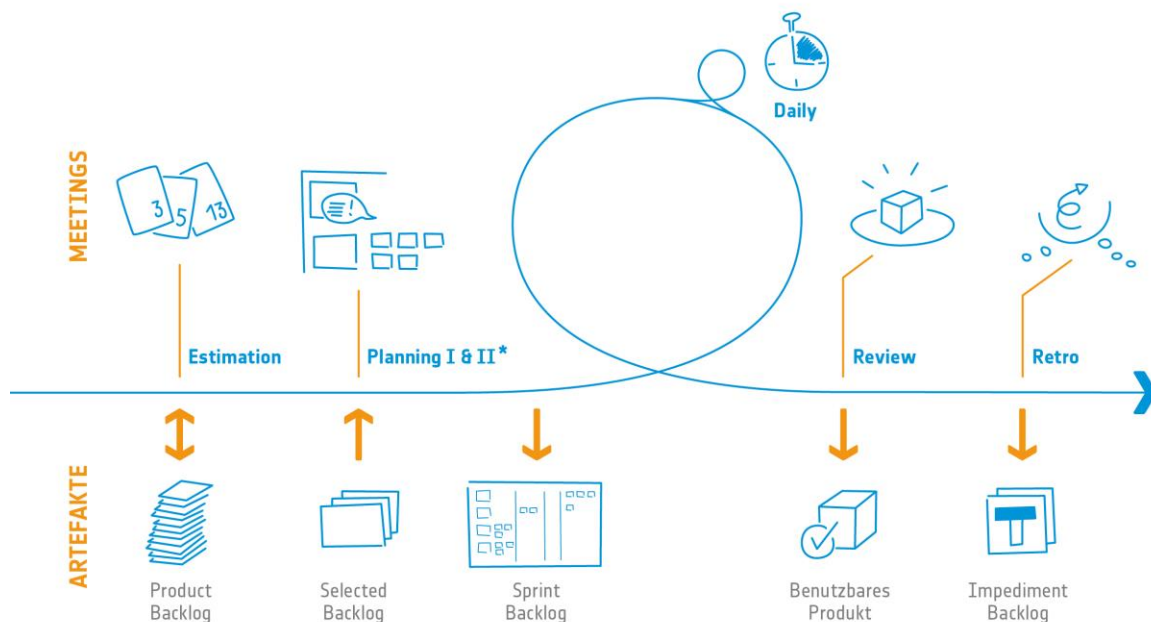
*Im offiziellen Scrum Guide wird das Planning heute nicht mehr unterteilt.

Source: https://www.leanovate.de/training/scrum/

At its core, agile product development involves frequent feedback processes and cyclical (iterative) action at all levels: in the actual doing, at the team level, and in management. Agile approaches appreciate that complex product development cannot be planned in advance in detail, as the requirements will most probably change during the project lifetime and often are not fully understood at the start of the project.
Instead, the agile approach alternates short planning and development phases. Team members agree on goals to be achieved during the respective following sprint, briefly check in with each other on a daily basis and review the increments at the end of each sprint. Through a methodological retrospective, additional process knowledge can be gained.

Important artefacts of any agile collaboration are: a shared backlog of tasks; a shared task board for the following sprint; and regular meetings. It is crucial for agile processes that they are facilitated by dedicated roles on two levels, namely the product (e.g. by a product owner) and the process level (e.g. by a scrum master or agile coach).

	Closed Source	Open Source
Planning / Whiteboard	https://mural.co https://miro.com https://stormboard.com/	https://openboard.ch https://wbo.openode.io/
Task Board	https://trello.com/ https://leankit.com/	https://wekan.github.io/ http://taskboard.matthewros s.me/
Remote Meetings / Calls	https://zoom.us/ https://tico.chat	https://jitsi.org/ https://unhangout.media.mit. edu/
Retrospective	https://www.teamretro.com/ https://www.parabol.co/ https://retrorabbit.io/	https://github.com/funretro/di stributed
Software Suite	https://www.atlassian.com/s oftware/jira	https://www.openproject.org/ https://gitlab.com https://taiga.io/

In addition to the above resources, the Coronavirus Tech Handbook[19] is a current crowdsourced resource of more technologies for remote work. It is important to note that agile remote collaboration is a novel form of research organization for many researchers in both LMICs and HICs. It would be beneficial for African researchers who have experience in this format to provide case studies and examples for further discussion.

Hardware

Collaborative hardware design and development is the core methodology of the global maker community t. Various tools and databases exist and are widely used to design and review designs online, which has already proved beneficial in rapid responses to Covid19. Thousands of makers around the globe have started using their 3D printers and laser cutters to produce face shields as donations to hospitals and care facilities worldwide, supported by the manufacturers of the necessary machines:

Community databases	3D Design	Electronics / Code Design
https://www.careables.org/ https://www.welder.app/ https://www.opensourceecology.org/ https://www.openhardware.io/ https://www.thingscon.org/ https://hackaday.io/ https://www.instructables.com/ https://makershare.com/	https://www.thingiverse.com/ https://grabcad.com/ https://www.prusaprinters.org/ https://fab365.net/	https://upverter.com/ https://easyeda.com/ https://library.io/ https://codebender.cc/

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[19] https://coronavirustechhandbook.com/remote

DIY Bio and Community Biotechnology

In addition to the challenges of using digital research tools, African researchers often have to contend with shortages of physical research equipment. DIYBio and Community biotechnology provide a growing bottom-up approach to research that leverages open science and open technologies to drive research and development. This growing community movement is key to opening up research output coming from Africa while enabling sustainable solution development. Efforts from research groups like the Open Bioeconomy Lab[20] and its lab nodes in Africa, Hive Biolab[21], are developing an open research tool kit to enable labs in resource-limited environments and labs in Africa, Asia and Latin Americato locally produce research reagents like enzymes that have the capacity for testing for SARS-CoV 2 virus.

Research Data Management

The management of COVID-19 data is an international topic, and has seen many influential data organizations, such as the Research Data Alliance (RDA) form working groups to outline research data management (RDM) practices. These RDM practices consider FAIR and CARE principles, but it is vital that African members of these international organizations engage in these discussions to ensure that the emerging standards and practices reflect the data being generated in Africa.

Mobilizing the engagement of African researchers in RDM discussions will provide a broader opportunity to assess current RDM practices, training and infrastructural provision on the African continent. This will allow for the evolution of RDM practices that align with international practices and reflect the realities of research in Africa. It will also influence the design of future data and publishing infrastructures.

Writing & Publishing

1) = Africa-specific, 2) = global, open source, 3) global, commercial

	collaborative writing	Institutional repositories	journals (OA), publishing platforms
1)		AfricArXiv, IAI/repositories, essa-africa.org/AERD, DICAMES	AAS Open Research, AJOL, https://upverter.com/ https://easyeda.com/ https://library.io/ https://codebender.cc/ Scientific African, African Minds
2)	Authorea, Overleaf, GitHub	OSF preprints PeerJ	DOAJ, academicjournals.org/journal, PKP's Open Journal System, Coko Foundation product suite, Open Publishing Awards, Janeway/ PubPub, ScholarLed, Directory of Academic-led Presses
3)	Google Docs		Qeios.com, academicjournals.org/

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[20] https://openbioeconomy.org/
[21] https://openbioeconomy.org/team/ghana-node/

Rapid publication process (>>>)

Research & Analysis	Text and data Open Access archiving	Global community peer review	Journal publishing
Screening and collecting relevant research literature and data, immediate/acute research on symptoms, viral strains, societal and economic impact of the lockdown https://github.com/dsfsi/covid19africa	AfricArXiv, DICAMES, bioRXiv, medArXiv, preprints.org	PREreview PeerCommunityIn Hypothes.is	AJOL, Le grenier de Savoir, DOAJ-listed journals

Africa-focused preprint and Open Access platforms like the pan-African preprint repository AfricArXiv[22], the Kenya-based AAS Open Research platform as well as internationally oriented preprint repositories, like Open Science Framework (OSF), Preprints.org, biorXiv, medrXiv and ScienceOpen/preprints, implementing an Africa-focused and yet internationally connected peer review mechanisms, e.g. by joining international community-driven rapid response initiatives such as Outbreak Science Rapid PREreview[23].

It is important to recognise that African institutions rely predominantly on the publication of peer-reviewed papers to assess research excellence and define promotion criteria. Such systems of assessment are under discussion around the world, but unlikely to change in the near future. Thus, the need for African researchers to publish peer-reviewed papers in internationally-recognized journals must be respected. Nonetheless, it is possible that the use of innovative publishing models, such as peer review being done on a preprint level via services like hypothes.is and peercommunityin.org, may streamline this publication.

Outreach, Assessment & Knowledge transfer

1) = Africa-specific, 2) = global, open source, 3) global, commercial

		Public engagement & Citizen Science	Tech communities and consultancies
1)		Global Lab Network, Pollicy, Science Communication Hub Nigeria, Café Scientifique, African Science Literacy Network, Under the Microscope	AfricaOSH, Vilsquare, African Open Data, EthLagos.io, Open Science and Hardware Network (OSHNet), STICLab, Robotech Labs
2)		ORCID	Gathering for Open Science Hardware (GOSH)

A small, but growing, number of Citizen Science initiatives and networks on the continent also provide an avenue for knowledge dissemination. Their involvement can be achieved by

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[22] https://info.africarxiv.org
[23] https://outbreaksci.prereview.org/

setting collaborative projects, such as keeping citizens informed in multiple languages by sharing consistent translated messages across social networks (Bezuidenhout et al, 2020).

Public engagement and science journalism is a small, but emerging field within Africa. While there remain challenges associated with low science literacy and historic lack of engagement between academia and the public, there have been many positive recent changes. It is vital that researchers continue to engage with the public to prevent misinformation and to provide up-to-date information about both local and international research. For this, further collaborations with African journalists to improve public access to research is key.

Reaching all citizens demands the catering for language diversity[24] via journalistic approaches as addressed by the African Science Literacy Network in Nigeria[25], e.g. via video messaging and dissemination of key information as provided by the WHO via social networks, as suggested by Bezuidenhout, McNaughton & Havemann (2020) or Artificial Intelligence (AI) approaches like "Wash your hands" in 500+ languages[26].

Improving Visibility of African Research

Interoperability is a key element in scientific and research communication. Information flowstream should be reliable to build sustainable research and academic infrastructure. Linking research works to different academic research platforms is defining interoperability and supporting discoverability across disciplines, borders and time.

A range of different African organizations are already engaged with these issues. In particular, the data-intensive research/high-performance computing institutions (such as DIRISA in South Africa) are developing considerable expertise in data sharing and interoperable research platforms. Such institutions are supported by both national and international funding and expertise, and represent an important resource for the emerging Open Science infrastructure in Africa.

Moreover, a number of independent organizations, such as AfricArXiv and similar pre-prints repositories are also assisting efforts to facilitate information sharing across platforms. With the support of Africa Open Access network partners, AfricArXiv provides an important resource for African researchers. Starting from the ORCID authentication and permission to read the researcher's contribution to the distribution through other platforms and channels as per Zenodo.

Capacity building and training

For researchers	For medical personnel

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[24] https://info.africarxiv.org/languages/
[25] http://www.africanscilit.org
[26] https://datadan.io/blog/wash-your-hands

https://www.tcc-africa.org/ http://www.authoraid.info/ // https://www.inasp.info/ http://eifl.net/ https://www.jstor.org/ https://science4africa.org/	CDC Africa COVOD-19 medical training webinar: https://vimeo.com/401111213/a4f2ac2720 AMREF, https://amref.org/

(Open) Educational Resources

There is already a long history of distance and online learning in Africa. For example the University of South Africa, founded in 1946, is one of the oldest and largest distance learning institutions in the world. Moreover, centres such as the Centre for Innovation of Teaching and Learning at the University of Cape Town, provide globally-recognized expertise in digital learning. Similar activities are hosted by institutions and platforms both nationally and on a continental level (https://oerafrica.org/). Mapping existing expertise in these areas will provide valuable resources for the expansion of OER in Africa. Moreover, collecting advice documents for the use of OER/digital learning tools in low-resourced settings (such as the one by UCT[27]) will provide useful resources.

The eLearning Africa Report 2019 lists 55 African countries with examples and capacities for ICT for education (country profiles), many of which can also be utilized during the research workflow from project development to publication of the results (Elletson and Stromeyer, 2019).

Financial sustainability

Optimizing immediate finances
In order to facilitate the evolution of an open infrastructure for COVID-19 response, it is vital that funds are found to facilitate coordination. There are many ways in which these funds could be sourced, including:
- Consolidate for overlapping activities
- Identify current projects and active funders addressing infrastructural reform (and form open database)
- Curate a list of open grant calls to co-apply to
- Approach intern/national funders and governments directly

Long-term financial sustainability
The coordination of open infrastructures in Africa will have benefits for African research far beyond the COVID-19 pandemic. Ensuring long-term financial sustainability to support the maintenance of structures emerging from the current crisis, and identifying new stakeholders to assist with the evolution, will be key. Issues to address will be:
- Gather evidence on the COVID-19-induced coordination and the impact of these open infrastructures

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[27] https://docs.google.com/document/d/1zPN7XUitOCw75FW6UeqrYAcWl41UqgKoZ_HRoYTKFZI/edit

- Continue to lobby for a bare minimum of 1% GDP for research from national governments, and ensure that steadily increasing investing in research infrastructures is at the foreground
- Critically assess national policies on data sharing and research to effect change that will support open infrastructures
- Engage with funding councils to ensure that Open Science infrastructures are on their agenda
- Call for international collaboration from the global Open Science community
- Identify funding models, or viable business models that work for and with the African research community. We propose a transparent and mixed funding model, inclusive of:
  - → pan-African: African Union, AfDB, …
  - → African national governments (R&E ministries)
  - → national research societies such as ASSAf (SA) and SRF (Sudan)
  - → African foundations such as Mandela / Mo Ibrahim / …
  - → Subsidized by international support via B&M Gates Foundation, Chan-Zuckerberg Initiative, Mozilla Foundation, Sloan Foundation, etc.
  - → USAID; European funding agencies: (UK) Wellcome Trust; (GER) DFG, Max Planck / Leibniz / Helmholtz Society, DAAD; (FR) CNRS; (SWE) SIDA
  - → Scholarly services: translations, Science Communication to the general public (simplifying academic slang), capacity building training for scientists, ECR and students // who pays for what service?

Limitations & challenges

Discussions on long-term financing of Open Science infrastructures need to be specific about who benefits from research results being shared openly early in the process, and what formats properly facilitate this. There is an urgent need to restructure the finance system of who pays for what and when. Scholarly literature and data repositories should be an integral part of the research process; but who pays for the operations/handling, DOI allocation, data hosting etc. at what level in the process?

Beware of sanctioned countries and what impact that might have on the national research landscape: Bezuidenhout et al (2019). The lack of reliable, affordable, fast internet connectivity still poses the biggest challenge to any attempts of online collaboration in many parts of the African continent.

Outlook

We call for partnership building and collaboration across the continent and with international support from other world regions and donor countries.

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Appendix: Organisations and digital services

African and non-African organisations and digital services as mentioned in this document. For an extended version of this table go to https://tinyurl.com/sfbb6xn

Organisation	url	country
Africa Infrastructure Knowledge Program	http://infrastructureafrica.opendataforafrica.org/	Pan-African
African Development Bank (AfDB)	https://www.afdb.org/en	Tunisia
African Information HIghway Portal	http://dataportal.opendataforafrica.org/	PanAfrican
African Journals Online (AJOL)	https://www.ajol.info/	South Africa
African Open Data	https://africaopendata.net/	Ghana
African Science Literacy Network	https://www.africanscilit.org/	Nigeria
AfricaOSH	http://africaosh.com/	Ghana
AfricArXiv	http://info.africarxiv.org/	pan-African
AfriLabs	https://www.afrilabs.com/	Nigeria
BASE Search	https://base-search.net/about/en/contact.php	Globa
bioRXiv	https://www.biorxiv.org/	USA
Café Scientifique	http://www.rouleauxfoundation.org/cafe-sci/	Nigeria|Global
Careables	https://www.careables.org/	EU	Global
Code for Africa	https://github.com/CodeForAfrica/	Kenya
Dataverse	https://dataverse.org/	USA
DICAMES	http://dicames.scienceafrique.org/	Madagascar
EthLagos	https://ethlagos.io/	Nigeria
Figshare	https://figshare.com/	London	USA
Gephi	https://gephi.org/	Global
Global Innovation Gathering (GIG)	https://www.globalinnovationgathering.org/	Germany	Global
Global Lab Network	https://glabghana.wordpress.com/	Ghana
Google Scholar	https://scholar.google.com/	Global
Hypothes.is	https://hypothes.is/	USA
Impact Hub Network	https://impacthub.net/	Austria
INASP	https://www.inasp.info/	United Kingdom
Jokkolabs Network	https://www.jokkolabs.net/	France
Just One Giant Lab (JOGL)	https://jogl.io	France| Global
KumasiHive	https://www.kumasihive.com	Ghana
Kumu	http://kumu.io/	USA
MboaLab	https://www.mboalab.africa	Cameroon
medrXiv	https://www.medrxiv.org/	Global
Mendeley	https://www.mendeley.com/	United Kingdom
Oceanprotocol.com	https://oceanprotocol.com/	Singapore
OER Africa	https://www.oerafrica.org/	South Africa

Open Africa	https://africaopendata.org/	Kenya
Open Knowledge Maps	https://openknowledgemaps.org/	Austria
Open Science and Hardware Network (OSHNet)	http://www.oshnet.africa	Tanzania
openAfrica	https://open.africa/	South Africa
ORCID	http://orcid.org/	USA
Open Science Framework (OSF)	http://OSF.io	USA
Paperhive	http://Paperhive.org	Germany
PeerCommunityIn	https://ecology.peercommunityin.org/	France
Pollicy	http://pollicy.org	Pan-African
Preprints.org	https://www.preprints.org/	Switzerland
PREreview	https://www.prereview.org/	USA
Protocols.io	https://www.protocols.io/	USA
rOpenSci	https://ropensci.org/	USA
Re3Data	https://www.re3data.org/	Global
ReFigure	https://refigure.org/	Global
ResearchGate	https://www.researchgate.net/	Germany
RLabs Network	https://rlabs.org	South Africa
Robotech Labs	http://www.robotech.co.tz	Tanzania
Science Communication Hub	http://www.SciComNigeria.org	Nigeria
ScienceOpen	https://www.scienceopen.com/	USA
SciLit	https://www.scilit.net/	Switzerland
STICLab	http://www.sticlab.co.tz	Tanzania
TCC Africa	https://www.tcc-africa.org/	Kenya
The Lens	https://www.lens.org/	Australia
Under the Microscope	https://www.underthemicroscope.net/	Kenya
Vilsquare	https://vilsquare.org/	Nigeria
Zotero	http://zotero.org/	USA