Computer Science Education in Selected Countries from Sub-Saharan Africa

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Computer Science education in sub-Saharan Africa has evolved over the past decades. The number of institutions offering distinct undergraduate programmes has grown, thus increasing the number of students enrolling in the Computer Science discipline. Several Computer Science degree programmes have emerged with one of the objectives being to satisfy the growing demand for local talent and skills. In this paper, we provide a snapshot of the evolution of undergraduate Computer Science education in selected countries in Sub-Saharan Africa over the past 20+ years and an overview of the developments in Computer Science education and observed trends. The setup of educational institutions in Africa and the operational context require unique modalities for the design and delivery of computer science education that meets the demands of the industry, amongst others. This paper provides insights into the best practices in the Computer Science curricula in the selected countries, as well as an overview of the pedagogical and delivery approaches to Computer Science education. The paper highlights case studies from institutions in the selected countries, namely Uganda, South Africa, Ghana, Tanzania, and Kenya with a consolidated summary of the current and emerging challenges and opportunities in all these countries. The paper concludes by providing perspectives on the future landscape of Computer Science education in Sub-Saharan Africa.

Additional Key Words and Phrases: computer, science, education, Sub-Saharan Africa

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1 BACKGROUND AND INTRODUCTION

The role of Computer Science education (CSE) in the digital transformation and economic development of Sub-Saharan Africa (SSA) cannot be overstated [4, 10]. To meet the growing demand for talent and a skilled workforce, many institutions of higher learning in SSA offer standalone degree programmes in Computer Science (CS) at undergraduate and graduate levels. Yet the progress and current state of CSE in SSA is not well documented. There is very little literature on the nature and diversity of CSE in SSA, success stories, or challenges.

The purpose of this paper is to provide a description of the current state of CSE in selected countries in SSA. These countries include South Africa, Ghana, Uganda, Kenya, and Tanzania. Figure 1 shows a map of the selected countries from different regions of Western, Southern, and Eastern Africa. The paper aims to provide an overview of the current trends in CS, the areas and focus of CSE, methods of delivery, emerging programmes, challenges and opportunities, as well as future prospects for CSE in SSA. The paper aims to answer the following questions:

(1) What is the current focus of CSE in selected countries in SSA?
(2) What areas of CSE are currently covered in the CS curricula in the selected institutions?
(3) What are the methods of delivery for the CS curricula?
(4) What has changed over the past 20 years in CSE in SSA?
(5) What are the emerging programmes in CSE in SSA?
(6) What are the emerging opportunities, challenges, and future prospects of CSE in SSA?

To address the above research goals and questions, we identified CS educators situated in the selected countries. Key considerations were a representation of the different regions in SSA, and experience in teaching and research in CSE in an institution in the selected country. We also aimed for gender representation of the CS educators with the selected educators forming the author list of the paper. For this paper, the focus was on undergraduate CSE. This excludes related computing courses such as Software Engineering, Information Systems, Information Technology, Computer Engineering, and Computer Networks. We reviewed the selected curricula to understand the focus areas in the CS programmes using frameworks such as the ACM Computing curricula guidelines [12]. We also conducted a survey among CS educators using an online survey form to gain insights into the delivery methods, curricula focus, challenges and emerging opportunities.

The rest of the paper is structured as follows. First we document the state of CSE in each individual country and then we present a consolidated view of the common challenges, opportunities and future directions of CSE in SSA.

2 COMPUTER SCIENCE EDUCATION IN UGANDA

Undergraduate CSE in Uganda started in the late 1990s. Before then, CS was embedded as a subject or an area of specialisation in other disciplines, including basic sciences, engineering, mathematics and statistics. In the late 1990s and early 2000s, CS started emerging as a discipline with a distinct degree programme. According to the National Council of Higher Education [24], a body responsible for the regulation of higher education in Uganda, 28 institutions are offering dedicated undergraduate degree programmes in CS, out of over 1,600 undergraduate degree programmes as of 2023. However, there are other computing-related and emerging programmes including Software Engineering, Information Systems, Information Technology, Computer Engineering, Business Computing and Computer Security. Until the late 2000s, CSE was limited to a few institutions such as Makerere University[1] the oldest and largest University in the

[1]Makerere University https://mak.ac.ug

Fig. 1. Selected countries (highlighted) for CSE in SSA

country, and Mbarara University of Science and Technology [2]. As the number of new public and private institutions has grown so has the number of undergraduate degree programmes across the different regions in the country.

There was a considerable effort in training the trainers of CSE as the first steps towards improving the quality of CSE in the country. There has been significant success in training staff through international collaborations. Staff train at an international institution for example in the USA and Europe and return upon completion. In other training modes, staff spend half of the time at the home institution and half the time at a foreign institution. For example, the Bright project [8] was a collaboration between universities in Uganda and Sweden. The collaborating universities were Makerere University, Chalmers University of Technology and University of Gothenburg. Other initiatives include the ongoing PhD exchange fellowships between the Department of Computer Science at Makerere University and The Paul G. Allen School of Computer Science and Engineering, University of Washington (UW) in Seattle, USA[3].

[2]https://must.ac.ug
[3]https://cs.mak.ac.ug/funding/fellowships/2023/fellowship

Table 1. Summary of Computer Science curricula from the selected universities in Uganda

	Location/Region	Name of the programme	No. of years	Graduation load (Cus)
Makerere University (Mak)	Central	BSc. Computer Science	3	124
Busitema University (Bus)	Eastern	BSc. Computer Science	3	130
Gulu University (Gul)	Northern	BSc. Computer Science	3	134
Kabale University (Kab)	South Western	BSc. Computer Science	3	120
Mbarara University of Science and Technology (Mba)	South Western	BSc. Computer Science	3	133

Over the past 20 years, capacity-building efforts have led to an increase in the number of faculty with PhD degrees in Computing. The availability of qualified faculty has contributed to the improved quality of teaching for undergraduate CS programmes and also helped establish and undertake research. Taking the example of the School of Computing and Informatics at Makerere University, the School has over 50 faculty with PhD qualifications with diversity from different continents, countries and universities. A sample of 15 faculty members from the Department of Computer Science at Makerere University shows the diversity of the Universities, including Vrije Universiteit Brussels (Belgium), Eindhoven University of Technology (The Netherlands), University of Leeds (UK), The Georgia Institute of Technology (USA), Makerere University (Uganda), The University of Edinburgh (The Netherlands), University of Gothenburg (Sweden), and Chalmers University of Technology (Sweden).

2.1 The demand and need

CS is considered a major component of the broad ICT sector and digital transformation agenda that has been earmarked as a key priority area for the national development plan three (Uganda NDP III 2020-25). In the early 2000s, as the government and the private sector embarked on computerisation, there was a growing demand for skilled people to set up and manage IT systems. There has been an evolution in available jobs and opportunities for graduates of Computer Science over time. Uganda's national development plan has projected a demand of over 500,000 jobs in the ICT sector, including in the CS specific jobs in software development and software engineering, embedded systems, machine learning, data science, computer vision, and computer security.

Across the East African region, countries increasingly leverage digital and computational technologies to increase access to and efficiency of service delivery. Startups are emerging in the application of CS to tackle challenges in different sectors, including Education, Agriculture, Health, Environment, and Tourism. For example, Makerere University undergraduate CS students developed malaria diagnostic tools[4]. The Department of Computer Science at Makerere University has pioneered research in natural language processing for African languages [20], [7], Internet of Things (IoT) for environmental modelling and analysis [1], computer vision for human and plant disease diagnostics [21]. The applications of CS in solving local challenges are creating a demand of skilled graduates in the discipline and also serving as local case studies for teaching CS at universities.

With the increasing opportunities for remote work and business outsourcing, the graduates of CS training from Uganda are working with international companies worldwide such as in Europe and the USA[5].

[4]https://www.bbc.com/news/business-44484581
[5]https://tunga.io/african-software-developers-best-countries-for-sourcing/

Table 2. Distribution of course categories by ACM 2020 knowledge areas for selected universities in Uganda, East Africa

	Bus	Gul	Kab	Mak	Mba
1. Users and Organisation (UO)	19.4%	21.2%	22.6%	17.5%	27.8%
2. System Modelling (SM)	11.1%	15.2%	9.7%	12.5%	8.3%
3. Systems Architecture and Infrastructure (SAI)	19.4%	27.3%	25.8%	25.0%	30.6%
4. Software Development (SD)	11.1%	6.1%	6.5%	10.0%	5.6%
5. Software Fundamentals (SF)	36.1%	24.2%	32.3%	32.5%	25.0%
6. Hardware (HW)	2.8%	6.1%	3.2%	2.5%	2.8%

2.2 Structure and focus of Computer Science Curriculum

Table 1 shows selected CS from five Ugandan universities. The selected Universities are government-funded public institutions representing the Central, Eastern, Northern and South Western regions of Uganda. Most undergraduate CS curricula are structured as three-year degree programmes (Table 1). The graduation load for the selected Universities range from 120 to 134 credit units (CUs). One credit unit represents one contact hour per week. One contact hour is equivalent to one lecture hour or two tutorial/practical hours. The Bachelor of Science Computer Science like other degree programmes are accredited by the national regulator for higher education, the National Council of Higher Education (NCHE). The three-year programmes are required to be revised for re-accreditation after every five years, which provides an opportunity to embed new and emerging knowledge areas. Mathematics at high school (A' Level) is one of the key admission requirements to the CS degree programmes.

For each of the selected Universities, assessment the curriculum against the focus areas in the ACM Computing curricula guidelines 2020 [12]. Tables 2 and 3 provide a summary of the analysis. The curricula follow and conform to the ACM definition of CS distribution of the knowledge areas, with the majority of the programmes having most of the courses under the category of Software Fundamentals, followed by Systems Architecture and Infrastructure, and Users and Organisation. In this analysis, we categorise mathematical courses as part of the foundations (i.e., Software Fundamentals). The analysis helps provides clarity on the distinction between CS programmes and other computing programmes such as Information Technology and Information Systems. The distinction between computing programmes including computer engineering, information systems, and software engineering can be unclear among learners and faculty and therefore this analysis helps to show the intended and current focus of CS programmes.

CS programmes continue to offer foundational courses including mathematical courses, Operating Systems, Data Structures and Algorithms, Automata, Complexity and Compatibility, Cryptology and Coding Theory, Computer Graphics, Compiler Design, and Graph Theory. In addition, the CS programme have a focus on practical skills and industry placement as means to enhance the training. There are emerging offering in the areas inline with the current global trends. For example, Makerere University's CS curriculum includes courses on artificial intelligence, machine learning, robotics, embedded and real-time systems, and cloud computing.

2.3 Enrolment trends

There is a growing trend in the number students enrolling in CS programmes. Figure 2 shows the trend of enrolment in the undergraduate CS programme at Makerere University. Most Universities provide multiple track entry options including for direct entrants from high school (A' Level), diploma entry schemes, and degree entry schemes. The majority of the entrants are via the direct entry scheme of students who have recently completed their high school studies.

Table 3. Course categories by knowledge area for selected Universities in Uganda

	Bus	Gul	Kab	Mak	Mba
UO	7	7	7	7	10
SM	4	5	3	5	3
SAI	7	9	8	10	11
SD	4	2	2	4	2
SF	13	8	10	13	9
HW	1	2	1	1	1

Sponsorship at public universities in Uganda is a mixture of government scholarship and private. For example, for Makerere University the government sponsors about 22 students every year to study CS, accounting for approximately 10% of the annual enrolment.

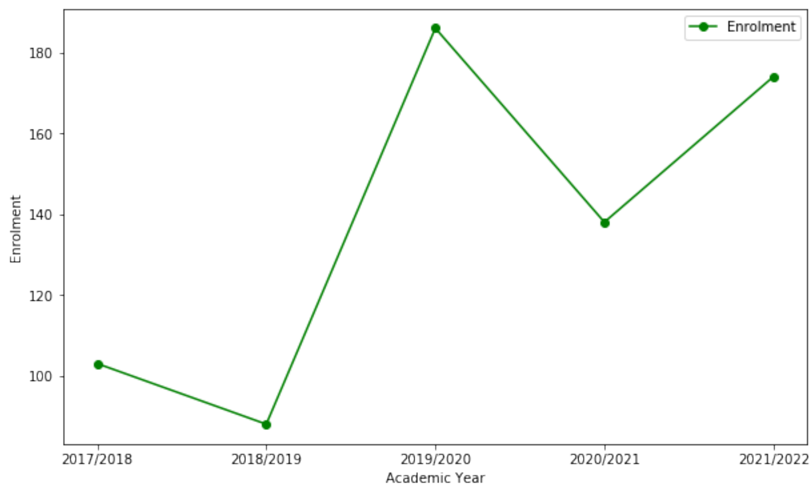

Fig. 2. Enrolment in undergraduate Computer Science in the Department of Computer Science, Makerere University, Uganda

3 COMPUTER SCIENCE EDUCATION IN SOUTH AFRICA

3.1 History of Computer Science Education in South Africa

The history of CS tertiary education in South Africa (SA) is well documented in [9]. As in many other countries, the first CS courses were taught in various Physical or Mathematical Science departments in the late 1960s and early 1970s before the establishment of independent CS departments. The first of these were established in 1970 at four universities, namely the Rand Afrikaans University (currently known as the University of Johannesburg or UJ), Stellenbosch University (SU), the University of Cape Town (UCT) and the University of Port Elizabeth, now known as Nelson Mandela University (NMU).

Shortly thereafter, based on when computing infrastructure was installed at the university, several other institutions around the country followed suit, and by 1980, seven of the country's universities were teaching CS courses from within a dedicated CS department. Several of the early founding CS teaching staff had completed post-graduate degrees at foreign universities, while others attended train-the-trainer workshops both nationally and abroad.

Today, three-year undergraduate CS degrees are offered at 18 universities and six technical universities in South Africa. All of the universities and a few of the technical universities also offer a Computer Science Honours degree as the fourth year of CS tertiary education.

3.2 Industry needs within South Africa

ICT skills are in short supply in SA as evidenced by the frequent articles published both by government, industry and educational institutions. An article in BusinessTech[6] highlighted the critical shortage in the IT and finance sector specifically going into 2023. Reasons for this shortage were given as the high cost of tertiary education and low salaries (compared with the global market) that has lead to many skilled workers emigrating.

A joint skills survey[7] by the Joburg Centre for Software Engineering (JCSE) and the Institute of Information Technology Professionals (IIPTSA) in 2021 identified the top four IT skills most in demand in South Africa as being: cyber security; big data analytics; DevOps, and artificial intelligence, which are exactly the skills that a degree in CS can provide. In addition, a survey of highest paying IT jobs in South Africa gave the top honours to the role of Computer Scientist, defined as someone "that does research on computers and computer systems to evaluate how well they function and find new technological applications. ... can create new software and programs .... [as well as] do study on future uses of technology for people."[8]

The above points to the fact that CSE is both in great demand within the South African economy to fill the skill shortages, but also a lucrative career for potential employees to pursue.

Most CS departments have collaborations with industry. Besides the many large international IT companies with offices in South Africa (including Amazon, Oracle, Google, IBM, Amazon Web Services, Microsoft, and many more), there are also many successful local IT companies and startups. Collaborations include amongst others, offering internships, funding for equipment, and scholarships for students. Compulsory work-experience is however, not a normal requirement for a Bachelor of Computer Science degree in South Africa.

3.3 Structure of Computer Science degrees

In keeping with the aim of this paper, the discussion in this section focuses on the traditional South African universities offering CS as a major subject, and not the technical universities that typically offer technology degrees or diplomas, such as the B.Tech and B.IT degrees or Advanced and Post-graduate Diplomas in Information Technology. Based on a recent survey that documents CS degree offerings at eight South African universities, Table 4 presents summary information on the degrees offered at selected universities, namely Rhodes University (RU)[9], UCT[10], UJ[11], University of

[6]https://businesstech.co.za/news/lifestyle/653227/theres-a-critical-shortage-of-these-skills-in-south-africa-going-into-2023/
[7]https://businesstech.co.za/news/technology/633659/massive-skills-warning-for-south-africa-with-these-skills-in-short-supply/
[8]https://topuniversities.co.za/bachelor-in-computer-science/article-highest-paying-computer-science-jobs-in-south-africa
[9]https://www.ru.ac.za/
[10]https://uct.ac.za/
[11]https://www.uj.ac.za/

Table 4. CS degree information for selected SA universities

University	Degrees offered	First year intake size	Minimum APS or equivalent	Other admission requirements
UP	BSc in CS	500	30 APS	60% Maths; 60% English First/Home Lang
US	BSc Mathematical Sciences in Computer Science BCom Mathematical Sciences	300	65% matric avg 70% matric avg	70% Maths; 50% First Language 75% Maths; 50% First Language
UCT	BSc Computer Science	1000	550 faculty points*	70% Maths; 60% Physics/IT; 40% English First/Home Lang
UKZN	BSc Computer Science BSc Computer Science and IT	Not known	30 APS 30 APS	60% Maths; 50% Physics/Life Science; 50% English First/Home Lang 60% Maths; 50% Physics/Life Science; 60% English First/Home Lang
RU	BSc BSc (Information Systems)	130	34 APS 40 APS	60% Maths; 50% English First/Home Lang 70% Maths; 50% English First/Home Lang
UJ	BSc (IT) BSc Computer Science and Informatics	370	30 APS 30 APS	60% Maths; 50% English First/Home Lang 60% Maths; 50% English First/Home Lang
WITS	BSc Computer Science	280	44 APS	60% Maths; 50% English First/Home Lang
UWC	BSc Computer Science	190	33 UWC points*	60% Maths; 50% Physics/Life Science/IT; 50% English First/Home Lang

* denotes alternative APS calculation in Column 4

Kwa-Zulu Natal (UKZN[12], University of Pretoria (UP)[13], US[14], University of the Western Cape (UWC)[15], and University of the Witwatersrand (Wits)[16].

Information presented includes in which degrees at each university CS features as a major subject (i.e., a subject that is studied during all years of the degree), the approximate size of the first year intake (from the post-Covid years), and what the minimum admission requirements are. The admission point score (APS) is a calculation based on the student's matriculation subjects and how they performed in the final high school examination[17]. Note that not all universities use the same 7-point calculation scale, and hence the discrepancies in APS entrance requirements.

To the best of our knowledge, UCT and UJ are the only universities whose three-year BSc degree together with the Honours year has been accredited by the British Computer Society, the Chartered Institute for IT in the United Kingdom. Many of the universities, however, do follow the ACM Curriculum guidelines in setting up their three-year

[12]https://caes.ukzn.ac.za/
[13]https://www.up.ac.za/
[14]https://www.cs.sun.ac.za/
[15]https://www.uwc.ac.za/
[16]https://www.wits.ac.za/
[17]https://bursaries-southafrica.co.za/how-is-aps-calculated-at-universities/

Table 5. Distribution of course categories by ACM 2020 knowledge areas for Rhodes University, South Africa

Category	Contribution %	Course breakdown
1. Users and Organisation (UO)	3	Social issues and ethics
2. System Modelling (SM)	15	Databases Data analytics (Hons) ICT for development (Hons) Web technologies and security
3. Systems Architecture and Infrastructure (SAI)	19	Computer networks Parallel and distributed programming (Hons) Computer and network security (Hons) Machine learning (Hons) GPGPU (Hons)
4. Software Development (SD)	6	Software development practices Software design, quality testing
5. Software Fundamentals (SF)	50	Python programming Computational thinking Java programming Data structures, algorithms, complexity Systems level programming Operating systems Theory of computation Functional programming Programming language translation Image processing (Hons)
6. Hardware (HW)	7	Architecture Interfacing (Hons)

Bachelor degrees continuing into the Honours year (i.e. a total of four years of CS education). A typical three-year Bachelor degree consists of 360 credits (equating to 3600 notional hours) with most South African universities requiring two major subjects (each of which contributes 130 credits). The remaining 100 credits come from ancillary subjects that complement the majors. In the case of a CS major, typical second majors could be subjects like Mathematics, Physics, Information Systems, and so on. Where only one major subject is required for the Bachelor degree, an increased number of credits is allocated to that subject with the remaining credits taken from ancillary subjects.

A breakdown of the undergraduate courses taught at Rhodes University aligned to the ACM Curriculum 2020 knowledge areas is given in Table 5. This table includes the courses taught at the Honours year to ensure alignment with the typical four-year undergraduate degree structure in the USA. Note that the calculations for the percent contribution of each knowledge area are based on the number of teaching weeks per course as a % of the total teaching weeks in a four-year degree.

Table 6 gives an indication of what courses are offered at the Honours level by some universities. In addition to the coursework modules, all Honours degrees in South Africa must include a research component of at least 25% and most universities include a compulsory Research Methods or Research Writing coursework module as the Honours year aims to introduce students to research.

As an extra-curricular activity, many SA universities encourage their CS students to participate in various competitions organised by industry or academic associations. For example, the Microsoft Imagine Cup and the International Collegiate

Table 6. Honours coursework modules in select SA universities

University	Examples of elective Honours courses
UP	AI and machine learning; Computer and info security; Software engineering; Formal aspects of computing; Computer graphics; Parallel and distributed programming; Computer networks; Generic programming; Data mining
US	Machine learning; Theoretical CS; Software testing; Advanced algorithms; Databases; Compilers
UCT	Advanced topics; Compilers; Functional programming; Big data management/analysis; HCI; AI; Network security; Game design; High performance computing; Graphics; Data analytics
UKZN	Image processing; AI and machine learning; Cryptography and network security; Language translation systems; Graphics; Optimization and modeling; Distributed computing
RU	Computer and info security; Advanced functional programming; Machine learning; Image processing; Distributed and parallel computing; GPGPU; Data analytics; Interfacing
UJ	Computer forensics; Systems programming; AI; Compilers; Mobile programming; Information security; Big data analytics; Data communication; Biometrics; Ethics; Functional programming
WITS	Machine learning; AI; Computer vision; Databases; High performance and distributed computing; Data analysis; NLP; Affective computing; Regulated rewriting in formal language theory
UWC	Advanced software engineering; ICT4D; AI; Cyber security; Big data engineering; Cloud computing

Programming Contest (ICPC) organised by the ICPC Foundation are well supported by students in various CS and Engineering Departments in South Africa. National competitions like the annual SANReN Cyber Security Challenge and Student Cluster Competition run by the Centre for High Performance Computing competition also attract a number of entries from departments that offer associated courses.

4 COMPUTER SCIENCE EDUCATION IN GHANA

4.1 History of Computer Science Education in Ghana

Existing literature [11] indicates that, computer education in Ghana dates back as far as 1966, and thus the beginning of computer education in Africa. This is confirmed in Prof Francis Kofi Ampenyin Allotey's statement (as quoted in [11]) that, "*... For instance, when I returned from Princeton in 1966 to Ghana, I noticed there was no school in Africa that taught CS. What happened was IBM would sell you a computer, and give you two weeks of lessons, but I thought that is not good enough - let them take it as a proper university course. So on my own, against my colleagues, I created the first department of computer science in Africa. I went to many parts of Africa preaching about not only physics but also the importance of computer science*". The said beginnings of computer education in Ghana and Africa started as a one year course in CS. In the following year, a second year course which reached diploma standard was also started. The founding father, Prof Francis Kofi Ampenyin Allotey, a physicist and mathematician, then went ahead to develop a full degree programme in CS at the Kwame Nkrumah University of Science and Technology (KNUST), hence making it the first university in Ghana and Africa to offer a degree programme in CSE.

From the said beginning in the late 1960s, CSE at the tertiary level in Ghana has seen a tremendous expansion. Of the existing 155 universities (including University Colleges and Technical Universities) out of the 302 accredited tertiary institutions in the country, 41 currently run CS degree programmes. These 41 institutions include seven public universities, five chartered private tertiary institutions, 22 private tertiary institutions (including university colleges), six public technical universities and one regionally-owned (West African) tertiary institution. With the exception of the technical universities and a few of the said universities and university colleges offering a three-year degree Bachelor programme in partnership with some foreign universities as approved by GTEC, the majority of the 41 universities run a four-year bachelor degree programme and these are accredited by the Ghana Tertiary Education Commission [13, 22]. The said institutions are summarised in Table 7. The list excludes public colleges of education (46), colleges of agriculture (4), private colleges of education (4), private nurses training colleges (14), public nurses training colleges (68), and tutorial colleges (11) as these do not offer CS degree programmes.

4.2 Structure of Computer Science degrees

Topical coverage of the curriculum for CS degrees in Ghana generally includes Computer Programming, Web Design, Databases, Computer Architecture, Data Structures and Algorithms, Operating Systems, Computer Networks, Human-computer Interaction, Software Reliability and Quality Assurance, Computer Graphics, Artificial Intelligence and Internet of Things. Beyond the generic topical coverage, some of the universities offer CS degrees with specialisations, including Cyber Security, Artificial Intelligence, Robotics, and Data Science and Analytics.

To develop holistic students armed with the additional skill set that they require in the industry, the CS curricula also cover topics in the area of communication skills, critical thinking, problem-solving, Mathematics, introductory electronics, microprocessors, ethics of computing, and some business skills, such as accounting, management and marketing principles. By said topical coverage, the universities are certain of producing computer scientists that are problem solvers, analytical, critical and innovative thinkers.

Though the curricula of most of the universities are similar in structure, small differences between these that make them unique lead the students into different career paths such as software development/engineering/programmers, data scientist, computing systems security professionals/cryptologist, system /software administrators and database administrators.

The methods of delivery of the CS curriculum in most of the said universities include face-to-face (and most recently online) lectures applying practical and knowledge-based learning, practices (including lab sessions), seminars, case studies, mini projects, discussion, demonstration, internships/attachments and field trips. Assessments are usually in form of assignments, mini projects, and final year project work, mid-semester and final examinations (practical in some schools), case studies, etc.

Inferring from the said topical coverage, it is noticeable that the ACM 2020 knowledge areas of Users and Organisation (UO), System Modelling (SM), Systems Architecture and Infrastructure (SAI), Software Development (SD), Software Fundamentals (SF) and Hardware (HW) are covered in the curricula for CSE. This is so because, as part of the CS programme curriculum development, universities are expected to benchmark with other universities and professional bodies nationally, regionally and globally.

4.3 Collaborations with industry

Government of Ghana has invested so much in the CSE and has even gone ahead to pass an ACT (1022) of parliament creating a university that solely focuses on computing education [18]. In support of Government efforts, existing

Table 7. List of universities and university colleges offering Computer Science degrees in Ghana

Category	Number of Tertiary Institutions	Number of Tertiary Institutions Running Computer Science Education	Names of Tertiary Institutions Running Computer Science Education
Public Universities	15	7	1. Ghana Communication Technology University
			2. Kwame Nkrumah University of Science and Technology
			3. University of Ghana
			4. University of Mines and Technology
			5. University of Cape Coast
			6. University of Energy and Natural Resources
			7. Ghana Institute of Management and Public Administration
Chartered Private Tertiary Institution	10	5	1. Valley View University
			2. Ashesi University
			3. Catholic University
			4. All Nations University
			5. Central University
Private Tertiary Institutions Offering HND/Degree Programmes	104	22	1. Wisconsin International University College
			2. West End University College
			3. Webster University, Ghana Campus
			4. Technical University College Of Tamale
			5. Unique Citizens College
			6. Regentropfen College Of Applied Science
			7. Regent University College Of Science And Technology
			8. Newlife College
			9. Knutsford College, Accra Campus
			10. Lancaster University
			11. Lakeside University College, Ghana
			12. Kings University College
			13. Kaaf University College
			14. Garden City University College
			15. Community College
			16. Data Link Institute Of Business And Technology
			17. Dominion University College
			18. Christian Service University College
			19. Akim State College
			20. Baldwin College
			21. Accra Institute of Technology
			22. Academic City University College
Public Technical University	10	6	1. Accra Technical University
			2. Sunyani Technical University
			3. Kumasi Technical University
			4. Cape Coast Technical University
			5. Ho Technical University
			6. Koforidua Technical University
Private Polytechnic	1	0	
Regionally-owned (West Africa) Tertiary Institution	1	1	1. Regional Maritime University
Registered Foreign Institution	4	0	
Distance Learning Institution	2	0	
Public Degree Awarding and Professional Institution	8	0	
Total	**155**	**41**	

computing / information technology companies has collaborated and supported universities in training of CS graduates. Among these companies include Google Ghana, Google's First Ai Lab, IBM Ghana, Msoft Ghana Limited, OMATEK, Rdk Consulting Services, Telcos (Vodafone, Mtn, Tigo/ Airtel), Fnet Services Limited, 1i Logistics & Trading, Bil-Lander Limited, Orange Luks Concepts, Baziq Technologies Llc, Ghasst Solutions Ltd, Softtribe Limited, Mpedigree Network Ltd, Oasiswebsoft and Smart Developers.

These collaborations include some of the companies setting up labs in the universities, students undertaking internships / industrial attachments with the companies, skilled members of the said companies giving talks and some mentoring to the CS students.

4.4 Demand and need in Ghana

CSE contributes towards achieving the Ghana ICT for accelerated development (ICT4AD) policy as it churns out graduates who fill the gap of the shortfall in critical computing skills and expertise in the Computing Science Industry in Ghana (ICT4AD Policy, 2003) [15]. For example, the skilled labour force in some of the computing / information technology companies given in the previous section, are graduates of the CS education programmes in Ghana. The CS education programme also contributes to Ghana's digitization agenda as it produces graduates equipped with skills that enables them to produce the needed computing tools, programs and platform to digitize the government services enabling the environment for the development of the needed digitization infrastructure (e.g., biometric national identity register, digital property addressing systems, etc.). Furthermore, the CS education programmes contribute to achieving SDG goal 9 (specifically targets 9.5 and 9.b) of supporting domestic technology and innovation [16, 17] and African Union agenda 2063 of doubling the 2013 GDP's level by 2063 through increase computing penetration [2]

5 COMPUTER SCIENCE EDUCATION IN KENYA

The history of CSE in Kenya can be traced back to the early 1960s when the nation gained independence from British colonial rule. The new administration established several technical institutions to equip Kenyans with technical skills and accelerate economic growth. As such, the first computer course was offered in 1963 at the Kenya Institute of Administration (KIA). The program was one of the focus areas for those undertaking the institution's management training course and was meant to train government officials in data processing and computer programming. A successful launch encouraged other educational facilities to offer CSE, and in 1976, the University of Nairobi (UoN)[18] established a CS department. UoN later provided the first Bachelor of Science in Computer Science program in Kenya to satisfy the ever-increasing demand for qualified computer professionals in Kenya.

What followed in 1983 was the Kenya Polytechnical University College – a government-funded college – that offered diploma courses in Information Technology and CS and 17 students in its first class [25]. The administration did so to boost access to CSE in Kenya. As a result, there was a significant expansion of CSE in Kenya in the 1990s, particularly with the establishment of new tertiary centers, such as the Strathmore University, Kenyatta University (KU), and the Jomo Kenyatta University of Agriculture and Technology (JKUAT)[19]. These institutions offered Bachelor of Science in Computer Science programs and related fields. The government also continued to invest in CSE in the 2000s giving rise to the Multimedia University of Kenya (MMU)[20] – another tertiary institution that offered a degree program in CS.

[18] https://myskuulkenya.com/history-university-nairobi-computer-science/
[19] https://jkuat.ac.ke/departments/computing/
[20] https://www.mmu.edu.my/programmes-by-faculty-all/programmes-by-faculty-fci/bachelor-of-computer-science-hons/

Table 8. Summary of universities offering Computer Science programmes in Kenya

	Name of the Program	No. of Years	No. of Courses
Jomo Kenyatta University of Agriculture and Technology (JKUAT)	BSc. Computer Science	4	65
University of Nairobi (UoN)	BSc. Computer Science	4	51
Kenyatta University (KU)	BSc. Computer Science	4	61
Multimedia University (MMU)	BSc. Computer Science (Hons.)	3	35

To complement these budding courses, the Kenyan administration launched the Kenya ICT Board in 2006 to boost the development of the country's ICT sector. This board's mandate was to promote technology adoption in education and ensure the expansion of the nation's IT industry. The Digital Literacy Program[21] – launched in 2013 – expanded on the ICT Board's efforts by equipping primary-school students and their instructors with fundamental computer skills while providing these institutions with laptops. Recently, the number of private tertiary institutions offering CSE in Kenya has continued to grow, including vocational training centers, colleges, and universities, primarily due to the government's investment in CSE.

5.1 Demand and need

Kenya is now home to several IT companies, for instance, Safaricom, IBM, Microsoft, Oracle, and Google. These private sector players have also joined the efforts to expand CSE in Kenya. Companies such as Safaricom, Google, and CISCO have launched countrywide initiatives to train university-level instructors and students and grant them resources to complement their learning. A direct result of this collaboration has been an upsurge in interest in programming among the Kenyan youth, leading to the emergence of hackathons, coding bootcamps, and coding clubs across the country.

Many technology companies here have partnered with universities and colleges to ensure students can gain in-demand skills as they learn and graduate, ready to contribute to the workforce. For example, Microsoft and JKUAT have partnered in creating and implementing a new curriculum for JKUAT's CS students[22]. Huawei has also established an Academy Support Center in UoN where trainers can receive instruction on networking courses[23]. These endeavours are expected to lead to a more competitive graduate cohort that can succeed in the current global labour market.

The government and industry's investment in CSE has also given rise to e-learning platforms offering short courses in CS subjects – a trend accelerated by the COVID-19 pandemic. Some universities, including JKUAT, UoN, and KU already had reliable and robust infrastructure that helped them transition smoothly to online instruction. Students and faculty members showed an excellent uptake of e-learning technology, ensuring minimal disruption of learning activities during this global event. All these developments have created more job opportunities for CS graduates since they can work as software developers, database administrators, system analysts, university lecturers, and other IT-related jobs.

5.2 Structure and focus of Computer Science curricula

Table 8 shows some of the major universities offering CSE in Kenya. In this section, the curricula of these university are evaluated according to the ACM 2020 guidelines, as shown in Table 9. Most courses offered relate to Software

[21] https://www.digischool.go.ke/Home/executivesummary
[22] https://kbc.co.ke/technology/article/35272/microsoft-jkuat-partner-in-developing-engineering-curriculum
[23] https://ict.uonbi.ac.ke/latest-news/uon-and-huawei-signs-collaborative-agreement

Table 9. Distribution of course categories by ACM 2020 knowledge areas for selected universities in Kenya, East Africa

	JKUAT	UoN	KU	MMU
1. Users and Organisation (UO)	12.3%	23.5%	18%	28.6%
2. System Modelling (SM)	13.8%	14.1%	14.8%	8.6%
3. Systems Architecture and Infrastructure (SAI)	15.4%	13.7%	11.5%	17.1%
4. Software Development (SD)	15.4%	11.8%	18%	20%
5. Software Fundamentals (SF)	27.7%	21.2%	21.3%	20%
6. Hardware (HW)	15.4%	15.7%	16.4%	5.7%

Fundamentals, including mathematical units, as the students focus primarily on foundational courses before taking specialized units in their later years.

Although all institutions offering CSE follow a curriculum tailored to their school, several themes emerge. Most importantly, many curricula adhere to the ACM's recommendations, especially those requiring that learners complete core courses in Programming, Algorithm Design, Computer Organization, Data Structures, and Discrete Mathematics [12]. Students also complete units related to Networking, Database Management, Operating Systems, Software Engineering, and Human-computer Interaction. They can also explore electives in specialized fields, including Artificial Intelligence, Computer Graphics, Data Science, Cyber Security, and Mobile Computing. In pursuit of a comprehensive framework for CSE, the ACM also recommends that students gain practical skills and hands-on experience in programming, debugging and testing, and teamwork [12]. Therefore, most institutions ensure that their CS students work on projects, participate in countrywide and international competitions, such as Microsoft's Game of Learners[24] and Huawei's ICT Competition[25], and complete industry internships.

In addition to following the ACM recommendations, universities also specify rigorous requirements for graduation to guarantee exceptional training. Specifically, students must have completed their studies for not less than three academic years and not more than six. During this period, they should complete on average 50-65 units, depending on the institution as shown in Table 8. Each unit is a series of 45 one-hour lectures equivalent to a two-hour tutorial or three-hour practical sessions. The learners must also complete a Computer Studies project during their final year that is evaluated through a written thesis and a demonstration of a software application that solves a local or global solution.

As a result, Kenyan CS graduates have a vast technical understanding of the computing field and remain familiar with essential concepts, including complexity, abstraction, resource use, and security. Many of these institutions' curricula allow them to appreciate the interconnection between practice and theory while granting them a system-level perspective on how computers function. These four-year programs expose the learners to multiple technologies, programming languages, and paradigms to ensure they can apply their knowledge broadly.

5.3 Enrolment trends

Most Kenyan universities offer multiple entry alternatives, for instance, high school students who have attained the minimum points in their KCSE results, diploma graduates with high scores, and students who have completed other related undergraduate programs. However, many of the students are high school graduates whose studies are either sponsored by the government or funded privately. The number of CS students accepted into public universities has

[24]https://www.microsoft.com/MEA/Gameoflearners/
[25]https://studentlife.uonbi.ac.ke/latest-news/invitation-huawei-ict-competition-2022-2023

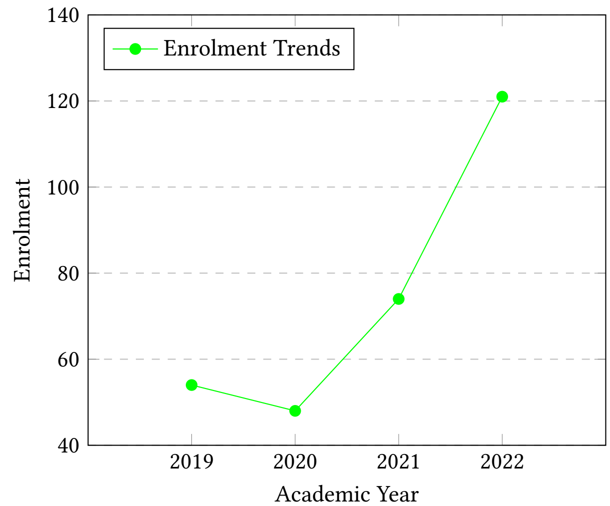

Fig. 3. Enrolment for undergraduate Computer Science in the Computing Department, JKUAT, Kenya.

grown steadily over the years. The figure below highlights the enrolment trend for JKUAT's undergraduate CS program since 2019. The number of students admitted into JKUAT's undergraduate CS program has risen steadily from 54 in 2019 to 121 in 2022.

6 COMPUTER SCIENCE EDUCATION IN TANZANIA

CSE in Tanzania is a rapidly growing field, as the country strives to increase its digital literacy and build a strong foundation for its technology industry. Tanzania is a relatively young nation and faces a number of challenges when it comes to providing CSE to its population. The first Bachelor of Science in Computer Science programme was established in 1999 at the University of Dar-es-Salaam. This was the only university offering CS tertiary education in Tanzania with an enrolment of fewer than 100 students per year [26]. Compared to the previous years, the demand for degree qualifications in CS and related disciplines has rapidly increased. To-date, there are more than 12 universities offering CS programmes or CS-related disciplines such as (BSc. Information Technology, BSc. Information Systems, and BSc. in Information and Communication Technologies) [27].

In addition, the Tanzanian government has made efforts to increase access to CSE and to improve the quality of the instruction provided to students [28]. The Ministry of Education, Science and Technology (MOEST) is the primary source of support for CSE in Tanzania [29]. The ministry is responsible for overseeing the development of CSE in the country. MOEST has established a number of initiatives to support the development of CSE in Tanzania, including the establishment of a national CS curriculum, the introduction of computer studies in universities, the development of CS clubs, and the establishment of computer-focused centers of excellence.

The government has also collaborated with a number of international organizations to improve the quality of CSE in Tanzania. With the support of international organizations, the government is investing in initiatives that will ensure

[26] https://cse.udsm.ac.tz/about-us/formation-of-cse
[27] The Tanzania Commission For Universities (TCU), 2020
[28] https://files.eric.ed.gov/fulltext/EJ1153332.pdf
[29] https://files.eric.ed.gov/fulltext/EJ1099588.pdf

Table 10. Enrollment in Computer Science at the selected universities in Tanzania, East Africa

No	University Name	Location	Number of Enrolment
1.	Mbeya University of Science and Technology (MUST)	Mbeya	50
2.	University of Dodoma (UDOM)	Dodoma	100
3.	National Institute of Transport (NIT)	Dar-es-Salaam	40
4.	University of Dar es Salaam (UDSM)	Dar-es-Salaam	130
5.	Institute of Accountancy Arusha (IAA)	Arusha	100
6.	Mwenge Catholic University	Kilimanjaro	100
7.	Jordan University College	Morogoro	50
8.	The Institute of Finance Management (IFM)	Dar-es-Salaam	40
9.	Ruaha Catholic University (RUCU)	Iringa	90
10.	State University of Zanzibar (SUZA)	Zanzibar	20

that Tanzanians have the skills necessary to participate in the digital economy. For example, the World Bank has supported the development of the Information and Communication Technology for Development (ICT4D) initiative in Tanzania, which aimed at providing access to CS skills and resources to marginalized populations [30]. Furthermore, the United Nations Development Program (UNDP) has provided support to Tanzanian universities to develop CS focused degree programs [31]. Despite these efforts, CSE in Tanzania remains limited. According to a report by the World Bank, only 33% of universities in Tanzania offer CS instruction [32].

However, CS instruction lacks depth, with few students going on to pursue post-graduate degrees in the field. In order to improve access to CSE, the Tanzanian government has committed to increasing the number of CS instructors in the country, as well as providing better training and resources. From the enrolment of fewer than 100 students at the University of Dar-es-Salaam in 1999, the number of students currently enrolled for the Bachelor of Science in Computer Science has increased across Tanzania to more than 700 students (Table 10).

6.1 The demand and need

The government of Tanzania has been increasingly investing in the Information and Communication Technology (ICT) sector in the last few years. A number of initiatives have been implemented to promote CSE in the country. The government has partnered with local businesses and international organizations to provide training and support for CS students. The aim is to develop a skilled workforce that can contribute to the growth of the ICT sector. Furthermore, the government has also partnered with the industry to create a platform for collaboration and innovation. This has allowed the industry to exchange ideas, develop new products and services and create job opportunities for CS graduates.

In Tanzania, the government has been making efforts to increase the number of CS students who are doing internships in industries. This is part of the government's effort to bridge the gap between academia and industry, as well as to help students gain practical experience in the field. The government has put in place initiatives such as the Tanzania ICT Internship Programme, which provides funding and support to CS students who wish to do internships in the industry. This programme has resulted in a number of students being placed in various industries, such as banking, telecommunications and IT services.

[30] https://documents1.worldbank.org/curated/en/485771622426544909/pdf/Tanzania-Digital-Tanzania-Project.pdf
[31] https://www.undp.org/tanzania/blog/disrupting-conventional-universities-space-collaborative-problem-solving
[32] https://documents1.worldbank.org/curated/en/299851580138262444/pdf/Tanzania-Secondary-Education-Quality-Improvement-Project-SEQUIP.pdf

In addition, the government has also been encouraging local universities to partner with the private sector to create internship opportunities for students. For example, several universities in Tanzania have partnered with the tech companies to offer internships to students in the field of CS. This has enabled the university to better prepare its students for the job market and to enable them to gain hands-on experience in the industry.

Also, there is a fracture of knowledge sharing between industry and the higher learning institutions in Tanzania. Internships are an excellent opportunity for CS students in Tanzania to gain valuable hands-on experience in the field. By taking on an internship in a local industry, students can learn how to apply their technical knowledge in a professional setting. Additionally, internships can give students the opportunity to network with industry professionals, build a portfolio of work and receive mentorship. Through internships, students can also gain insight into potential job opportunities and build relationships with employers that could lead to future employment. The majority of universities reported collaborations with industries only for placement of students (e.g. internships), which contributed to 100% of the consulted institutions. However, 50% of the respondents agreed to have collaborations with industries in terms of students internships, guest lectures, co-teaching and sharing of problem sets.

6.2 Structure of Computer Science degrees

The curriculum for CS in Tanzania typically includes a set of core topics such as Internet of Things, Data Science, Artificial Intelligence, Networking, Machine Learning, Data Management, Computer Programming, Web Design, Databases, Data Structures and Algorithms, Operating Systems, Computer Networks and Graphics. Some universities offer more specialized emerging topics such as Cyber Security, Robotics, Computer Vision and Natural Language Processing. In addition to the core topics, most CS curricula include courses in problem-solving, communication, and ethics [33]. Some curricula also include courses in Mathematics, Physics and Engineering.

The CS curriculum in Tanzania is designed to prepare students for a successful career in CS [34]. It emphasizes the development of technical and analytical skills, as well as the ability to think critically and creatively. The CS curriculum across universities has either similar or different focus however, the most common career paths of the graduates are hardware engineering, software development, IT and network management and data scientists (Table 11). In addition to that, methods of delivering the CS curriculum by many Tanzanian universities are through seminars, projects, practical and knowledge based learning, discussion, online learning, demonstration, case studies, face-to-face lectures and assignments. Students are also encouraged to become involved in research projects, internships, and other activities to gain experience in the field.

7 CHALLENGES AND OPPORTUNITIES FOR CSE IN SSA

Despite efforts by African governments and universities to promote CSE, there remain challenges that affect CSE in Africa. These include limitations in student background, minimal resources and funding limitations, inadequate infrastructure, poor pedagogical approaches, gender imbalance, and a shortage of qualified instructors [3, 14]. There are several challenges and opportunities for CSE in Africa. Many of these are cross-cutting across multiple countries, while some of them are unique to some of the countries in this study. In this section, we summarise these challenges and also discuss opportunities to improve CSE in Africa.

[33] https://core.ac.uk/download/pdf/15167009.pdf

[34] $https : //wrap.warwick.ac.uk/72077/1/mwasaga_{a}piola_{s}uhonen_{j}oy_{i}ce_{1}5.pdf$

Table 11. Career paths for Computer Science students from the selected universities in Tanzania, East Africa

No	University Name	Affiliation	Programme Name	Career Path
1.	Mbeya University of Science and Technology (MUST)	Public	BSc. Computer Science	Software development
2.	University of Dodoma (UDOM)	Public	BSc. Computer Science	Software development
3.	National Institute of Transport (NIT)	Public	BSc. Computer Science	Hardware engineering
4.	University of Dar es Salaam (UDSM)	Public	BSc. Computer Science	Software development
5.	Institute of Accountancy Arusha (IAA)	Public	BSc. Computer Science	IT and Network management
6.	Mwenge Catholic University	Private	BSc. Computer Science	Software development
7.	Jordan University College	Private	BSc. Computer Science	IT and Network management
8.	The Institute of Finance Management (IFM)	Public	BSc. Computer Science	Software development
9.	Ruaha Catholic University (RUCU)	Private	BSc. Computer Science	Software development
10.	State University of Zanzibar (SUZA)	Public	BSc. Computer Science	Data scientists

Challenge One: Computer Science Knowledge Gap. The first challenge in CSE in Africa is the CS knowledge gaps in the areas of mathematics, programming, logic, and problem solving skills of our secondary school leavers (or matriculants). Students entering first year at universities have hugely divergent skill levels, mostly dependent on what type of secondary school the student attended. For example, the schooling system in South Africa categorises three types of secondary school, namely private schools (which are typically very expensive but provide excellent education), model-C schools (which are well run government schools, mostly with functioning parent governing bodies and good pass rates in the final matriculation examinations), and finally, the largest category, government schools that do not have functioning governing bodies, and with the lowest average pass rates for the matriculation exit examinations. This difference in secondary schools attended by the students provides a critical challenge in the school system that cascades to CSE at university level[19]. In some of the countries, like Uganda, Ghana, and South Africa, ICT and computer studies are offered as a subject at secondary schools but these are oriented towards the use of computer (i.e. ICT literacy) and software applications and less on the foundational concepts of CS. Most of the students admitted to a CS degree programme learn programming and computational aspects for the first time at the university, which impacts on their learning curve across the CS content.

Moreover, a number of CS undergraduate students in universities are unprepared for their study programme as they lack knowledge of CSe as a discipline and also have had no prior counselling and guidance in choosing to undertake the programme. It is not uncommon for CS to be misunderstood as being the same as “computer studies” or “computer literacy”. As a result, most part of their first and second year is spent in trying to reorient and understand the programme and/or area of study instead of spending it on grasping the basic concepts and logic that would need to be applied in their higher years of study. This eventually affects their level of passion for the programme and additionally, the quality of output of graduates from the programme.

Challenge Two: Insufficient Exposure to Mathematics. STEM subjects in African schools have been the worst affected by the various disruptions in the past few years, like natural disasters and COVID-19 [35]. However, the result is that the mathematical skills required for university courses in the Science and Engineering faculties are not developed prior to entering university. Due to the fact that most students do not get sufficient counselling and guidance on choosing their study programme, students may underestimate the prior mathematics background required for the CS programme. As a result, students who meet the minimum requirement to enter the university but have Mathematics challenges, end up in the CS programme and struggle to go through it and this eventually affects the quality of output of

[35]https://mg.co.za/special-reports/2022-11-04-stem-education-disruptions-and-the-future/

graduates from the CS programme. For example in South Africa, many secondary school learners are being encouraged to take Maths Literacy rather than normal Mathematics in government schools, as this is an easier subject in terms of content and one for which teachers might be more readily available.

This challenge is even bigger for private and newer universities whose programmes have existed for a shorter time, and have to compete with the traditional public universities who have been in existence much longer. This is seen in Ghana and Uganda, where the traditional public universities with government funding, are able to set up departmental admission requirements (usually higher than the minimum admission requirements) and as a result, most often would get students with good passes in Mathematics. However for the other private universities, in order for them to meet their financial needs, they admit based on the minimum admission requirements to get sufficient student numbers and this impacts the quality of the CS graduates. Jonathan Jansen (a former Vice-Chancellor of the UFS) warned in 2018 that the standard of South Africa's secondary school exit exams are dropping and university entrance requirements are being lowered, especially in the case of mathematical skills [36].

Challenge Three: Availability of Teaching Staff. Many African universities are faced with the challenge of finding suitably qualified CS teaching staff. The number of staff in the CS discipline with PhD degrees is limited. Moreover, retaining qualified CS teaching staff (especially young staff members) is also a challenge in some countries as the staff are easily 'poached' to take up employment positions in private companies offering higher salaries than in the education sector. This attrition also means that CS researchers are not conducting IT research maximally, leading to slower IT interventions expected to bring about positive economic and social outcomes for local contexts [14]. Competing with the high salaries offered by ICT companies is very difficult for most tertiary education institutions.

Challenge Four: Gender Imbalance. Despite an increased number of computer scientists in African institutions, there is still gender imbalance in CS in both the student population and the teaching staff across most African universities. Gender imbalance does not only occur in CS programs but also cuts across the STEM fields [6]. A study carried out by ICT consultants in Uganda showed that Makerere University, and other African universities had a ratio of male to female students in the ICT programs of 3:1 [23].

Challenge Five: Student Field Attachment. Due to limited growth of the CS industrial sector in some African countries, there is usually a challenge in student field attachment activities or industry linkage. It is expected that second-year CS students take up field placements at different CS focused organisations and companies during their recess term. During this internship or field attachment activities, students are equipped with practical skills in CS such as programming, databases, software engineering, artificial intelligence and general hardware maintenance[37]. This field attachment has shown that it improves student employability and entrepreneurship skills [5]. The challenge however, is that quite often, there is a limited number of organisations with suitable internships for CS students, as many tend to be oriented towards general ICT management. The emerging startups that are oriented towards the CS fields tend to have limited capacity to take on interns.

Challenge Six: Lack of Funding. Another obstacle for CSE is limited funding opportunities for undergraduate students. For example in South Africa, the national government has in place a National Student Funding Assistance Scheme (NSFAS) to support students from families below the poverty line. However, but there is a "missing middle"

[36] https://mybroadband.co.za/news/government/283121-1998-vs-2018-matric-maths-exams-how-much-easier-it-is-today.html
[37] https://cs.mak.ac.ug/curriculum

group of students, who do not qualify for NSFAS funding, and whose families cannot afford the university fees [38]. Besides the limitations on funding for students, universities are also experiencing challenges related to limited resources such as hardware, software, ICT teaching resources for the practical programming and CS courses, and administration support.

Challenge Seven: Teaching Methodologies. Usually the challenge of inadequate Mathematical skills should be surmountable as most CS programmes have introductory Mathematics courses such as linear algebra, calculus, discrete mathematics, probability and statistics. However the pedagogical approach to teaching seems to still make it challenging for the students that are already challenged by the subject. The same applies to computer programming courses (which most first year students would not have encountered prior to enrolling at the university) and other ancillary CS degree courses. Hence, the pedagogical approach is a challenge. Some lecturers would want to go the traditional way of teaching using the white/blackboard approach instead of practicing with students in the labs especially for practical courses. The issue of pedagogy is further complicated by the lack of sufficient CS degree programme lecturers as mentioned previously.

Challenge Eight: Problem-solving Skills. A prevailing challenge is that graduates struggle with abstract problem-solving capabilities. Computer scientists should do more than code because they need to be able to improve or design systems and communicate their solutions – a skill only possible through life-long learning. Most topics are covered only as introductory courses, meaning some students can hardly appreciate the domain-specific nature of their classes. This issue remains difficult to address because while students can master the concepts introduced, many struggle to apply them concretely or consider them from multiple viewpoints.

7.1 Opportunities

A number of universities have taken several approaches to address the challenges in CSE. For example, Makerere University initiated outreach programmes targeting secondary school students to educate them about what is and is not CS and the opportunities available in the CS field to address the CS knowledge gap. Some South African universities have added a bridging year to the undergraduate curriculum (making the normal Bachelor degree four years) to mitigate the deficiencies in the schooling system and address the challenge of the lack of mathematics background. Other remedies are to include life skills and computational thinking courses, as well as introductory computing courses in the CS curricula at universities. At the other end of the interventions, particular CS modules (such as, Theory of Computation and Algorithm Analysis) may be "dumbed down" to eliminate the need for a higher foundation of mathematical knowledge.

To address the funding challenge, African governments are currently searching for ways to mitigate this issue, possibly by way of student loans, for example in Uganda and Kenya. Universities have launched numerous initiatives to increase the intake of students, for example through the collaboration with international organizations, such as the Mastercard Foundation[39], in Uganda and Kenya to provide scholarships to prospective and current CS students and their instructors. For instance, 20 years ago, it was challenging to convince instructors that investing their effort and time in learning computer systems for their learners' benefit was difficult [25]. However, numerous African university faculty members have obtained diverse international training as CS faculty. As a result, having numerous trained instructors has boosted teaching quality for CSE as the widely-trained faculty bring about a diverse range of teaching

[38] https://www.careersportal.co.za/news/government-exploring-ways-to-fund-missing-middle-students
[39] https://mastercardfdn.org/our-work/where-we-work-in-africa/kenya/

methods while also expanding research in CSE and other computing fields. The capacity challenge has been addressed through staff training in collaboration with international institutions [8, 14] in addition to the in-country PhD training.

8 FUTURE DIRECTIONS OF CSE IN AFRICA

The presentation of case studies from selected countries and universities shows the trend and the current state of CSE in Sub-Saharan Africa. There are a number of common points that are worth noting. Most of the CS curricula are structured as three-year degree programmes, underpinning the need for a fast CSE delivery. Although different selected countries note that there are challenges around the deficiency of mathematical and computational knowledge at the entry-level. This challenge could inform continent-wide discussions to shape the future of pre-university CS education. The other alternative is an exploration of four-year CS degree programmes as has been trialled in South Africa. CSE programmes across the region increasingly have considerations for non-technical courses such as communication skills, digital innovation and entrepreneurship, emphasizing the role of CSE in training the continent's CS-driven innovations and digital transformation. In line with global trends, many CSE programmes have introduced new areas including Artificial Intelligence, Machine Learning, Cloud Computing and Internet of Things (IoT). However, CSE programmes have maintained the focus on the foundational technical courses of CSE.

Over the past few decades, there has been an increase in the number of institutions offering CSE degree programmes. There is also an increase in the number of enrolments across most of the institutions in the selected countries. This is linked to and driven by the growing demand for CS graduates from within and outside the continent. There are indications that some of the graduates from SSA are servicing the industry needs outside the continent. There is a need for further studies across the continent to understand the job categorisations and career trajectories of CS graduates. Despite the growing enrolment, the gender gap is noted in most of the institutions, with fewer female students compared to male students. Countries and institutions are taking different approaches to address this issue. For example, Makerere University has recently introduced initiatives aimed at increasing the enrolment of female students in STEM programmes.

This paper was limited to a few selected countries from Sub-Saharan Africa. In future, this landscape can be enriched by the inclusion more countries from the continent, providing more diverse perspectives of CSE.

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