Science Systems in Africa: An Examination of the Contribution of African Universities to the Advancement of Scientific Knowledge.

Conceptual Paper

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Abstract

This paper critically examines African universities' contribution to scientific knowledge advancement. The paper sets the context by discussing the debates and contestations surrounding science systems, particularly in relation to European and non-Western states. It identifies two dominant critiques of Eurocentric narratives: European-based scientists' narrow and reductionist perspectives over scientific epistemologies in non-western societies and the establishment of patriarchal, racial, gender and sexual hierarchies that privilege male dominance over females and distinctions. These hierarchies continue to be institutionalised and propagated by higher learning institutions to date.

The paper argues that knowledge production during the eighteenth century was embedded in global contexts and that scientific knowledge was not confined to European academic institutions but rather a product of co-constructive processes from communities and individuals worldwide. It discusses the emergence and nature of modern Science in Africa, highlighting the impact of colonialism on existing knowledge systems. Despite this, Africa contributed to the advancement of European science, although European scientists overlooked advanced indigenous science and knowledge. The paper concludes by stressing the need for a more inclusive and equitable approach to science systems, particularly in non-western societies, and the importance of recognising and valuing diverse knowledge systems' contributions to scientific knowledge advancement.

Science systems: Setting the context.

Science systems as understood today have been debated and contested over the years. Discourses often attempt to compare scientific development in the seventeenth century between European and non-western states, including China, India, and the Islamic states.[1] Most discourses portray science systems as a herald of the so-called 'scientific revolution' during the Enlightenment era, which gradually institutionalised throughout the 19th century, leading to what we now consider 'modern science'.[2] These perspectives assumed that significant advancements in science were catalysed by pioneers like Galilei Galileo (1564-1648) to Isaac Newton (1642-1727), who challenged established knowledge foundations upheld by philosophers like Aristotle.[3]

However, these narratives have been critiqued equally, and the debate has been endless. As Peter Reill notes, the legacy of the scientific revolution itself is "extremely complex, contradictory and rich in various interpretations".[4] Although the intention is not to rehash these debates here, two strands of criticism stand out.[5] First, while popular discourses attribute Europe as the genesis of scientific systems,[6] these accounts are narrow and as Kapil Raj has noted, modernity and scientific institutions 'are not simple emanations from a pre-existing centre but, rather, they emerge from a 'complex saga of the collisions, compromises and comings' of many countries in and outside Europe.[7]

The second and related dominant critique of Eurocentric narratives is the domineering and reductionist perspectives of European-based scientists over scientific epistemologies in non-western societies, especially within their colonies. One tendency among Eurocentric scientists is to discount and underrate non-Western societies' scientific epistemological and ontological knowledge systems. They often consider these societies, including African ones, as 'passive' entities of Western science without contributing to their discourses. [8] There is broad literature explaining the factors behind this. Still, one comprehensive explanation is Walter Mingolo's perspective on the rhetoric behind modernity, which he analogises as the 'four-headed and two-legged monster'.[9] Walter argues modernity, which came along with coloniality, led to the emergence of the 'colonial matrix of power' comprised of two 'legs',

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[1] This debate is extensive, and various authors have been reviewed in this paper, including Roy Porter, ed. *The Cambridge History of Science.* Vol. 4. The Cambridge History of Science, (Cambridge: Cambridge University Press, 2003); and Toby E. Huff. *Intellectual Curiosity and Scientific Revolution: A Global Perspective*, (New York: Cambridge University Press, 2010).

[2] James McClellan, "Scientific Institutions and the Organization of Science," in *The Cambridge History of Science* 4, ed. Roy Porter (Cambridge: Cambridge University Press, 2003),87-90.

[3] For an excellent analysis of these debates, see Peter Hanns Reill, "The Legacy of the Scientific Revolution: Science and the Enlightenment, in *The Cambridge History of Science* 4, ed. Roy Porter (Cambridge: Cambridge University Press, 2003), 23-43.

[4] Ibid, 25.

[5] See a broader debate of these in Kapil Raj, Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe 1650-1900, (Basingstoke and New York: Palgrave Macmillan, 2007):1-10

[6] This literature is wide, majority of the debates are summarised by Jonathan Daly, *How Europe made the modern world: Creating the great divergence*, (London: Bloomsbury Publishing, 2020)

[7] Ibid. *Op.Cit*., 7.

[8] Specifically on Africa, see Gloria Emeagwali and Edward Shizha, eds., "'Introduction" in *African Indigenous Knowledge and the Sciences Journey into the Past and Present* (Rotterdam: Sense Publishers, 2016), ix – x.

[9] Walter Mignolo, *The darker side of western modernity: Global futures, decolonial options*. Durham and London: Duke University Press, 2011), 3-9.

that is, race and patriarchal foundations of knowledge that were used as tools of control in four domains of human relations, particularly in African and Indian colonies. These domains include economy, authority, gender and sexuality, knowledge, and subjectivity. Science (initially preceded by theology), Walter argues, was the foundation of the colonial matrix. The logic behind the colonial matrix was that human relations are structured along racial, gender and sexuality hierarchies that privilege white, European male, and heterosexual social relations.[10]

Several outcomes of these hierarchies exist in non-Western societies, including in Africa; two are particularly relevant to this paper. First, as noted above, is the establishment of a scientific epistemic hierarchy that over-privileges Western epistemologies over other knowledge systems in non-Western societies.[11] Also related is the creation of linguistic hegemony that subalternises non-Western languages.[12] This hierarchy continues to be institutionalised and propagated by higher learning institutions to date.[13] Second, is the establishment of patriarchal, racial, gender and sexual hierarchies that privilege male dominance over females.

Most discourses have widely critiqued European epistemic hegemony of scientific systems. Sebastian Conrad critiques European Enlightenment accounts and notes that knowledge production during the eighteenth century was embedded in global contexts.[14] As such, most historians of modern sciences observe that scientific knowledge was not confined to academic institutions in Europe but rather a product of co-constructive processes from communities and individuals in Latin America, Africa and Asia.[15] As discussed later in the paper, this perspective is crucial in understanding complexities that underline the development of science systems in states that emerged from European colonies, particularly in Africa.

One of the notable works that discusses the emergence and nature of modern Science in Africa is Hellen Tilly's study of how colonialism used Africa as a testing environment for European ecological models. Hellen argues that Africa contributed to the advancement of European science despite the European scientists overlooking advanced indigenous science and knowledge.[16] Moreover, as various historians have observed, no civilisation has monopolised scientific and technological developments that led to the emergence of

[10] Walter has discussed these ten points. See, *Ibid*., 17-19.
[11] There is wide literature on this: See, Ezeanya-Esiobu, ed., "Indigenous knowledge and curriculum in Africa," in *Indigenous Knowledge and Education in Africa*, (Singapore: Springer, 2019): 1-8; Francis Adyanga Akena," Critical Analysis of the Production of Western Knowledge and Its Implications for Indigenous Knowledge and Decolonization," *Journal of Black Studies* 43, no.6. (2012): 599–619.
[12] For a comprehensive debate see Alfa I. Sow and Mohamed H. Abdulaziz, "Language and Social Change," in *General History of Africa 8, Africa Since 1935,* eds., Ali Al'Amin Mazrui, and Christophe Wondji, (London: Heinemann Educational Books*, 1993*): 522 -552. For discussion based on hegemony of English over African languages in Kwesi Kwaa Prah, *The Burden of English in Africa: From Colonialism to New-colonialism,* (Cape Town, South Africa: CASAS, 2009),1-14.
[13] Akena, *Critical Analysis of the Production of Western Knowledge*, 586-588.
[14] Sebastian Conrad, Enlightenment in global history: A historiographical critique, *The American Historical Review* 117, no.4 (2012), 1009.
[15] Ibid., 1011-1012.
[16] See especially chapter three in Hellen Tilley, *Africa As a Living Laboratory: Empire, Development and the Problem of Scientific Knowledge, 1870-1950* (Chicago and London: University of Chicago Press, 2011): 115-168.

contemporary science systems.[17] Indeed, a study of multiple traditions of antiquity in Egypt, Mesopotamia and China shows that their cultures had established institutions and administrative frameworks for scientific practices. Moreover, Allan Chalmers contends that most of the dominant narratives of science are generalised historical narratives of physical sciences and do not offer comprehensive development accounts for physical and social science disciplines. [18] Consequently, there is hardly a universally accepted definition of science and scientific systems.

Another crucial point to note is that the advancement of modern science and technology following the Western Industrial Revolution, such as medical and military technologies, is often portrayed as a solely European innovation that was transferred to and adopted by its colonies. However, Karsten Schulz's discussion on coloniality (seen as a core element of modernity that perpetuates both epistemic and ontological lived experiences of colonialism) argues that these modernisation narratives are interwoven with Western civilisation narratives that, in effect, 'silence and subalternises' non-western society's knowledge systems.[19]

On the one hand, this framing shows how these narratives overlook the relationship that the advancement of technology had with colonialism and capitalism. Taking account of these intersections demonstrates how scientific and technological progress was also enabled by, and arguably would not be possible, without slavery and exploitation of resources.[20] On the other hand, and more importantly, these discourses obscure the role of 'local ingenuity' such as asymmetric resource flows of cheap resources, labour and, arguably, from Hellen Tilly's viewpoint. These indigenous societal knowledge systems essentially fuelled scientific and technological progress. Indeed, as Hornborg sums it, 'Ingenuity is a necessary but insufficient condition for modern technological advancement.[21]

The modernist perspective of science systems

Contemporary modern science perspectives consider eighteenth-century Europe as the genesis for modern academies, science societies and journals that form the elements of science systems.[22] The prominence or rather the 'divergence' of scientific development in Europe from other states is attributed to the novelty among European scholars interested in applying analytical scientific methods to explore, interpret and critically examine ideas about the natural world gathered around the globe.[23] As Toby Huff describes it, the' intellectual

[17] Pierre Papon and Remi Barré, "Science and technology systems: a global overview," *World Science Report* (Paris: UNESCO Publishing, 1996): 8.
[18] Allan Chalmer, *What is thing called Science?* 3rd ed., (Queensland Australia: Hackett Publishing, 2013): 247
[19] Karsten, A Schulz, "Decolonizing political ecology: ontology, technology and 'critical enchantment." *Journal of Political Ecology* 24, no. 1 (2017): 132.
[20] Alf Hornborg, "The political ecology of the Technocene: Uncovering ecologically unequal exchange in the world-system," in *The Anthropocene and the global environmental crisis*, (London: Routledge, 2015): 59-61.
[21] *Ibid*., 60.
[22] See James McClellan, *Scientific Institutions.*
[23] Jonathan Daly, *How Europe made the modern world: Creating the great divergence*, (London: Bloomsbury Publishing, 2020): 97-99;

curiosity' in Western civilisations led to the development of a 'surplus of human capital' scientists and education systems that were unmatched globally.[24]

This approach to questioning the natural world differed from other Chinese, Indian and Islamic scholars. Writing about why modern science did not develop elsewhere, like in China, despite having advanced artisans and philosophers, Jonathan Daly attributes this to their disdain for innovation, disinterest in exploration and resistance to foreign ideas.[25] On the contrary, Ian Inkster observes that Asian countries such as Japan, China, and India already had advanced industrial technologies before the arrival of European industrial techniques, which had minimal impact on countries such as Japan.[26]

Nevertheless, the United Nations Educational, Scientific and Cultural Organization (UNESCO), which gives a global status of science in the world through the World Science Report, considers science as more multifaceted than a stand-alone activity.[27] A widely accepted view is that modern science is interconnected with other public and private sectors of society. This perspective, described by Peter Tindemans as 'the triple helix', refers to the systemic cooperation between knowledge institutions, corporations, and government bodies to foster innovation and economic and societal development. Therefore, science is rarely seen as a standalone entity; instead, it is linked to technology and innovation. The premise is that interconnectedness between universities, corporations, governments, and private investors is crucial in creating innovation and economic networks. Local and national knowledge networks are vital in advancing progress and prosperity in societies. As such, the growth of science, technology, and innovative problem-solving approaches are essential components of science systems.

'Modern' Science systems, typically in developed states, are considered an amalgamation of formal scientific institutions and processes dedicated to the pursuit of generating, organising, and disseminating scientific knowledge. [28] This includes education systems, entities that perform research and development, such as universities, laboratories and institutes, and processes involved in generating knowledge, from research methodologies to peer and ethical review processes. Equally, enablers of the scientific process, from government and international funding agencies to private foundations that provide financial support to scientific research and data management and technological systems crucial to analysing, storing, and sharing information, are considered part of scientific systems. In addition, institutions involved in disseminating scientific knowledge, such as publishing houses, conferences, scientific journals, workshops and seminars to actual processes of applying scientific findings and influencing policy to address societal challenges, are critical components of scientific systems.

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[24] Huff, *Intellectual Curiosity,* 7-8.
[25] Ibid *Op.Cit*., 99 – 100.
[26] Ian Inkster, "Technological and Industrial Change: A Comparative Essay," in *The Cambridge History of Science* vol. 4, ed. Roy Porter (Cambridge: Cambridge University Press, 2003), 853-4.
[27] M.G. K. Menon, "Introduction," *World Science Report*, (Paris: UNESCO Publishing, 1993),3.
[28] John Mouton, "African Science: African Science African Science: A diagnosis," in *The Next Generation of Scientists in Africa*, eds., Catherine Beaudry, Johann Mouton and Heidi Prozesky, (Cape Town: African Minds, 2018): 5-6.

Understanding Science Systems in Africa

This paper argues that the starting point for discussing the science system in Africa ought to begin by decolonising Western ontologies and epistemologies of knowledge. As Walter Mignolo notes, decolonising knowledge does not mean rejecting Western thoughts and their contributions to the world but realising and de-chaining their imperialistic underpinnings.[29] As such, the decoloniality of Western notions of science also means 'mutual learning', bridging building and examining the middle ground to generate new ideas. This approach is essential to interrogate contemporary challenges because singular perspectives have their limits.

Moreover, applying Walter Mignolo's ideas of decolonial thinking,[30] decolonising science systems in Africa needs to recognise the intersections between the epistemology of geographical factors that have influenced African societies and the epistemology of their lived experiences with science systems. This approach aims to recognise the value and legitimacy of what Mignolo describes as 'I am where I think'.[31] Simply put, it is acknowledging the value of one's thoughts lived experiences wherever your context is, and more importantly, delinking from imperial imaginaries. In the next section, contemporary ideas of science systems juxtaposed with the nature of these systems in Africa are discussed.

To be certain, before the advent of Western scientific knowledge systems, Africans had always had indigenous forms of science. Indigenous knowledge systems were not only utilised to understand their natural world but also to solve and improve their livelihoods.[32] Although most historical discourses on science in the continent focus on colonial and post-colonial periods, science (in its broadest and historical sense) has a longer existence in Africa.[33] Historians have noted that science advanced and flourished as widely in the medical and scientific fields as far back as 300AD in Egypt.[34] However, what has been underexplored in Africa are indigenous knowledge systems such as Traditional Medicine, which Gloria

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[29] Walter Mignolo, *The darker side of western modernity: Global futures, decolonial options*. Durham and London: Duke University Press, 2011), 82.

[30] Decolonial thinking aims to understand and overcome the logic of coloniality that underpins modernity, structures of control that emerged from colonialism. See, Ibid., 10.

[31] Ibid, 91.

[32] See a broader discussion on this in Gloria Emeagwali and Edward Shizha, eds., "Interconnecting History, African Indigenous Knowledge Systems and Science," in *African Indigenous Knowledge and the Sciences Journesy into the Past and Present* (Rotterdam: Sense Publishers, 2016), 2-11

[33] The idea of science here is from a historical perspective, one that goes beyond limits in contemporary modern discourses, to include medieval forms of systematic obtaining knowledge. Such a definition sees science as explained by David Pingree as a 'systematic explanation of perceived or imaginary phenomena, or else based on such an explanation'. This broad view, allows one to see astrology magic, superstitions and divination as elements of science. See David Pingree, "Hellenophilia versus the History of Science," *Isis* 83, no. 4 (1992): 559.

[34] Vivian Nutton, David C. Lindberg, and Michael H. Shank, "Early-Medieval Medicine and Natural Science," in *The Cambridge History of Science*, vol. 2, eds, David C. Lindberg, and Michael H. Shank (Cambridge: Cambridge University Press, 2013) 323–40.

Emeagwali argues is a vibrant and often preferred healthcare system in many parts of the continent due to its effectiveness compared to conventional medicine practices. [35]

Understanding scientific systems in Africa needs to begin with examining their emergence on the continent. Historians have already observed that the majority of present science systems in Africa mirror Western models of modern scientific institutions and attribute the adoption of these models to the continent's stalled scientific and technological development.[36] Most of the present institutions, including primary and secondary schools, teacher training, technical institutions, and universities, were established at the onset of the colonial period from the 1860s, albeit at different times in various colonies triggered primarily by the spread of European and American missionaries.[37] Needless to say, as Ali Mazrui and other scholars remind us, long before universities in the Western World were established, scholars in African Universities, such as Timbuktu in Mali and Al-Azhar in Egypt, had already made significant scientific advancements linking religion with science as well as developing of numerals used in mathematics.[38]

Discourses on the state of African universities focus on their emergence in the post-colonial period.[39] Although many of the universities that emerged began functioning in the 1950s, the establishment was uneven; they were expensive, and graduates aimed to attain status symbols and prestige and increase their social mobility and influence.[40] In addition, contrary to popular expectations, the universities were insufficiently set up to respond to societal challenges, such as developing valuable technologies for agriculture and public health in rural communities.[41] Furthermore, at the time, female students were inadequately represented in universities, and those who joined tended to focus on social science disciplines and humanities, which were seen as less of a national priority.

The structural dissonance between universities and societies has been extensively discussed. One of the primary reasons for this can be attributed to language disparities. Scholars have pointed out that colonialism had a destructive impact on African languages, as the education system aimed to create a group of loyal administrators and professionals proficient in European languages. [42] These individuals eventually became leaders of their respective

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[35] See Gloria Emeagwali,"African Traditional Medicine Revisited," in *African Indigenous Knowledge and the Sciences Journesy into the Past and Present* eds., Gloria Emeagwali and Edward Shizha (Rotterdam: Sense Publishers, 2016), 161.

[36] Helen Tilley, "The History and Historiography of Science." *Oxford Research Encyclopedia of African History*. (Nov. 2018): 1-39. See also, Ali Mazrui and J.F. Ade Ajayi in collaboration with A. Adu Boahen and Tshishiku Tshibangu, "Trends in philosophy and science in Africa, in G*eneral History of Africa VII: Africa since 1935,* eds. Ali A. Mazrui, assisted by C Wondji (Heinemann, UNESCO: California, 1993): 639-644

[37] Aklilu Habte and Teshome Wagaw, in collaboration with J. F. Ade Ajayi, "Education and social change," in G*eneral History of Africa VII: Africa since 1935,* eds. Ali A. Mazrui, assisted by C Wondji (Heinemann, UNESCO: Carlifornia, 1993): 678-679.

[38] Ali A. Mazrui, "The Re-Invention of Africa: Edward Said, V. Y. Mudimbe, and Beyond," *Research in African Literatures* 36, no.3 (2005): 72-74. See also, a discussion of the religious and intellectual evolution in the sixteenth century of the Songhay peoples who settled in Niger and Sudan in S. M. Cissoko, "The Songhay from the 12th to the 16th century," in G*eneral History of Africa IV: Africa from the Twelfth to the Sixteenth Century,* ed. Niane, D.T. (Heinemann, UNESCO: California, 1984): 207-210.

[39] Ali Mazrui and J.F.Ajayi, *Trends in philosophy and science in Africa*, 639-640.

[40] Aklilu Habte, *Education and social change, 693-*

[4141] Ibid.

[42] See Alfa and Abdulaziz, *Language and Social Change*, 523-528; Kwesi, *The Burden of English in Africa* 4-6;

nations, including university chancellors. Ngugi wa Thiong'o aptly highlights the paradox that the European education system inherited after independence, and the leaders of these institutions entrusted to emancipate Africans and their economies were alienated from their societies and struggled to articulate their ideas in African languages.[43]

Second, as discussed later in the paper, the continent's weakening political and economic conditions in the post-colonial period slowed the development of science systems. Despite these challenges, there have been some positive developments in the field of science in sub-Saharan Africa in recent years that will be elaborated further in the paper. These include the emergence of robust scientific institutions in some countries, increased funding for science and technology, and a growing recognition of the importance of science for development. However, much more must be done to address science's challenges in sub-Saharan Africa.

Towards a contemporary view of science systems in Africa

It is worth noting that emerging scholars, including Rebecca Hanlin and Johann Mouton, have extensively examined science systems in Africa.[44] The view of science systems here aligns with Rebecca Hanlin et al.'s conceptualisation of science systems. The authors apply system thinking and consider science systems a vast network of institutions and 'actors involved in the study, accumulation and use of knowledge'.[45] These institutions, they argue, are not only connected to research, knowledge or innovation systems but are also influenced by other societal institutions, from broader organisations such as education, finance and cultural organisations to sector-focused bodies like health, agriculture and manufacturing.

This approach is applicable for two reasons. First, it paves the way for inclusive ideas beyond dominant Western-biased ideas of what constitutes knowledge. Second, it enables the paper to break through the hierarchies and problematise existing structural impacts of Western-based systems to examine unique and emerging patterns, innovative processes, norms and institutions in the continent. To this end, in this section, the main elements that constitute science systems will be highlighted. Thereafter, the section delves more into universities due to their central position in science systems.

Rebecca Hanlin et al. suggest that science systems comprise the following systems. (1) Research systems, (2) technology systems, (3) Innovation systems, and (4) Allied Systems. This paper focuses on research and innovation systems and attempts to analyse them in the context of knowledge systems in Africa. This paper delves into the intersection of knowledge and science systems, looking beyond the traditional perspectives of Science, Technology, and Innovation. By exploring both formal and informal knowledge actors and innovation-related activities that aim to address societal challenges, the paper offers a comprehensive understanding of the contemporary nature and process of research and innovation systems.

[43] Ngugi wa Thiong'o, "Europhonism, Universities, and the Magic Fountain: The Future of African Literature and Scholarship," *Research in African Literatures* 31, no.1 (2000): 4-5.
[44] Rebecca Hanlin, Aschalew Demeke Tigabu and Gussai Sheikheldin eds., *Building Science Systems in Africa: Conceptual Foundations and Empirical Considerations,* (Nairobi: African Centre for Technology Studies ACTS, 2021)
[45] Ibid., 5-6.

Moreover, it shed light on the broader application of African knowledge systems by integrating diverse conceptual frameworks.

Research systems

Research systems, also often referred to as knowledge systems, are viewed as a network of agents, practices and institutions that organise knowledge production, transfer and use. [46] At the core of research systems is what Boaventura Santos has described as an 'abyssal invisible of thinking', which presumes that contemporary scientific thought has an exclusive monopoly of truth on knowledge and thus disregards the value of other forms of knowledge, including philosophy, theology indigenous, lay and plebian thought systems.[47] These forms of knowledge are often overlooked and dismissed as irrelevant or incompatible with scientific methods of generating actual knowledge. The crux of the challenges with the centrality of scientific thought is that the universal validity of scientific truth is always relative. The dilemma, then, when examining existing and emerging research systems for this paper is how science relates to other knowledge ways of generating truths, such as philosophical, faith or cultural beliefs and ideas of nature, which may have validity and contextual relevance but cannot be rationalised using scientific methods? Despite this, it is worth noting that scientific practices continue to be the preferred method of creating knowledge in contemporary research systems.

Most contemporary research systems in developing African countries have mainly been connected to four main pillars. First, education systems; second, to some extent, private non-profit organisations; third, enterprises; and fourth, government research organisations.[48] Within education systems, universities, particularly research universities, function as spaces for generating new knowledge from research and bridges for transferring knowledge to society through education.[49] As discussed in length in the paper, although many Universities in the education system globally are not research universities, they remain crucial engines of local knowledge production. Private enterprises also conduct applied research mainly for innovation, industrial and development purposes.

Role of Research Systems

Undoubtedly, research systems play a crucial role in leveraging scientific knowledge to propel societal advancement, influence the trajectory of progress, and facilitate economic development. However, as noted earlier, there are contentions over the scientific approaches and methods used to generate research knowledge, and long-running exclusion, marginalisation, and delegitimising of non-Western knowledge systems have subdued the

[46] Sarah Cornell *et a*l, "Opening up Knowledge Systems for Better Responses to Global Environmental Change," *Environmental Science & Policy 28*, (2013): 61.

[47] Boaventura de Sousa Santos, "Beyond Abyssal Thinking: From Global Lines to Ecologies of Knowledges," *Review Fernand Braudel Center* 30, no. 1 (2007): 47.

[48] Ajoy Datta, *Strengthening research systems: concepts, actions and actors,* K4D Helpdesk Report. (Brighton, UK: Institute of Development Studies, 2013): 7-8.

[49] Research universities are differentiated from conventional universities in the wider higher education systems due to their unique focus on research. Philip Altbach's conceptualisation notes research universities are well-resourced academic institutions committed to the creation and dissemination of knowledge in a range of disciplines and fields. See Philp G. Altbach, "Advancing the national and global knowledge economy: the role of research universities in developing countries," Studies in Higher Education 38, no. 3(2013): 316.

advance of research ecosystems. Legacies of the domination of Western-based scientific methods through the globalisation of knowledge and Western culture, argues Linda Tuhiwai, did not disappear with the end of colonialism. Instead, dominance today is maintained by exploiting and 'commodifying' indigenous knowledge systems through intellectual property rights by scientific communities, international organisations and multinational corporations.[50]

The dominance of Western- scientific approaches, argues Mazrui and Ajayi, disrupted the development of Africa's traditional technological sciences by subordinating societal processes that nurtured local cultural knowledge and expertise. In addition, it separated science from and rendered other grounded scientific ways of knowing, from agricultural practices, divination and healing systems to the complex study and analysis of social ordering and natural phenomena to incommensurable and inscrutable ideas that do not conform to the established scientific ideas. The ultimate impact was visible within research systems, including university systems, which have been trying to recover from these stifling effects since independence.

To be clear, despite facing various challenges, including political instability, civil wars, economic shocks, structural adjustment policies, inadequate funding, and brain drain, African research systems and, arguably, scientific systems as a whole have made significant progress in recent years. Research systems in Africa have demonstrated remarkable resilience and improvement in recent years. Recent studies have analysed the scientific research landscape in Africa from 2005 to 2018, examining factors such as research publication output, strength of scientific networks, collaboration trends, and citation impact point to these positive trends. [51] The findings indicate that South Africa, Egypt and Kenya have been at the forefront of this progress, with their share of publication output doubling from 1.5% to 3.2% by 2016.

Most research outputs have traditionally centred around tropical medicine, infectious diseases, and agriculture. Recent data suggests there has been progress in the social sciences. [52] Moreover, the findings show that the citation impact that assesses the visibility of scientific publications through citation metrics—although this measurement approach is heavily contested— has been on an upward trend in the last three decades.[53] Moreover, some studies that have, for example, mapped computer research activity beyond traditional indexes (Scopus and Web of Science) and included acidic network sites and data sources

[50] See especially discussion on twelve ways to be researched (colonised) in Linda Tuhiwai Smith, *Decolonizing Methodologies Research and Indigenous Peoples*, 2nd ed. (London: Zed Books, 2012): 102-107.

[51] See, Johann Mouton and Jaco Blanckenberg, "African Science: A bibliometric analysis," in *The Next Generation of Scientists in Africa*, eds., C. Beaudry, J. Mouton & H. Prozesky (Cape Town: African Minds, 2018):13-25. See also, Toluwase Victor Asubiaro and Sodiq Onaolapo, "A comparative study of the coverage of African journals in Web Science, Scopus, and CrossRef," *Journal of the Association for Information Science and Technology* 74, no. 7 (2023): 745-758.

[52] Asubiaro and Onaolapo, *A comparative study of the coverage of African journals* 751-752.

[53] Concerns have been raised over the use of journal indexes such as Scopus and Web of Science that track both outputs and impacts of research publications largely because the majority of journals published in the global South, including Africa are often excluded from these indexes. See David Mills et al, *Who Counts? Ghanain academic publishing and global science* (Cape Town: African Minds, 2022): 30-33

such as 'Academia.edu' and ResearchGate show a more significant percentage of regional collaborations that are not captured from mainstream indexes.[54]

The progress above has been attributed to several factors, including increased Gross Domestic expenditure in research and development (GERD)—although no single country has managed, despite policy commitment, to spend at least 1% of GERD.[55] In addition, there is an emerging trend of greater involvement of states in the research ecosystem as well as the creation of science granting councils (SGC) at national, regional and continental levels that act a 'boundary-bridgers' and 'coordinators' of scientific activities between various actors such as academia, private and governments.[56] The state's involvement in funding, giving leadership and policy direction, coordination and regulation is providing a cue to researchers, actors, and donors on the nation's priority areas. The continued investment is beginning to bear fruit; not only are there avenues for increased investment in contextually relevant needs to nurture indigenous knowledge systems, but the research outputs and innovation are more likely to be backed politically and socially, relevant, and accepted in societies.

Despite the progress noted above, Africa still produces a lesser share of global scientific output than other countries.[57] The majority of authorship on publication literature, including on subjects that touch on core challenges that affect many societies in the continent, and on subjects such as peace and security, continue to be dominated by scholars in the global North.[58] Moreover, studies on literature such as geoscience - A key concern is limited collaboration between scientists, especially at a regional level, where there are more opportunities and touchpoints such as proximity and common language and heritage ties.[59]

Although some indications of collaboration can lead to knowledge exchange, intra-African collaboration remains significantly lower than international collaboration. Studies show that intra-African collaboration still lags considerably behind international collaboration. Between 2000 and 2014, scientific collaboration within Africa only reached 25.8%, compared to 74.2% outside of Africa in 2000. By 2014, the percentage had risen to 29.3% within Africa while remaining at 70.7% outside of Africa. [60] However, the data by countries are yet to explore their full potential. The current patterns and outputs of scientific collaborations in Africa suggest that African countries are still far from fully exploiting the great potential of the synergies and complementarities across national research systems.

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[54] See Mathew Harsh et al, "Mapping computer science research in Africa: using academic networking sites for assessing research activity," *Scientometrics* 126, (2021): 327-328.

[55] Rigas Arvanitis, Johann Mouton, and Adeline Néron,"Funding Research in Africa: Landscapes of Re-institutionalisation," *Science, Technology and Society*, (2022):355; Julius Mugwagwa et al., *New Approaches for Funding Research and Innovation in Africa,* (Nairobi: African Technology Policy Studies Network, 2019): 27.

[56] See also for an extensive discussion of SGC in Julius Mugwagwa and Geoffrey Banda, "Science Councils and Financing of Research, Development in Africa," in 134

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[58] D. Adegoke, and Oni O., *Knowledge Production on Peace and Security in Africa: Mapping the Epistemic Terrain of Peace and Security in Africa 1960–2018*, (London: African Leadership Centre, King's College London, 2018): 75.

[59] Mafini Dosso, Lorenzo Cassi and Wilfredo Mescheba, "Towards regional scientific integration in Africa? Evidence from co-publications," *Research Policy 52,* no. 1 (2023):

[60] Raf Guns and Lili Wang, "Detecting the Emergence of New Scientific Collaboration Links in Africa: A Comparison of Expected and Realized Collaboration Intensities," *Journal of Informetrics 11*, no. 3 (2017): 899.

Furthermore, the concern over data exploitation is an emerging and perhaps understudied pitfall of collaboration with external actors in the wake of the increased importance or 'power of data'. Linda Smith suggests increased collaboration between researchers and private actors has demonstrated how contemporary scientists embedded with state and private enterprises, for example, engage in exploitative data practices, which Catriona Gray calls 'data colonialism'[61] through the 'proliferation and commodification of digital data' people's lives and environments outlined several ways in which scientific communities.

Innovation systems

Innovation, defined as introducing new or improved products, processes, services, and business models in various contexts, plays a pivotal role in science systems, especially in addressing business societal challenges.[62] It encompasses the intricate process of generating, accessing, and utilising knowledge, information, and technology to meet economic needs and promote sustainable development. [63] Historically, innovation is partly rooted in industrial economics discourses because of the long association with generating creative ideas for products and services for economic growth. Hence, Clapperton Mavhunga argues therein lies the challenge, particularly when conceptualising innovation dynamics in Africa.

Mavhunga observes contemporary definitions of innovation in Africa as elitist, university-centred practices that are Western-centric, negating nuanced African meanings and practices of innovation; more often, they consider African innovation systems as informalised and passive receivers of Western research and development.[64] Yet Mavhungs notes colonial practices 'killed, disrupted or delegitimised' multiple sites of African innovations that existed in the continent.[65] In addition, the definition decouples innovation from invention and, in effect, only focuses on commercially relevant ventures, which, Jan Fagerberg argues, unlike invention, require market knowledge, distribution systems and financial capital, which is strained in the continent.[66]

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[61] On exploitative elements of science and technology see Smith, *Decolonizing Methodologies,* 91-93. On data colonialism see, Catriona Gray, "More than Extraction: Rethinking Data's Colonial Political Economy," *International Political Sociology* 17, no.2 (2023):

[62]ASchalew Demeke Tigabu and Winnie Khaemba, "Science Councils in Africa: Catalysts of Innovation for Sustainable Development," in *Building Science Systems in Africa: Conceptual Foundations and Empirical Considerations,* eds., Rebecca Hanlin, Aschalew Demeke Tigabu and Gussai Sheikhldin,(Nairobi: African Centre for Technology Studies ACTS, 2021):27-28

[63] OECD/Eurostat, *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation*, 4th Ed, The Measurement of Scientific, Technological and Innovation Activities, (Luxembourg: OECD Publishing, Paris/Eurostat, 2018):20-21. See also for the development concept of innovation, Bitrina Diyamett and Athman Mgumia, "Innovation Systems Building and Structural Transformation," in *Building Science Systems in Africa: Conceptual Foundations and Empirical Considerations,* eds., Rebecca Hanlin, Aschalew Demeke Tigabu and Gussai Sheikhldin,(Nairobi: African Centre for Technology Studies ACTS, 2021): 57.

[64] Clapperton Chakanetsa Mavhunga, eds., "Introduction: What Do Science, Technology, and Innovation Mean from Africa?," in *What do Science, Technology, and Innovation mean from Africa*, (Cambridge, MA: The MIT Press, 2017) 8-10.

[65] 8 See also various forms of pre-colonial examples of innovation described by the author. 8 – 17.

[66] Jan Fagerberg, "Innovation: A Guide to the Literature," in *The Oxford Handbook of Innovation*, eds., Jan Fagerberg and David C Mowery (Oxford: Oxford University Press, 2005): 5.

The present dominant literature shows that innovation differs according to type, context, processes, and institutions involved. [67] One common approach in delineating the differences and dynamics of innovation relevant to this paper is the systematic perspective. The systematic approach focuses primarily on the network or structures at national, regional and sectoral levels, activities, actors and interdependencies within them for the development, diffusion and use of innovation.[68] This approach has several strengths (and weaknesses), especially for academic and policy analysts to consider. One strength is the centring on innovative learning processes and the production of knowledge through combining existing and new elements of knowledge. Second, innovation systems also view innovation processes as evolutionary, continuous and developing over time and space.[69] Some scholars have nonetheless critiqued the system approach, particularly the National System Innovation (NSI), for its bias on formal institutions and science-based activities as the primary sources of innovation.[70]

Nevertheless, with the above strengths, it is possible to briefly explore contemporary African innovation systems, who engage them and determine their relevance to society as constituted. It is important to note that multiple scholars have extensively examined innovation systems within sciences and technology in Africa.[71] The value added for this section is to highlight the conceptualisation of innovation in Africa, their nature, main features and contribution to the science systems, and the main challenges and how they are being dealt with.

As noted earlier, current ideas surrounding innovation in Africa focus on narrow, and Western-driven formalised ideas such as institutions, research and Development processes and associated indicators of the state of science and technology such as patents, science publications, and expenditure (in GDP terms), among others.[72] This conceptualisation, argues Chuck Daniels, overlooks alternative ideas of innovations within informal spaces, especially those that utilise indigenous knowledge and learning practices. Indeed, as noted earlier, some of these indicators are often generated from dominant indexes that often discount collaboration, for instance, and non-indexed publications at the local level.[73] The impact of this perspective is apparent, as resources tend to be invested in formal institutions, especially in areas that generate value. In Africa, for example, research has shown that most foreign direct investment for innovation from multinational enterprises and donors has centred around the extractive industries. Yet, most economies in the continent are primarily reliant

[67] Jan Fagerberg has provided a brief but comprehensive summary on these differences. See Ibid., 14-17.
[68] See Charles Edquist, "Systems of Innovation: Perspectives and Challenges," in *The Oxford Handbook of Innovation*, eds., Jan Fagerberg and David C Mowery (Oxford: Oxford University Press, 2005): 183-184.
[69] Ibid., 184-185.
[70] Ibid.
[71] There is wide literature and this paper has reviewed in detail these works. Tigabu and Khaemba, *Science Councils in Africa* 27-50; Diyamett and Mgumia, Innovation Systems, 56-85; various chapters in Clapper Chakanetsa Mavhunga, ed., *What do Science, Technology, and Innovation mean from Africa*, (Cambridge, MA: The MIT Press, 2017
[72] Chuck Daniels, "Science, Technology, and Innovation in Africa: Conceputalization, Relevance and Policy Direction," in *What do Science, Technology, and Innovation mean from Africa*, eds., Clapper Chakanetsa Mavhunga (Cambridge, MA: The MIT Press, 2017):170-172.
[73] Harsh et al, *Mapping computer science research in Africa*, 328.

on and driven by informal sectors.[74] As such, there is a need to re-conceptualise and re-theorise innovation perspectives in Africa that are essentially not captured but, more importantly, widen frameworks to include undervalued informal sectors and indigenous and locally driven innovations.

In the African context, understanding innovation systems can be challenging because the systems are complex and current approaches used to analyse them are still in trial.[75] In the meantime, a relevant and viable approach would be to view innovations, as Mavhunga argues, as 'locally generated and inbound ideas, instruments and practices'. [76] Building on this, such innovation integrates local knowledge, needs and resources to create something new and relevant to the particular context. As such, however, two significant categories emerged that can give us a general idea of innovative systems in the continent. Two of these are essential for this paper.

First, innovation systems are widely recognised as critical drivers of social and economic development, but they must be purposeful to achieve this goal. In particular, they must address wicked challenges associated with poverty, insecurity, and under-development in societies. Scientific innovation systems are seen as transformative pathways that can be leveraged to tackle structural issues, such as capitalising on under-utilised yet potential drivers of structural change. Experts have long argued that Africa can leverage science and technological innovations to help it shift away from the raw production system towards a high-value-added industrial production system.[77] More recent research suggests that the FIRE sectors (Finance, Insurance, and Real Estate) have potentially added structural transformation compared to the traditional industrial and manufacturing route. [78]

A more elaborate perspective is a systematic approach to development that aligns with innovation, which Garrick Louise et al. have suggested. The authors argue that innovation has to be centred on sustainability and emphasises strategic innovation focused on African development.[79] In particular, the innovation system needs to address human services as pathways to growth, built on the domestic capacity for sustainable development, build capacity for innovation in the continent and redirect aid to prioritise African-based innovation

[74] To read a comprehensive and insightful discussion on this topic see Erica Kraemer-Mbula and Watu Wamae,eds., "Adapting the Innovation Systems Framework to Sub-Saharan Africa," in Innovation and the Development Agenda (Paris:OECD Publishing, 2010):66-85.

[75] Some of the suggested frameworks include analysis of National Systems of Innovation, for example analysis of flow of technology, knowledge and information between different actors at national level. Other framework are sectoral analysis of structures, nature of organisation and production of various sectors. Each approach has merits and demerits that have been discussed. See Diyamett andMgumia, *Innovation Systems* 65-67.

[76] Mavhunga, *Introduction: What Do Science,* 9

[77] Gareth Austin, Ewout Frankema and Morten Jerven, "Patterns of Manufacturing Growth in Sub-Saharan Africa: From Colonization to the Present," in *The Spread of Modern Industry to the Periphery since 1871,* eds., Kevin Hjortshøj O ' Rourke and Jeffrey Gale Williamson (Oxford: Oxford University Press, 2019):365-379. Tafah. Edokat, & Aloysius Njong, "Institutional and Governance Weaknesses and African Transformation," in Governance for Structural Transformation in Africa, eds., Elhiraika, A., Ibrahim, G., Davis, W. [online] Palgrave Macmillan, Cham 2019): 27.

[78] Maria Enache, Syed Ejaz Ghani, Stephen D. O'Connell, and Amparo Palacios-Lopez, "Structural transformation in Africa: a historical view," *World Bank Policy Research Working Paper* 7743 (2016).

[79] See, Garrick Louise Neda Nazemi and Scott Remer, "Innovation for Development: Africa," in *What do Science, Technology, and Innovation mean from Africa*, eds., Clapper Chakanetsa Mavhunga (Cambridge, MA: The MIT Press, 2017):152-168.

that addresses development needs. Already, these forms of innovations have emerged, and the majority centre around information and technology. Africans are changing mobile technology by integrating local knowledge and aligning with society's needs to create new products. [80] However, an attempt to systematically study the performance progress, efficiency and outputs of innovation systems in Africa is challenging, not least because of the heterogeneity and infancy nature of contemporary NIS but also because of scantiness and unavailability of uniform data.[81]

Universities and Knowledge Systems and Society

Numerous models have been created to explore the significant impact universities can have beyond the traditional areas of education and research. These models are often referred to using abstract terms such as the 'third mission' or 'contribution society', the 'Triple/quadruple Helix', 'entrepreneurial university', and the Knowledge Triangle. [82]Despite their differences, these models all share a common goal - expanding the university's economic development involvement. Crucially, despite acknowledging knowledge production as an essential element of innovation in Africa and most of the global south, formal institutions still account for significantly low contribution to this sector.

The models above, such as Triple Helix, attempt to find linkages between formal institutions such as universities, crucial industries, and the government and consider universities central to the innovation process. The model, conceptualised in the 1980s, has evolved and varied. The model's rationale is that, despite the non-linear nature of knowledge flow and the overlapping interactions between universities, industry, and government, the interface among them facilitates the exchange of ideas and knowledge. This exchange, in turn, engenders a culture of innovation, thereby generating novel solutions for businesses and industries. Hence, the argument is that universities can maintain their traditional teaching and knowledge roles while engaging in innovation systems, hosting start-up companies, patents, and technology transfer.[83] The entrepreneurial University model, like the third mission model, emphasises using academic knowledge in the economic and social contexts. The model evolved in the US and is greatly influenced by American Universities, where universities are closely linked to private corporations. [84]

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[80] See a number of examples in Mavhunga, *Introduction: What Do Science,* 19-21.

[81] An recent attempt to analyse innovation systems has been done by Simon Ndicu, Dianah Ngui Laura Barasa, "Technological Catch-Up, Innovation, and Productivity Analysis of National Innovation Systems in Developing Countries in Africa 2010-2018," *Journal of the Knowledge Economy* (2023): 21-22.

[82] The literature on these models is extensive and two major systematic reviews of these literatures broadly most of the themes in these debates. See Kristel Miller et al., "A Systematic Literature Review of University Technology Transfer from a Quadruple Helix Perspective: Toward a Research Agenda," *R&D Management 48*, no. 1 (2018): 7-24; Lorenzo Compagnuccia, and Francesca Spigarellib, "The Third Mission of the University: A systematic literature review on potentials and constraints," *Technological Forecasting & Social Change* 161, no. (2020).

[83] Several variations of the Triple Helix model have been discussed see Loet Leydesdorff and Henry Etzkowitz, "The Triple Helix as a model for innovation studies," *Science and Public Policy* 25, no. 3 (1998) 196-197. On the expanded rationale of the involvement of universities in innovation see Yuzhuo Cai and Henry EtzKowiz, "Theorizing the Triple Helix model: Past, present, and future," *Triple Helix 7,* no.1 (2020): 203.

[84] Compagnuccia, and Spigarellib, *The Third Mission of the University* 8.

The Triple Helix model, while more prevalent in developed economies, is increasingly gaining traction in emerging economies such as Brazil, Russia, China, and South Africa. International finance and development agencies have touted this model as a policy solution to address innovation deficits in developing countries.[85] This situation is not by coincidence; as Terry Wotherspoon argues, in contemporary knowledge economies, there is an underlying expectation that repositions the value of knowledge production from universities as a public good to an emphasis on generating capacities for science, innovation and creativity.[86] This shift in expectation, Wotherspoon notes, creates tensions and contradictions.

Universities engaging in entrepreneurial ventures have faced criticism from some sceptical scholars who argue that entrepreneurial undertakings create added expectations and pose strategic challenges for universities. These critics argue that universities face a dilemma due to increasing accountability demands from other sectors, such as industry and society, when the institutions already face enormous internal pressures touching on their survival.[87] In addition, some scholars observe that the outcomes of university-driven entrepreneurial ventures are often exaggerated. At times, they are disconnected from and mismatched with the business needs of the local societies.[88] Related studies conducted in developing contexts in Asia and South America allude to associated findings. They observe that although the commercialisation of research in universities is in its early stages, it is often weakly justified and does not necessarily translate to meaningful, practical commercial ventures.[89]

Although rare and in their early stages, studies analysing the role of universities in driving innovation and entrepreneurship note that many African states still have weak higher learning institutions and low investment in science and technology. This hinders the implementation of the triple helix model.[90] In the next section, the paper will discuss these challenges in Africa's higher education institutions. The paper begins by discussing the evolution and changes in universities since the post-independence period and challenges that impact the development of science, research and knowledge systems.

The evolution of higher education in Africa has been a complex process that has undergone several phases since the post-colonial era. The initial phase of nationalist euphoria following the end of colonial rule saw the establishment of several prominent African Universities, among them the University of Ibadan in Nigeria, the University of Dare Salam in Tanzania, the University of Nairobi in Kenya and Makerere University in Uganda among others that became

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[85] Cai and EtzKowiz, *Theorizing the Triple Helix model*

[86] Terry Wotherspoon, "Triple Helix or Triple Jeopardy? Universities and the Social Relations of Knowledge," in The Age of Knowledge: The Dynamics of Universities, Knowledge and Society, eds James Dzisah and Henry Etzkowitz, (Leiden, Netherlands: Koninklije Brill NV Brill, 2012): 53

[87] See summary of literature in Compagnuccia, and Spigarellib, *The Third Mission of the University* 16-17.

[88] It is important to note these findings are gathered from experiences in Scotland UK. See, Ross Brown, "Mission impossible? Entrepreneurial universities and peripheral regional innovation systems," *Industry and Innovation* 23, no. 2, (2016): 195-198

[89] See Bruno Fischer, et al,. "Universities' Institutional Settings and Academic Entrepreneurship: Notes from a Developing Country," *Technological Forecasting and Social Change 147*, (2019): 243-252; Maksim Belitski, et al., "Commercializing University Research in Transition Economies: Technology Transfer Offices or Direct Industrial Funding?" *Research Policy 48*, no. 3 (2019): 601-615

[90] Norman Clark et al, "The Status of Innovation in Africa's Development Strategy: Where Should Science and Technology Fit In?," in *Entrepreneurial Universities Creating Institutional Innovation in Times of Turbulence,* eds., Sola Adesola and Surja Datta, (Cham, Switzerland: Palgrave Macmillan, 2020): 26-28.

sites of resistance against dominant Eurocentric ideas. Prominent African scholars Claud Ake, Walter Rodney and Issa Shivji led the opposition by advocating for African-centred knowledge. Still, their efforts were overwhelmed by the neo-liberal structural adjustment policies implemented in many African countries.[91] This resulted in a decline phase, and the sector faced significant challenges, including inadequate funding and resources, poor academic standards, limited capacity for teaching and research, colossal brain drain, and limited access to education for marginalised communities.[92]

The decline in higher education in Africa stems primarily from linked structural factors. The core, as widely acknowledged, was the initial interference in the governance of higher learning institutions accompanied by hostile policies by international finance institutions, as well pressure as post-colonial authoritarian regimes took shape and the attendant scarcity of financial resources due to the economic crisis of the 1970s and 1980s.[93] These reform packages, which emphasised funding as a critical influence on the determination of education policies, led to cutting funding from higher education and shifting it to primary and secondary education.[94] Reduction in fiscal spending in higher education led to significant deterioration of standards from infrastructure and collapse of central departments deemed unprofitable, but more importantly, was the deterioration of research capacities in science and technology, which continue to rank low around the world.[95]

Despite facing numerous challenges, African universities have grown remarkably since the post-independence period. The number of universities has significantly increased from 170 in the 1970s to over 1639 by 2016, indicating a substantial improvement. Furthermore, the enrolment rate has also increased by over 12 per cent, which, although lower than the global average, is now on an upward trend of nearly 33 per cent, which still represents significant progress. This indicates that Africa is moving towards a more vibrant education sector, which is crucial for the continent's growth and development.[96] The demand for higher education has increased significantly, leading to a rise in private universities due to funding and capacity gaps in public universities. Despite this progress, Africa still falls behind in global research and science performance, particularly in science and technology innovation indicators. The funding levels are still inadequate, which has weakened the ability of universities to facilitate

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[91] Samuel Ojo Oloruntoba, and Toyin Falola,, eds. “Africa in the Changing Global Order: The Past the Present and the Future,” in *The Palgrave Handbook of Africa and the Changing Global Order*. (Cham: Springer International Publishing AG, 2021): Samuel Oloruntoba, "Pan-Africanism, knowledge production and the third liberation of Africa," *International Journal of African Renaissance Studies-Multi-Inter and Transdisciplinary* 10, no. 1 (2015): 16-17.

[92] Tade Akin Aina, “Beyond Reforms: The Politics of Higher Education Transformation in Africa,” *African Studies Review* 53, no. 1 (2010):26-28; see also, Christine Scherer, 'Challenges to Higher Education in Africa and the Decolonized “Academia We Want”', in *The Oxford Handbook of the Sociology of Africa* eds., R. Sooryamoorthy, and Nene Ernest Khalema. (Oxford: Oxford University Press, 2023): 526

[93] [93]Tade Akin Aina, “Beyond Reforms, 27;

[94] Brock-Utne, Birgit. “Formulating Higher Education Policies in Africa: The Pressure from External Forces and the Neoliberal Agenda.” *Journal of Higher Education in Africa / Revue de l’enseignement Supérieur En Afrique* 1, no. 1 (2003): 24–56..

[95] Nico Cloete, Ian Bunting and Peter Massen, “Research Universities in Africa: An Empirical Overview of Eight Flagship Universities,” in Knowledge Production and Contradictory Functions in African Higher Education. Nico Cloete, Peter Maansen and Tracy Bailey eds., (Cape Town, South Africa: Africa Minds 2015): 29-35.

[96] Zeleza Tiyambe, “*The Role of Higher Education in Africa’s Resurgence* (Eric Morobi Inaugural Memorial Lecture, Johannesburg: University of Johannesburg, 15 October 2016).

research and publish findings. Consequently, as seen earlier in the publication of research findings, for instance, the number, as previously noted, remains still low. Although the publishing rate of scientific outputs has increased from 1.58 in 2005 to 3.18% in 2016 in Africa, scholars still face numerous challenges in publishing findings, at times having to seek assistance to publish through Western publishers to popularise their work. [97]

Moreover, African governments' inadequate investment in science within universities has made it difficult for African countries to develop their own scientific capabilities. Although there is growth in several African countries, notes Nico Cloete et al., there are still systemic difficulties and foundational weaknesses from both the low number of and capacity of students who enrol and conduct research, as well as institutional incapacities of the universities to support research. According to the Higher Education Research and Advocacy Network in Africa (HERANA), which analysed the contribution of universities to development in Africa, there have been significant developments in the research performance of universities in eight African countries over three phases between 2007 and 2017 (stages I – 2007-2010, II – 2010-2014, and III – 2014-2017). The report highlights several unique findings backed by empirical data that track the growth of universities in science, research and development.[98]

First, in the initial phase concerning coherence with national policies and between universities and national policies, the studies found a lack of clarity and understanding about the role of higher education institutions in research and development. While some governments acknowledged the importance of universities in the knowledge production economy, there was no coordinated effort among the government, external stakeholders, and universities to strengthen their contribution to development.[99] According to the study, the University of Cape Town in South Africa was the only exception regarding universities' research output being productive enough to make high-impact outputs.

The research observed that despite having adequate staff, most of the chosen universities lacked personnel with the necessary qualifications and funding to participate in research. However, while it was clear that the state provided limited funding for research, there are alternative pathways that universities like Makerere have tapped into, for example, using private partnerships that fund research programmes.[100] The outcome of these entrepreneurial-leaning programmes is new products and results in a win-win outcome. On the one side, they contribute to strengthening research capacity in universities through infrastructure injection student training and building research capacity. On the other side, they create business prospects for businesses to develop products at times with both exploitable commercial value and responding to societal challenges.

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[97] On publication data see) Nico Cloete, Ian Bunting and Francois Van Schalkwyk, *Research Universities in Africa,* (Cape Town, South Africa: African Minds, 2018) 33; David Mills et al, *Who Counts* 25-26; Tiyambe Zeleza, *Manufacturing African studies and crises*, (Dakar: Codesria, 1997):55

[98] The eight countries include Botswana, Ghana, Kenya, Mauritius, Mozambique, South Africa, Tanzania and Uganda. See

[99] Ibid., 18-20

[100] Maurice Bolo, et al., Public-Private Partnerships in Research and Innovation, in *Building Science Systems in Africa: Conceptual Foundations and Empirical Considerations,* eds., Rebecca Hanlin, Aschalew Demeke Tigabu and Gussai Sheikhldin,(Nairobi: African Centre for Technology Studies ACTS, 2021):182-184

More importantly, the research found that only three universities had at least 50 per cent of their permanent staff engaged in producing high-level research.[101] In subsequent phases of HERENA research, not only had the number of staff increased by 38 per cent, but the study highlighted a sectoral differentiation of staffing levels in various scientific fields. The research observed a marginal change in the number of senior academics in the universities between the end of phase I and II (2010). The average proportion of senior scholars in 2010 was 40.6% compared to 40.8% in 2015, where the University of Cape Town remained at the top with the most senior permanent academic staff.

Furthermore, most of the universities performed below in the three phases in terms of doctoral enrolment as a percentage of total student enrolment and total graduates. The study found that apart from the University of Cape Town, all seven other universities had below 2 per cent against a Herana average of 5 per cent. Moreover, the study noted that the ratio of doctoral graduates to academics with doctoral qualifications was below the HEREN research project average of 0.29.[102] These figures indicate that there are still core weaknesses in the ability of the universities to produce doctoral candidates and future researchers.

For doctoral graduates in science and technology, as well as education, humanities, and social sciences, there were 0.38 and 0.23 graduates per academic with a doctoral degree, respectively. However, when considering all doctoral graduates in all fields, the adjusted ratio was 0.29 per academic with a doctoral degree. Similarly, research publications in science, technology, education, humanities, and social sciences had ratios of 2.0 and 1.0 articles per academic with a doctoral degree. Nevertheless, the adjusted average for all fields was 1.40 research publications per academic with a doctoral degree.

To address these challenges, scholars have argued for many pathways that Saidi Trust summarises aptly; they include a paradigm shift in the education system and noted the need to draw research knowledge from society and shift from top-down models by producing scientific knowledge and technologies that benefit citizens. Second, acknowledging the relevance and value of utilising indigenous knowledge systems to inform scientific policies to address development challenges affecting societies is essential. Third, promoting a culture of original thinking, problem-solving and critical thinking rather than regurgitating old paradigms and over-emphasising publishing. [103] Fourth, increased budgetary allocation and investment in science and development by African governments in the continent. These investments must be followed by revisiting and revising existing science and technology policies at national, regional and continental levels.

[101] Nico Cloete, et al., *Research Universities in Africa*, 25
[102] Ibid 73.
[103] Saidi Trust, "Knowledge Valorisation for Inclusive Innovation and Integrated African Development," in *Advances in African Economic, Social and Political Development*, eds., Samuel Ojo Oloruntoba (Cham, Switzerland: Springer, 2019): 96-101.

Conclusion

In conclusion, this paper has presented an extensive review of various discourses on the history of science, specifically focusing on African epistemologies and their science systems. The paper argues that a critique of Scientific epistemologies in non-Western societies is the starting point for acknowledging the rich history of science and technology in the continent, which Western discourses have largely ignored. Furthermore, the paper notes that recent research has shown that Africa has significantly contributed to the development of science and technology, particularly in mathematics, astronomy, and medicine.

The paper also examined the role of universities in Africa in promoting science and technology. The literature review showed that a lack of funding, infrastructure, and resources has hampered African universities. Many universities have also struggled to attract and retain qualified staff, which has hindered their ability to develop and maintain high-quality science programs. Despite these challenges, some examples of African universities have excelled in the sciences. These universities have attracted funding and resources from international organisations and partnerships with universities in the developed world.

Several recommendations can be made to improve the quality of science education in African universities. First, there is a need for more funding and resources to be directed towards science programs. Governments and international organisations should prioritise science and technology in their funding and development agendas. Second, universities should work towards attracting and retaining qualified staff by offering competitive salaries and benefits packages. This will require restructuring university budgets to prioritise science programs and research. Third, universities should develop partnerships with other institutions within Africa and internationally. These partnerships can provide access to resources, funding, and expertise lacking in African universities. They can also facilitate knowledge exchange and collaboration, leading to innovative solutions to scientific challenges.

Therefore, developing science and technology in Africa is critical for economic, social, and political development. African universities have a crucial role in promoting and advancing science and technology. However, they face significant challenges that must be addressed to succeed. African universities can play a critical role in advancing science and technology in Africa by prioritising science programs, attracting and retaining qualified staff, and developing partnerships with other institutions.

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