Description of Computer Science Higher Education in Sub-Saharan Africa: Initial Explorations

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ABSTRACT

Many countries in Sub-Saharan Africa (SSA) are in need of technology innovators who are equipped to leverage technologies in locally relevant domains such as health, government and education. To create skilled graduates who can build and shape locally relevant technologies, higher education institutes in Africa must have Computer Science (CS) education programs that meet local needs, for example, to satisfy the demand for entrepreneurs to build industry and strengthen an economy.

This paper characterizes the current state of CS education in SSA in order to identify opportunities for addressing education challenges and to make suggestions that may improve the Information and Communication Technology (ICT) infrastructure in this region. We present the results of a survey of CS educators in SSA institutions of higher education, which was aimed at exploring the issues they face. In addition to the continued chronic under-funding of SSA education, we found that universities in SSA have smaller departments, less focus on Human Computer Interaction (HCI) and offer a variety of courses aside from undergraduate Bachelors degrees.

We discuss directions to improve CS curricula through investing in locally tailored courses and changing perceptions of the value of SSA CS higher education programs, standards and educators. Further, we reflect on the challenges of conducting research on SSA. We conclude that further research in this area is needed to build on the ideas we offer here to continue to strengthen CS higher education in SSA.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*computer science education*

General Terms

Design, Experimentation, Human Factors

Keywords

Sub-Saharan Africa, undergraduate computing education

1. INTRODUCTION

Sub-Saharan Africa ranks among the poorest regions worldwide and continues to experience substantial levels of extreme poverty [1, 2]. Studies have shown that increased access to education and leveraging technologies in locally relevant ways—at all levels—leads to poverty reduction but we need to know more about what educational resources currently exist in Sub-Saharan Africa (SSA), particularly related to Computer Science (CS). Our goal in conducting this survey was to better understand the bigger picture of CS higher education in SSA. We wanted to investigate this space because we saw a range of conflicting evidence. For example, recently some US-based philanthropic foundations such as the MacArthur Foundation have come together to develop a program to provide resources for SSA education, suggesting a need for improved education. At the same time, examples of prestigious institutions exist such as Ashesi University in Ghana and the Kigale Institute of Science and Technology in Rwanda. Minimally, this suggests a range of possibilities, and we wanted to understand them empirically in order to better inform how to provide CS higher education more generally.

We focus on CS because CS education enables the creation of a work force of skilled individuals able to develop and leverage technologies for local development, particularly since Information and Communication Technologies (ICTs) have proved to be important tools for economic development [3]. ICTs have been declared effective tools to assist in the alleviation of poverty as well as assisting the rise of literacy and education [1]. They have also been shown to have direct positive effects on the economy by spurring ICT manufacturing industries, and indirect positive effects in developing nations by creating opportunities for e-Health, e-Government and e-Commerce and other services [4].

The ability to leverage ICTs to their full potential requires a solid higher education in computing skills. Strengthening CS undergraduate education in SSA therefore will help stimulate entrepreneurial spirit and decrease brain drain throughout the continent. Yet little is known about the variety and quality of CS undergraduate programs currently being offered in Sub-Saharan Africa.

To identify opportunities for addressing the challenges of CS higher education in SSA and to make suggestions that may improve the ICT infrastructure in this region, we investigated the diversity and range of CS and Information Technology-related undergraduate degrees across Sub-Saharan Africa by surveying CS undergraduate educators across the continent. The remainder of the paper is set out as follows: Section 2 presents background material needed to understand the details of our study, Section 3 outlines the methods used for our survey and Section 4 presents our results and study limitations. In Section 5, we suggest directions for CS curricula for parts of SSA, how perceptions of value in SSA CS programs need to be changed and reflect on the process of conducting the study in an infrastructure poor setting. Finally, we conclude in Section 6 that further research in this area is warranted.

2. BACKGROUND

Surveys on Computer Science higher education, such as the CRA Taulbee survey [5] in USA, the ACM/IEEE CC2001 survey on curriculum [6], the National Science Foundation in the USA [7] have largely been conducted in westernized countries to uncover trends in undergraduate and graduate CS higher education. In Canada, Statistics Canada, has compiled information on major fields of study including Computer Science [8] and elsewhere crossing-cutting international surveys conducted to influence CS related curricula in Europe, South America, North America and Asia exist, e.g. [9].

In general, fewer surveys of SSA higher education exist and of those that do tend to focus on one country or higher education in Africa in general. Those few studies focusing on CS are usually of one country in Africa, e.g., studies examining learning styles of CS students in a South African university [10], on transitioning from high school to first year CS [11] also in a South African university. However, to date no studies have been conducted to compare CS higher education across different countries in SSA.

Our work seeks to fill this gap with an initial snapshot of CS higher education in SSA, specifically to draw inferences about undergraduate CS curricula across this region.

2.1 Higher Education in Africa

Before discussing the details of the survey we conducted, it is necessary to set the context of higher education in Africa and why there is a need for research in this area.

Building local capacity in developing nations requires a pool of skilled and knowledgeable individuals who understand country needs and innovate in an increasingly global knowledge economy. Thus supporting higher education in the global south is paramount [12]. Yet, in Sub-Saharan Africa, higher education suffers from low enrollment rates and lack of resources such as qualified staff and faculty, equipment and poor access to information such as journals and the internet [13, 14]. Additionally, retaining existing qualified faculty with competitive salaries is often beyond the means of most institutes in this region. General difficulties in using ICTs for education also exist, e.g., dealing with students entering university with limited computer knowledge [15]. Because of the often inadequate and poorly resourced institutes available locally, 1 out of every 16 students going onto tertiary studies in Sub-Saharan Africa does so abroad [16]. Further complicating the problems in higher education in Africa, most curricula are based on European and US equivalents and may not be entirely relevant for local needs.

Foreign aid organizations, religious institutions, international organizations such as the World Bank and UNESCO and private foundations such as the Partnership for Higher Education in Africa and universities have all at one time invested money to improve higher education in Africa. Funding bodies have generally tried to address the lack of resources problem by providing basic teaching materials, buildings and computing equipment. Additionally, external organizations have sponsored staff and student development initiatives for study abroad programs and for attending international conferences [13]. In the 1990's, foreign support for higher education in African shifted focus dramatically to support basic instead of higher education, a move led by the World Bank [17, 18]. The shift of aid inhibited the growth of many higher education institutes on the continent. In recent years, after realizing that investing in human capital is the key to economic growth, funding bodies have once again made a commitment to invest in higher education in Africa.

Many examples of interventions in higher education in Africa involve distance and online education [19, 20]. Since distance education extends the reach of education to those who may not be able to attend a traditional university, it was seen as a solution to help under resourced universities. However, given the technologies and local support mechanisms need for successful distance education [21], this method may not be cost-effective in poor infrastructure scarce settings. Examples of successful distance education initiatives include the University of South Africa (UNISA), one of the largest distance education universities in the world, servicing much of Africa [22]. For most courses UNISA uses paper based correspondence and/or local support - one possible reason for its continued success in Africa where many people in Africa are still without access to ICTs.

The African Virtual University (AVU), another distance education initiative, was first started as a standalone virtual university by the World Bank, offering courses and degrees online [19, 22]. However, the technologies used to deliver the content were expensive and unreliable in the target countries and providing local support for the AVU added to overheads. AVU has since converted to a model which focuses on providing supplementary materials for existing courses at various institutes and only offering standalone CS degree in attempts to boost CS graduates on the African continent. Researchers have also studied the use of both online and face to face learning [23] and how interaction with students from other countries can enrich e-Learning experiences [24].

Other initiatives to improve higher education in Africa have focused on building local capacities, for example, NetTel@Africa [25] trains policy makers, regulators and academic institutions through e-learning courses and fosters regional networks of institutions. Similarly, the African Virtual Open Initiatives (AVOIR) [26] has created a regional network of universities in mostly Southern Africa to promote and develop open source software for education. Others focus on creating digital libraries to create repositories of academic material that can be distributed not only by the internet but also on CD-ROMs [27]. Researchers have also investigated gender in higher education in Africa, for example, investigating how women in ICT programs view their roles and seek employment [19].

Industry is also interested in building capacity in less developed countries through investing in higher education, particularly in SSA. For example, Cisco offers both network training academies and internet training centers in effort to help bring more people into the global ICT and knowledge economy [28].

Generally, initiatives supporting higher education in Africa aim to increase the output of skilled graduates. For countries to advance technologically, skills in using, developing and maintaining ICTs are crucial [3]. To this end, quality CS programs are needed and undergraduate curricula may have to be tailored for local needs [29].

However, less research has been conducted on what kinds of CS curricula changes may be important in Africa or how to implement these – one example of an initiative is Project Kane at Carnegie Mellon University [30]. In this project, CMU collaboratively developed a robotics course with professors from a private university called Asheshi university in Accra, Ghana. This course was designed to allow students to broaden their perception of CS and engage in hands-on activities while learning skills in an area not usually taught in Asheshi. Students were enthusiastic about the course and although a more fully developed robotics course was not deemed feasible, the need for students to work on locally relevant problems and a suitably supportive curriculum became evident. Similar initiatives on a larger scale may help uncover the right skills to teach to provide CS graduates with entrepreneurial skills for example. The question then becomes what is the current state of CS higher education in SSA and what are the needs for CS curricula in this region.

3. METHOD

To begin achieving our research goal, we conducted a survey of undergraduate CS higher education departments in Sub-Saharan Africa. Similar studies using survey methods have been conducted to assess what computers can offer schools in Africa [34] and to understand what kinds of PhD program offerings exist in Sub-Saharan Africa universities across fields [35]. Most similar to our regional multi-institution survey in terms of logistics is the African Tertiary Institution Connectivity Survey (ATICS) conducted in 2004 to determine internet infrastructure amongst African universities [36].

In addition to the survey, we attended several meetings with professors and dignitaries from Ghana, South Africa, Liberia, Tunisia and Rwanda to gather informal information about CS higher education in the SSA region.

3.1 Survey Instrument

Our survey consisted of 20 questions, following formatting suggested by Fowler Jr. [37] with a mixture of closed and open-ended questions. Several survey formats were made available (email/online/plain text) since it was anticipated that internet connectivity in the regions we were targeting was low [36]. Since the primary medium of instruction in SSA, tends to be in European languages such as French, Portuguese and English [38], a legacy of the colonial era, we decided to deploy the survey in multiple languages. Because English tends to be a preferred medium of instruction in much of SSA [39] and there are more Francophone countries than Portuguese speaking countries in SSA, we deployed French and English versions of the survey.

The survey content was developed after a meeting with the project team members to identify information most relevant to a study on undergraduate Computer Science programs. Questions were designed to elicit information on the types of programs being offered, teaching materials used and subjects taught; on the number and background qualifications of the staff teaching undergraduate CS; on students attending these programs, their numbers, the male/female ratio and the path for them post graduation as well as the department facilities available for use by the students. For instance, we asked:

What is your role in your institution? (Please mark the most appropriate description):

Department Head

Lecturer

Professor

Instructor

Administration Staff

Other (Please specify).

Open-ended questions were composed in order to uncover the respondents' opinions positive and negative aspects of the existing Computer Science programs, facilities and resources that are needed, obstacles faced, whether collaboration with a US institute would be beneficial and for any pointers to relevant reference material and additional contacts who might be interested in completing the survey. For example, we asked:

How have the curricula for the undergraduate computing programs been shaped to meet local country needs, if at all? If you were to implement changes to the curricula, what would these be and why?

3.2 Recruitment

Since no pre-existing contact lists for Computer Science and related departments in SSA exists, we compiled our own list from the World Wide Web, a non-trivial task. For each university in Sub-Saharan Africa on a list compiled by the United Nations Educational, Scientific and Cultural Organization (UNESCO) [40], we visited their website for contact information and information about CS undergraduate degrees.

We also used the United Nations defined regions of Africa to group our deployment efforts. Since North Africa is more economically stable and established than other regions in SSA, we decided to exclude this region from our survey, focusing the survey on four regions West, East, Middle and Southern Africa. We supplemented the contact information harvested from the web, with contact information from personal contacts in Africa.

Emails were deployed between October 2006 and December 2006 over a 6 week period to approximately 350 educators in SSA and posted to two online forums for education in SSA. Many emails that we sent out bounced and we estimate that between 50-80 emails failed to be delivered to recipients. Participation in the survey was voluntary and no incentives were provided to respondents. Since there were no explicit rewards for participation it is likely that those who responded have an interest in CS higher education in SSA and overcoming challenges associated with computing education in SSA.

3.3 Data Analysis

In total, we received 44 replies. Of these, 2 responses were empty and were discarded. Of the remaining 42 responses, 2 were from the same individual who had completed part of the survey in one response and part in a second response – these responses were combined. 1 response from South Africa was discarded because it was for a graduate institute in CS higher education which was beyond the scope of this survey. Therefore only 40 responses were valid and analyzed, representing 29 unique institutions in 15 different countries.

Quantitative data was analyzed using descriptive tests. Since participants were permitted to skip questions for which they did not want to provide a response to, many of our responses are partially completed surveys. Due to the low number of responses, instead of discarding partially completed responses, we included as many data points per question as possible. For responses from the same institution, the average response was used and if no average could be computed, the responses were not used in analysis. To highlight this peculiarity in analysis, we indicate sample sizes wherever we report the percentages in the paper.

From Figure 1, it becomes obvious that the responses were mostly from Southern Africa, only two of which were not from South Africa. Since our results were sometimes skewed towards South Africa which has a fairly well developed economy (for instance the GDP of South Africa is at least four times higher than the average GDP of Africa [2]) and an advanced educational system, we decided to analyze the South African results separately where appropriate from the rest of the results to paint a clearer picture of SSA CS higher education.

Qualitative data was analyzed by coding the responses for the qualitative questions and grouping them into higher categories and higher themes.

4. RESULTS

In this section, we report descriptive statistics from the responses received in the survey and on the qualitative responses form the

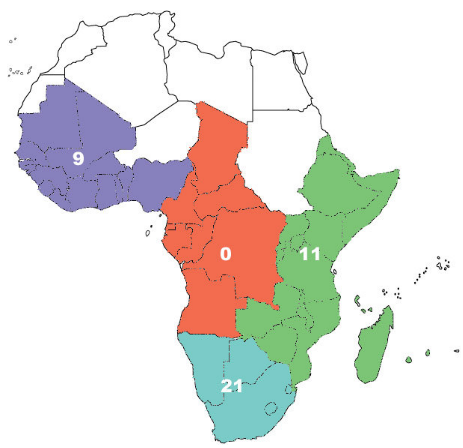

Figure 1. Response breakdown by region: West Africa in purple, Middle Africa in red, East Africa in green and Southern Africa in blue.

Fifteen countries responded including Benin, Botswana, Ethiopia, Ghana, Kenya, Liberia, Nigeria, Rwanda, Senegal, South Africa, Swaziland, Tanzania, Togo, Zimbabwe and Uganda.

open ended questions.

4.1 Demographics

Table 1. Role of respondents at their institutions (n=40).

Department Head	27.5%
Professor	12.5%
Lecturer	45%
Instructor	2.5%
Administration Staff	0%
Other	12.5%

We chose to ask respondents about their role in their institution using terms as defined in the National Science Foundation report on Science and Engineering indicators [41] and common understandings of the terms as used in the USA. Thus "Department Head" refers to a faculty member with a PhD degree whose primary role is to run the department (on top of teaching and research obligations), "Professors" are senior faculty members with a PhD degree, "Lecturer" and "Instructor" are used interchangeably to mean faculty members who have teaching and/or research responsibilities with a masters or PhD degree and "Administration Staff" are non-academic staff members in a department. We acknowledge that these terms may hold other meanings in SSA and this may have affected the responses survey participants chose.

As shown in Table 1, most of our respondents were lecturers in CS related undergraduate degrees (45%), the rest were a mixture of department heads (27.5%), professors (12.5%) and instructors (2.5%). Several respondents reported their role in their institution as "Other" (12.5%) to indicate that they were a department head as well as an instructor, a vice rector (also analogous to "chancellor" and "president"), an adjoint director (analogous to "associate director") and an associate professor.

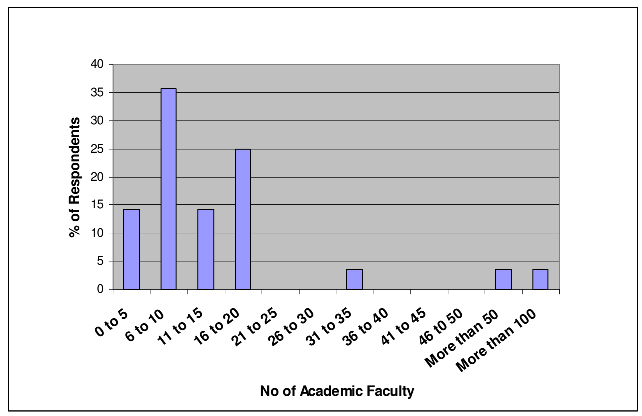

Figure 2. Number of Academic Faculty Teaching Computing Related Undergraduate Courses (n=28).

4.2 Staff

Respondents reported fairly low numbers of academic faculty members teaching undergraduate computing related courses overall as shown in Figure 2. In total, 79% of respondents (n=28) reported that they had 20 or less faculty members overall in their departments. The two outliers indicating more than 50 academic faculty members in their departments were from institutions in South Africa – one from the university with the largest CS department in South Africa (UNISA) and one from a university which was a merger of several smaller institutions.

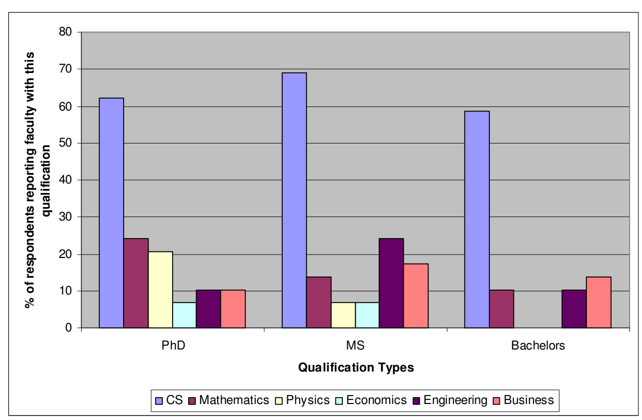

Figure 3. Academic Faculty Qualifications (n=29).

Note, for this question, respondents could choose more than one

option.
In terms of academic qualifications of faculty members (see Figure 3), slightly more respondents indicated a higher percentages of faculty members with CS masters degrees as opposed to PhD degrees. Various other degrees were indicated by 37.9% of respondents who chose the "Other" not shown in the graph. Qualifications constituting "Other" as indicated in an open response included higher national diploma in computer studies, lab technicians, certificates, PhD in mathematical statistics, PhDs in higher education, diploma in computer science, higher national diploma in computer science, PhD in Zoology and bachelor of science honors degrees. Thus these departments vary in qualifications for academic teaching faculty.

4.3 Students

In terms of numbers of students in a department pursuing computing related undergraduate degrees (n=23), 68% of respondents indicated that they had 150 or less students and 32% reporting more than 150 students. All the South African institutions indicated more than 50 students. For other countries, responses varied across the scale from some indicating less than 10 students to some indicating more than 500 students.

Table 2. Percentage of students that are female (n=21).

% of Female Students	% of Respondents
At least 10%	47.6%
At least 25 %	38.1%
At least 50%	9.5%
At least 75%	0%
100%	0%
Other	4.8%

As seen in Table 2, most schools indicated that a quarter or less of their student population was female (86%). One school indicated that their female student population was 40% or less of the student body. Efforts to increase women in computing might be worthwhile to address this gap.

For the path of graduating students, most respondents indicated that at least a quarter of their students are hired by the government (64%) or do further studies at the university or in another country (72%). More than half of the respondents (56%) said that at least a quarter of their graduates are hired by international firms in another country.

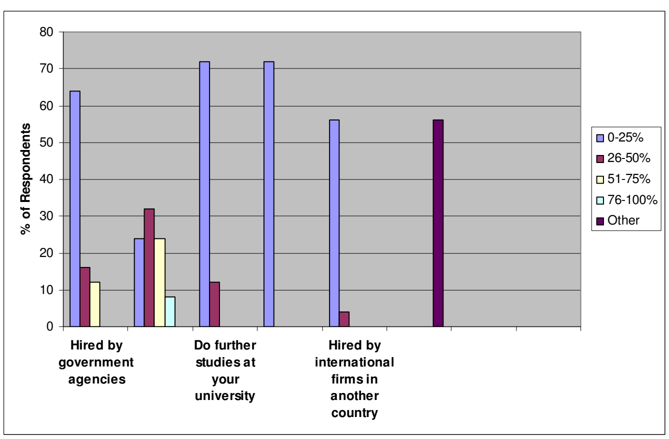

Figure 4. Path of Graduating Students (n=25).

Note that respondents could choose multiple options in this question. The legend indicates what percentage of students entered this career path as indicated by respondents.

56% of respondents gave open ended answers to the career paths of graduate students' question. South African respondents who chose "Other" reported that graduates go on to do research, start their own businesses, become entrepreneurs, go on to do an optional fourth year in the undergraduate degree or work for local companies in banking, business analysis, systems support, financial management or programming. Non-South African respondents in the open ended responses reported that graduates sometimes start their own businesses, which may involve sales and maintenance, are hired by the university or go on to do other international certifications or exams. One respondent indicated that they did not know where graduating students go, perhaps suggesting that not all universities track alumni information.

4.4 Facilities and Teaching Materials

Table 3. Types of teaching materials provided to students.

	Rest of Respondents (n=15)	South Africa (n=9)
Printed notes created by dept. or staff	73.3%	55.6%
Online notes (accessed by worldwide web)	33.3%	66.7%
Textbooks	40%	55.6%
Students purchase their own textbook	53.3%	77.8%
Photocopies of text book section	26.7%	33.3%

When asked about the types of teaching materials that are provided for students, less of the South African institutes reported using printed notes compared to the rest of the respondents (see Table 3). Also, more of the South African institutes reported that students often purchase their own textbooks, and that online notes are provided. Given that South Africa has a higher GDP on average than the other countries surveyed, this may be because the internet infrastructure in this country is better developed.

Table 4. Types of computing facilities provided for students.

	Rest of Respondents (n=15)	South Africa (n=9)
Computer labs in your department	80 %	100%
Computer labs on the university campus	60%	55.6%
Students have their own machines	40%	77.8%
Internet café	33.3%	33.3%
Student email addresses are provided by the university	46.7%	77.8%

For the types of facilities provided for undergraduate computing students shown in Table 4 (with non-mutually exclusive categories), all the South African schools reported having computer labs in their department, as opposed to only 80% of schools in the West, East and the rest of Southern Africa. Further, 77.8% of schools in South Africa reported students having their own machines as opposed to only 33.3% of other schools. This difference may again illustrate the fact that South Africa may have better resourced universities in terms of internet connectivity and infrastructure, 77.8% of schools reported that email addresses are provided by the university compared to only 46.7% of schools in the rest of the surveyed regions.

Table 5. Types of undergraduate computing programs offered.

	Rest of Respondents (n=14)	South Africa (n=9)
Diploma in computer science	28.6%	22.2%
Diploma in information technology	21.4%	22.2%
Bachelors of science in computer science	57.1%	88.9%
Bachelors of science in information technology	0%	44.4%
Bachelors of information technology	14.3%	22.2%
Cisco networking management and administration program	50%	22.2%
Other	28.6%	55.6%

In the "Other" category, South African respondents mentioned that students use wireless networks on campus and may use off-campus computing facilities, including network access in student housing. One non-South African respondent commented that very few students have their own machines and not all students have email addresses provided by the university. This points to the variation in infrastructure in South Africa as compared to other parts of SSA.

4.5 Degrees and Programs Offered

The types of programs offered are shown in Table 5. Perhaps the most interesting finding here is that in the countries other than South Africa, half of the schools that responded offer a Cisco program in network management and administration, compared to only 22.2% of schools in South Africa offering this program. This might indicate more of a need for this program in the other African regions. Further, 88.9% of South African universities reported offering a Bachelors of Science degree in CS as opposed to only 57.1% of universities elsewhere.

In open ended responses, schools reported also offering degrees combining information technology and engineering and shorter 6 month-1 year basic studies in Computing which result in a certificate or diploma. Some schools also offer N+ and A+ certification courses in addition to bachelors degrees.

Table 6. Subjects offered in undergraduate computing.

	Rest of Respondents (n=15)	South Africa (n=9)
Computer Architecture	73.3%	100%
Databases	86.7%	100%
Networking	100%	100%
Programming Languages and Compilers	86.7%	100%
Software Engineering	73.3%	100%
Theoretic computer science (Algorithm analysis)	80%	100%
Operating Systems	86.7%	100%
Graphics	66.7%	88.9%
Human Computer Interaction	26.7%	77.8%
Data Security/Cryptography	46.7%	66.7%
Artificial Intelligence	46.7%	88.9%
Educational technology	0%	22.2%
Other	73.3%	55.6%

For the Bachelors of Science (BS) degree in Computer Science, 39.1% of all the respondents for this question (n=23) reported that the degree is only 3 years long, with 26.1% of respondents reporting the degree is 4 years long. 17.4% of respondents indicated that the Cisco degrees are 2-3 years and 4.3% said this degree was only 1 year long. Thus in general the standard BS in CS might be only 3 years.

Table 6 shows the range of subjects covered by undergraduate computing programs. Education technology is the least taught component according to respondents. In South Africa, HCI is taught by 77.8% of the respondents as compared to only 26.7% of the rest of the surveyed regions, pointing to a large gap in HCI in the rest of the regions. Strengthening this component of curricula seems to be a good focus particularly since HCI is crucial for building usable systems in often challenging conditions in infrastructure poor settings.

Other subjects mentioned by non-South African respondents in open responses were telecommunications applications, project managements, computer operation, computer maintenance and troubleshooting, web and mobile computing. The South African respondents who indicated the response of "Other" said that they taught subjects such as digital libraries, ethics, VR, web-based and cluster computing, parallel computing. Thus elsewhere in Africa apart from South Africa, respondents indicated that more basic computing skills were being taught.

Table 7. Practical components of undergraduate computing (n=24).

Students participate in a practicum as part of coursework	70.8%
Students participate in internships with external companies which are arranged by the institution	41.7%

Students participate in internships with external companies which they arrange themselves	33.3%
No internship component	37.5%
Other (please specify)	16.7%

We asked participants about the practical portions of their undergraduate computing offerings as seen in Table 7. Most participants (70.8%) said that students do a practicum as part of coursework but far less reported students participating in internships arranged by the institute or by the students themselves.

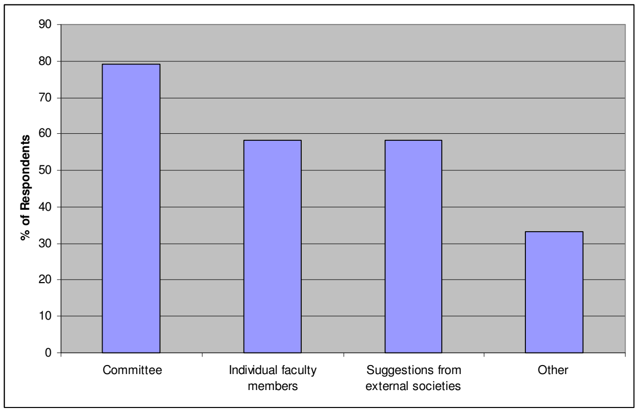

Figure 5. **Parties responsible for implementing curriculum changes (n=24).**

Finally, we enquired about how each department makes changes to their undergraduate computing curricula and the results are shown in Figure 5. Most respondents (79.2%) indicated the changes to the undergraduate computing curricula are made by a committee. Any changes to the computing curricula therefore depends on the pace at which committee approve changes. We did not ask respondents if there is room to experiment with the curricula of certain courses. For the respondents who indicated a response of “Other”, most stated that the curricula was driven by ACM and IEEE standards or in some cases by standards laid out by the British Computer Society. One respondent also mentioned that the curricula changes need to be ratified by the University senate.

4.6 Curricula Changes in SSA

From our open ended responses, one main theme emerged regarding CS higher education curricula. Most respondents reported that they were trying to make curricula changes to make the CS higher education more locally relevant or that they desired this change. Some felt that their curricula needed no changes because they were structured according to ACM/IEEE standards or meeting with “international standards on the internet”. Respondents also mentioned that curricula changes should take into account local industry needs to be “demand driven” so that graduates are able to “fit into the working environment”. Respondents also emphasized the need to be aware of governmental restrictions and still meet international standards.

This theme suggests that a standardization body to address Africa specific needs may be required. Since there is no one size fits all type solution, this body could work on developing modules for curricula to meet specific needs. Two institutions did report that they were in the process of implementing streams in their BS in CS programs to be aligned with issues for developing countries and AIDS awareness, including topics on ethics and legal training.

Several obstacles to changing CS higher education in SSA were also mentioned in the open ended responses. Foremost, most respondents indicated that a general lack of resources and funding is still a huge barrier to CS higher education in SSA. Respondents reported lacking funding for teaching materials, equipment, staff salaries and internet infrastructure. Further, respondents reported that lack of funding made it more difficult to compensate and retain qualified faculty members. Addressing this issue seems difficult because it involves improving a country’s overall spending on education and economy.

Another barrier that respondents indicated was that students entering CS higher education programs are not adequately prepared for university level CS, either usually because they lack fundamental mathematical skills, are “very new to computers when they enter university” or “have to start at a base level”. Focusing on high school students and introducing CS courses at this level may reduce this obstacle to CS in higher education.

Other barriers cited included highlighting the fact that many SSA faculty are not adequately trained to teach CS. More staff development programs and curricula for these programs might be a future avenue of research for CS. Finally, SSA also faces problems of declining interest in CS and low retention rates. Thus CS educators working to address this need in the developed world have a lot to offer faculty in SSA institutions also wanting to overcome these education challenges. In fact, most respondents commented on the benefits that collaboration with a US institute might offer including to “strengthen curricula”, provide “foreign input in new areas/tools” and “teaching methodologies”.

5. DISCUSSION

Based on our results, we discuss directions for CS curricula in SSA, changing the perceptions of value of CS higher education programs in this region and highlight the challenges of conducting a survey of this nature.

5.1 CS Curricula Directions

Our initial explorations have highlighted possible “roles” for both CS departments and for computing graduates that a curriculum may have to support but more data is needed to generalize these results. In terms of CS departments, roles refers to the multiplicity of functions that a university fulfills, including providing courses that do not fit in with a westernized understanding of a “university” but may be considered part of a more technical or vocational school. In terms of CS graduates, roles refers to the career paths that CS graduates may follow in SSA. We elaborate on these roles below.

One issue reflected by our data is that in the universities surveyed, apart from South Africa, often a university fills multiple roles in that it not only offers three or four year undergraduate degrees but also shorter practical certificates or diploma courses, for example in PC management, which in more westernized countries is associated with vocational and technical schools.

Streamlining the CS curriculum for some countries in SSA then may have to include course structures for courses typically not accounted for by standardizing bodies in the west. Further, the development and introduction of these courses, indicates that some adaptation for local market is already occurring in many SSA institutions, sometimes driven by industry needs, for instance, in the Cisco programs. Perhaps more investment is needed in courses to support local graduates through shorter and more varied certificate and diploma courses on other useful content for fulfilling a career locally or internationally. For example, graduates may need CS focused courses that help them understand how to position and grow a business both locally and internationally. Pulling from multiple disciplines and integrating relevant materials from economics, business and so on in tailored short certificate courses might complement technology skills and help graduates gain the skills to increase their chances of success in the job market.

Specifically, we foresee two important career paths or roles for graduates that need to be supported by appropriate curricula, in shorter certificate courses or as modules in the mainstream CS curriculum. The roles we suggest here are general and by no means should be taken as a one size fits all. As mentioned earlier in this paper, the specific situation of the institute which adopts these roles will change how the curricula is adapted and appropriated. The two roles are that of entrepreneur and transnational.

The Entrepreneur role would require courses geared towards teaching business savvy, to create graduates that can contribute to the local economy by starting their own businesses, for example, teaching business accounting. Courses might also be tailored to teach ethics for the local context, for example, on the ethics and challenges on how to work with and develop solutions for underserved communities.

Supporting the transnational role in a CS curriculum would mean not constricting the curricula to local standards only so that graduates have the opportunity to not only study abroad but also compete in the international job market should they choose to.

Combining these roles, would allow graduates to start transnational businesses, also increasing participation in the global knowledge economy. Thus international foundations and universities wanting to invest in CS higher education in Africa, might wish to consider supporting these university and graduate roles by investing in curricula development programs designed to make shorter certificate courses and electives that help graduates make the most of the local situation to achieve success locally and elsewhere if desired. Moreover, to further enhance graduate skills, Human Computer Interaction courses and programs that teach students the importance of creating usable students will increase the likelihood of success of local systems and even for giving graduates more clout in the international job market.

Further research is need to determine whether there are other roles might be appropriate as well as the courses needed to support graduates wanting to follow these paths. Also, investing in these kinds of efforts from now would be beneficial, since introducing curricula changes is a long term process, being governed by committees, influenced by government and university restrictions.

5.2 Changing Perceptions

Our results reflect embedded cultural values in the CS higher education curricula and we suggest that perceptions of value may have to change in order for CS higher education in SA to move forward in terms of meeting local needs. First, our results show among faculty there is a great desire to comply with international standards for CS curricula. Using standards from ACM/IEEE, BCS and other non-African bodies is still perceived as having more value than having programs that are home-grown which may not comply with international standards. Fostering the sense of value in local standards and creating SSA bodies for standardization which are perceived as just as valuable as other international standards will help strengthen moves to develop CS curricula suited for local needs.

Second, there is no emphasis on a formal/informal internship program for students to gain industry experience while engaging in their studies yet there is a need to connect graduates more with industry. Developing a culture of programs to allow students to engage in industry internships during their studies might help strengthen graduate skills and also help place graduates when they complete their studies, and provide direct feedback from industry on how to streamline CS curricula for local needs.

Third, women are still under-represented in computing. Investing in programs that change perceptions of women as empowered individuals who can wield technology, particularly in more patriarchal societies may indirectly affect and attract more women to CS higher education.

Changing perceptions through empowerment campaigns focused on creating a sense of value in SSA CS education standards and culture is therefore a worthwhile investment in SSA higher education in general.

5.3 Challenges of CS Higher Education Research in SSA

Conducting a survey of multiple institutions in Sub-Saharan Africa was not trivial. Difficulties with the survey included the time-consuming process of compiling a contact list to which to deploy the survey to our knowledge no list or database of CS departments along with contact information in SSA exists.

Furthermore, harvesting emails addresses from the web was difficult and near-impossible at times. Many universities or CS departments did not have a web presence at all, and those that did, had minimal or incomplete information in most cases and those not in English, our own mother tongue had to be translated using web based language translation tools.

We were surprised that almost all our respondents preferred to complete the survey online as opposed to in email format because we assumed internet connectivity in many parts of SSA would be poor as indicated by previous research [36]. However, we did notice subtle indicators of a lack of or unreliable internet infrastructure and this may have affected survey response by causing emails to bounce. For instance, many of the people that we contacted had email addresses from commercial sites like Yahoo! and MSN's Hotmail.

In sum, conducting a large scale survey seems to require an on the ground presence or partners in each of the institutions one is interested in.

6. CONCLUSION

Strong CS higher education programs are important to create skilled CS graduates for the SSA region who can help develop locally relevant technologies for their countries and also technologies for export to other countries. To understand more about the current state of CS higher education in SSA, we presented and discussed the results of a survey of CS higher educators representing 15 different countries.

We suggest that investing in programs to help universities fulfill responsibilities of both a university and technical school may be beneficial. Coupled with this, developing locally tailored courses to support graduates to become entrepreneurs and to be skilled enough to work internationally are needed. Further, fostering a sense of value in local standards and curricula tailored for SSA through empowerment and media campaigns may indirectly help strengthen CS programs.

Finally, we reflected on the challenges of conducting this survey such as dealing with respondents living in regions with poor internet connectivity. We offer our work as initial exploration and we hope to spark further research in this area.

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