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Mathematics Education in Sub-Saharan Africa Status, Challenges, and Opportunities

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Abstract

Increasingly, mathematics is seen as an important vector of opportunities for economic and social advancement and mobility. There are currently concerns that economic development in the sub-Saharan region is being hampered by the limited availability of high-quality education. In particular, the poor performance of mathematics in schools is seen as a major obstacle to improving economic and social outcomes at the individual and national levels. The main objective of the study was to examine the current state of mathematics education in this large and diverse region of Sub Africa, analyze the learning gap between countries in the region, and look at the efforts to improve mathematics education in sub-Saharan countries. The outcome and results of this study will expose the variety of necessary prerequisites needed to boost performance in the Science, Technology, Engineering, and Mathematics subjects to realize the full potential in the competitive global market and use of new technologies.

Keywords: *Mathematics, Education, Sub Saharan Africa, Status, Challenges, opportunity*

Introduction

Sub-Saharan Africa is, geographically, the area of the continent of Africa that lies south of the Sahara. According to the United Nations, it consists of all African countries and territories that are fully or partially south of the Sahara. [3] While the United Nations geo scheme for Africa excludes Sudan from its definition of sub-Saharan Africa, the African Union's definition includes Sudan but instead excludes Mauritania.

Red: Arab states in Africa (Arab League and UNESCO).

Dark and lighter green: Definition of "sub-Saharan Africa" as used in the statistics of the United Nations institutions.

Lighter green: However, Sudan is classified as Northern Africa by the United Nations Statistics

Division, [1] though the organization states "the assignment of countries or areas to specific groupings is for statistical convenience and does not imply any assumption regarding political or other affiliation of countries or territories". The population in Sub-Saharan Africa is growing and according to Global Trends in 2019 the population was 1.1 billion. 1,038,627,178 (2018)

There is concern that children in developing countries are not learning sufficient mathematics skills. Focus on enrolment and literacy may have led to neglect of mathematics learning and less is known about the status in this area. According to a UNESCO study in 2014 fewer than 50 per cent of grade 6 students have achieved a minimum level in mathematics in three quarters of eastern and southern African countries (UNESCO, 2014).

Education in Sub-Saharan Africa

Forty percent of African scientists live in OECD countries, predominantly in Europe, the United States and Canada. [3] This has been described as an African brain drain.[4][5] According to Naledi Pandor, the South African Minister of Science and Technology, even with the drain enrollments in sub-Saharan African universities tripled between 1991 and 2005, expanding at an annual rate of 8.7%, which is one of the highest regional growth rates in the world. In the last 10 to 15 years interest in pursuing university-level degrees abroad has increased. [3]

According to the CIA, low global literacy rates are concentrated in sub-Saharan Africa, West Asia and South Asia. However, literacy rates in sub-Saharan Africa vary significantly between countries. The highest registered literacy rate in the region is in Zimbabwe (90.7%; 2003 est.), while the lowest literacy rate is in South Sudan (27%). [6]

Research on human capital formation was able to determine, that the numeracy levels of Sub-Saharan Africa and Africa, in general, were higher than numeracy levels in South Asia. In the 1940s more than 75% of the population of Sub-Saharan Africa was numerate. The numeracy of the West African countries, Benin and Ghana, was even higher with more than 80% of the population being numerate. In contrast, numeracy in South Asia was only around 50%. [7]Sub-Saharan African countries spent an average of 0.3% of their GDP on science and technology on in 2007. This represents an increase from US$1.8 billion in 2002 to US$2.8 billion in 2007, a 50% increase in spending. [8][9]

As of 2015, governments in sub-Saharan Africa spend on average 18% of their total budget on education, against 15% in the rest of the world. [10] The greatest advance was in access to primary education, which governments had made their absolute priority. The number of children in a primary school in sub-Saharan Africa thus rose from 82 million in 1999 to 136.4 million in 2011. In Niger, for example, the number of children entering school increased by more than three-and-a-half times between 1999 and 2011[11]. In Ethiopia, over the same period, over 8.5 million more children were admitted to primary school. The net rate of first-year access in sub-Saharan Africa has thus risen by 19 points in 12 years, from 58% in 1999 to 77% in 2011. Despite the considerable efforts, the latest available data from the UNESCO Institute for Statistics estimates that, for 2012, there were still 57.8 million children who were not in school. Of these, 29.6 million were in sub-Saharan Africa alone, a figure which has not changed for several years. [10] Many sub-Saharan countries have notably included the first

year of secondary school in basic education. In Rwanda, the first year of secondary school was attached to primary education in 2009, which significantly increased the number of pupils enrolled at this level of education.[11][10] In 2012, the primary completion rate (PCR) which measures the proportion of children reaching the final year of primary school was 70%, meaning that more than three out of ten children entering primary school do not reach the final primary year.[10] Literacy rates have gone up in sub-Saharan Africa, and internet access has improved considerably. Nonetheless, a lot must yet happen for this world to catch up. The statistics show that the literacy rate for sub-Saharan Africa was 65% in 2017. In other words, one-third of the people aged 15 and above was unable to read and write. The comparative figure for 1984 was an illiteracy rate of 49%. In 2017, only about 22% of Africans were internet users at all, according to the International Telecommunication Union (ITU). [12]

Historical Background of Mathematics in Sub- Saharan Africa

Most histories of mathematics devote only a few pages to ancient Egypt and to northern Africa during the middle Ages. Generally they ignore the history of mathematics in sub-Saharan Africa and give the impression either that this history is not knowable/traceable, or even stronger still, that there was no mathematics at all south of the Sahara (cf. the critics of [37, 41]). "Even the Africanist of Egyptian mathematics is often denied" [44, 25]. Prejudice and narrow conceptions both of 'history' (cf., e.g., [36]) and of 'mathematics' form the basis of such Eurocentric views (cf., e.g., [33, 34]). These factors only worsen the situation in mathematics education, in which African countries face the problem of low levels of attainment. Not only is "math anxiety" widespread, but many children (and teachers too!) experience mathematics as a rather strange and useless subject, imported from outside Africa. One of the causes of this is that the goals, contents, and methods of mathematics education are not sufficiently adapted to the cultures and needs of the African peoples ([29, 30, 32]).

Mathematics in sub-Saharan Africa

During recent years, a whole series of research projects on spoken and written numeration systems in Africa have been initiated. These include studies on \cite{Gerdes1994}

- Counting in traditional Ibibio and Efik societies (I.O. Enukoha, University of Calabar, Calabar, Nigeria);
- Numeration among the Fulbe (Fulani) (S.O. Ale, Ahmadu Bello University, Bauchi, Nigeria
- Pre-Islamic ways of counting (Y. Bello, Bayero University, Nigeria);
- Mental arithmetic, algorithms, and counting among the different ethnic groups of Nigeria (Ahmadu Bello University, Zaria);
- Pre-colonial numeration systems in Burundi (J. Navez, University of Burundi, Bujumbara);
- Methods of learning counting in C6te d'lvoire [45, 46];
- Numeration systems used by the principal linguistic groups in Guinea (S. Oulare, University of Conakry); Counting among the various ethnic groups in Kenya (J. Mutio, Kenyatta University, Nairobi);
- Oral and possible graphic numeration systems from Zaire [38];
- Numeration and geometric figures in Great Zimbabwe [39];
- Traditional counting in Botswana (H. Lea, University of Botswana, Gaberone);

Number and pattern in selected cultures in Uganda (E. Segujja-Munagisa).
The relationships between the development of mathematics in sub-Saharan Africa and the development of mathematics in ancient Egypt, in both Hellenistic and Islamic northern Africa, and across the Indian and Atlantic Oceans also deserve further study. In connection with ancient Egypt, many open questions still exist. For example, do relationships exist between the duplication and symmetry patterns in pre Bantu rock paintings in Mozambique, the 'binary combinatory' of Pedi Augurs in Transvaal (South Africa, [35]), elements of a binary structure in some African numeration systems and in the Akan weight measurement (Ghana, C6te d'lvoire, [40]), the Mbosi duplication (Congo, [42]), etc., and the Egyptian duplication method [31] for multiplication? Another important open question concerns the role of "black Africa" in the development of "classical Greek society" and its mathematics (Bernal's study Black Athena [27, 28]. [43] Reanalyzes the mathematical documents of Ancient Egypt and stresses their importance in the development of philosophy in Africa. As the history of mathematics in Africa should not be considered in isolation from the development of culture in general or be dissociated from the evolution of art,

cosmology, philosophy, natural sciences, medicine, graphic systems, and technology in particular, the historiography of African mathematics should take into account research findings from other disciplines.

Raising the status

It is difficult to assess the current status of progress in mathematics in the sub-Sahara Africa countries with the assessment data that are available. Data that exist in the World Bank database and from the Education Policy and Data Center are not available for recent years or not available at all in some countries of the region. Key country-level findings around mathematics achievement include:

- Mathematics achievement data from the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) scale are available from 2000 to 2007 for Kenya, Malawi, Mauritius, Namibia, and Zambia. Mean performance in 2007 is highest in Mauritius, followed by Kenya and then Zimbabwe. Zambia scores the lowest. Malawi and Namibia also fall below average. Crude comparison with average scores from 2000 and 2007 show a reasonable improvement for Namibia and some improvement for Malawi. Kenya shows a slight decline in performance. The direction and magnitude of temporal differences are similar for average scores on the reading scale as for mathematics in each country. In most countries, boys appear to be outperforming girls (with the exception of Mauritius).
- Data from Program for the Analysis of CONFEMEN1 Education Systems (PASEC) are available for 10 francophone African countries for 2014 only, so trends over time are not available as an indicator of progress. Burundi, The Republic of Congo and Burkina Faso consistently rank higher across the different mathematical attainment measures. Niger and Chad tend to rank lowest. Rankings for mathematics and English performance scales are similar. Boys have higher averages scores than girls in most countries except Benin and Burundi.
- Young Lives survey data from Ethiopia suggest a decline in mathematics performance between 2006 and 2013. This may be due to the enrolment of new students who are not yet reaching foundational learning levels. Data on national primary school-level mathematics are not available for

Ghana but attainment for grade 8 students show an upward trend. It aims to enhance mathematics education in developing countries by supporting the educational capacity of those responsible for mathematics teachers, and to create sustained regional networks of teacher.

Challengers

There is a growing concerned with the state of mathematics education in Sub-African region The central place of mathematics is fully recognized in the school curricula of Sub-Saharan Africa. It is a compulsory, core subject at primary and junior secondary levels. In some countries, mathematics also features as a compulsory subject in school leaving qualifications at the senior secondary level. The importance of mathematics is also reflected in the time dedicated to its teaching which is comparable to that allocated in more developed systems, and, in some cases, exceeds international norms (World Bank, 2008). While Sub-Sahara African countries differ from one another in many features, yet the one that are similar in key issues of concern include.

Low numbers of secondary school teachers and mathematicians at the master's and PhD levels Both primary and secondary level mathematics education are weak in most Sub-Sahara African countries, reducing the potential population of talented students who choose mathematics majors at the university level. This condition has been attributed at least in part to inadequate teacher recruitment and laws requiring universal elementary education. The educational level for secondary mathematics teachers also varies from country to country, ranging from a bachelor's or master's degree at the high end to various certificates and diplomas that may not be in mathematics.

Low salaries a poor public image of mathematics and shortage of mentors, so many students switch to alternative programs that offer a better prospect of employment/salary after university.

Class sizes and enrollment the growth rates of student enrollment in higher education in African countries, especially in sub-Saharan Africa, were among the highest in the world during the last decades. However, the recruitment of teachers has not been sufficient to keep up with this growth.

Teacher capacity and improving foundational mathematics learning A World Bank commissioned study on mathematics education in Sub-Saharan Africa highlights teacher capacity as a priority area for improvement. Enhancing their knowledge and equipping them with technologies (Bethall, 2016). A study of

six countries (Ghana, Kenya, Mali, Senegal, Tanzania and Uganda) investigating factors shaping teacher educators, trainee teachers, and newly qualified teachers found there needs to be a focus on how mathematics is taught and not just on improving teachers knowledge (Pryor et al., 2012).

Curriculum over the past decade or two, efforts have been made to reform curricula in all countries of Sub-Saharan Africa. In mathematics, as in other subjects, attempts have been made to reduce curriculum overload and improve sequencing. A UNESCO Institute of Statistics report was identified which looks at how cognitively challenging the curricula are in different developing countries in grades 5 and 6 finding high variation (Benavot, 2012). There are no focus curriculums that incorporate industrial and entrepreneurial components of mathematics to create more interest in the subject. There are no short-term programs such as summer schools aimed at showing high school students the power of mathematics and how it can be used to solve real-life problems so that interest is stimulated at an early age.

Gender and mathematics The Millennium Goals recommended equity in education and the encouragement of African females to choose mathematics studies and to embrace scientific and technological careers. While there are no meaningful differences between boys' and girls' achievements upon entry to school, however, the gender gaps in achievement and participation in mathematics persists, as does the underrepresentation of women from primary through tertiary education to employment. In Sub-Africa, It is obvious that education has been seriously affected by poverty, but with respect to the education of girls, history, religion and culture have been more important determinants. These socio-cultural barriers are most pronounced for scientific, technical and vocational education and tragic in their negative effect on participation in mathematics. Girls' low participation in mathematics is also a function of other factors. According to the UNESCO Institute for Statistics (September 2010), the adult literacy rates in sub-Saharan Africa is 71.6% for males and 53.6% for females, and in Northern Africa they are 76.7% and 58.1% respectively. The net enrolment ratio in the primary school age population in sub-Saharan African countries is around 52.3% for girls and 60.7%.

Linkages and networks, there are few mathematical linkages or networks between universities in Sub- Africa and the rest of the world. Where these appear, they are funded from abroad, often in amounts that permit only local

training. Such programs are insufficient to support for the critical ability to move between universities

Few employment opportunities, most African countries have few employment opportunities for mathematics graduates. Many young Africans have benefited from mentorship and capacity building programs offered by developed countries, but nearly half of those Africans who study abroad do not return to Africa due to the lack of local employment opportunities.

Governments lack research funds, most governments do not award research funds to mathematics, so there is little or no incentive for doing research in mathematics. Students hoping for advanced study in mathematics must search for funding from foundations or foreign governments, which is scarce and difficult to secure.

Weakness of journals, many regional and local journals in Sub-Africa lack support and readership, and fail to thrive. Only a few countries, like Nigeria, have local journals in mathematics.

Identifying talent: Few countries have screening tools to identify talented mathematics students or career development opportunities for these students.

Poverty During the research, poverty was highlighted as an issue that limited the ability of the affected households to purchase the required gadgets and to access internet services required for online learning. Social, political and economic factors and other factors such as corruption and mismanagement of funds largely contribute to the high levels of income poverty in the

Sub-Sahara Africa.

Technology Access to ICT Technologies are identified as having potential to assist with mathematics teaching and learning but the best approach has not yet been ascertained (Bethall, 2016). Over the last few years, information Technology and Communication (ICT) has experienced robust growth in the Sub-Sahara Africa region. By 2025, online classes are predicted to be the main preferred form of learning throughout the world (Malan, 2020). Even though countries across the world are making significant steps in online learning, research by Malan (2020) found out that ICT in most states in Africa is still in infancy.

Opportunities

There is some consensus that mathematics learning outcomes will increase with improvements in overall school quality (Bethall, 2016). The World Bank report

notes the complexities contributing to low mathematics achievement and that there is no simple answer to improve them. It is difficult to make shifts in large education systems. Government and stakeholder efforts must be sustained long-term. Early childhood development program should be considered as an opportunity for accelerating progress in foundational mathematics. These include

Children in Botswana and South Africa who had taken part in early numeracy activity with parents had higher learning outcomes (UNICEF, 2016b). Activities include counting different objects, card games, playing with shapes and building blocks.

The Early Literacy and Math's Initiative (ELMI) in Rwanda implemented in homes and in childcare settings produced positive results in preliminary evaluation of school-readiness in mathematics (Save the Children, 2015).

Maternal education level and socio-economic status also played a role in Rwanda which adds some limitation to findings. Some reports of different models of school have been found to produce better mathematics results. Evaluations of low-cost private schools in developing countries have shown higher mathematics achievements compared to government schools (Winthrop et al., 2016).

Impact assessment of USAID Primary Math and Reading (PRIMR) Initiative in Kenya finds positive results (Piper et al., 2016). The initiative supplied books for pupils, and supported teachers with training and instructional support. Significant improvements were found for procedural numeracy in early grade and smaller effects in conceptual numeracy. The study notes that there is little evidence on improving mathematics education in the developing world. Interventions suggested in the World Bank mathematics education study include (Bethall, 2016):

Since the 1990s, both African and international funding agencies have noticed the effectiveness of networks of institutions in strengthening both research and education in mathematics. The following examples include networks at various stages of development and scale.

- Ethiopia: One of the more successful collaborations is that between the Addis Ababa University mathematics department; the East African Universities Mathematics Program (EAUMP); Uppsala University in Sweden; and the International Science Program of Sweden (ISP). Ethiopia has reported several advantages, including experience sharing,

staff and student exchange, research and training collaborations, and motivating mathematicians.

- The Africa Mathematics Project: Funded by the Simons Foundation, this program began in 2013 with five-year grants to three awardees: Tony Ezome, of the Université des Sciences et Techniques de Masuku, Gabon, whose group focuses on number theory, cryptography and allied fields; Edward M. Lungu of the University of Botswana, whose group studies mathematical biology, random differential operators, geometry, and topology; and Diaraf Seck of the Université Cheikh Anta Diop de Dakar in Senegal, whose group studies the mathematics of complex real-world phenomena such as coastal erosion, urban networks, and cancer.
- AMMSI, the African Mathematics Millennium Science Initiative, established in 2004, is a distributed network of mathematics research, training and promotion. There are six Regional Offices, each run by a Regional Coordinator, located in Botswana, Cameroon, Morocco, Nigeria, Senegal, and Tanzania. The mission of AMMSI is to nurture the next generation of African mathematicians and mathematical leadership. It administers, among other initiatives, a graduate student scholarship program.
- Mentoring African Research in Mathematics (MARM), a partnership of the London Mathematical Society, the IMU; and AMMSI. Begun with grants from the Nuffield Foundation and the Lever hulme Trust, MARM promotes mentoring relationships between mathematicians on other continents and sub-Saharan African colleagues, together with their students.
- African Institute of Mathematical Sciences: AIMS was established in 2003, near Cape Town, South Africa, as a center for education and research, recruiting postgraduate students from across Africa. AIMS has recently expanded into other African countries as a network called the Next Einstein Initiative

Conclusions

Mathematics education is currently facing numerous problems at all levels in Sub-Africa, despite the strong mobilization of governments and international support. There is a need to have an educational improvement as the overwhelming need facing the mathematics enterprise today. There is a need to

re-focus the curriculum to incorporate industrial and entrepreneurial components of mathematics to create more interest in the subject. There is also a need to start short-term programs such as summer schools aimed at showing high school students the power of mathematics to solve real-life problems so that interest is stimulated at an early age.

Overall, the story of mathematical development in Africa is one of potential unfulfilled. Based on the outstanding achievements of some individuals and institutions, it is clear that no African country lacks talented potential mathematicians. But without a stronger educational structure at all levels, few of them are able to reach their potential.

Recommendations

- More relevant and exciting teaching of primary and secondary students
- More direct government support for teachers, faculty, and infrastructure
- Strengthened and expanded training and research activities, especially regional networks of people and institutions
- Scholarships for graduate students and fellowships for faculty
- A clearer path to interesting, rewarding mathematics-based career
- Identify collaborative partners and create research groups that identify, develop and promote applications of mathematics in industry.
- Strengthen the role of regional and continent-wide mathematics associations. Such organizations can play a vital role in identifying talented students through national mathematics contests.
- When associations identify promising students, they can take two productive steps. The first and more obvious is to award prizes to winners. The second, and more valuable, is to follow the identified talent and to provide mentoring and assistance in moving toward a career in mathematics. Like NMC
- Classify raising mathematics standards as a national priority.
- Changing attitudes within the public and education sector, this should include highlighting the benefits of mathematics knowledge and skills; that mathematics is for everyone and not just for especially skilled people; and better results are achievable with hard work in and out of school. Changing the view where it is held that mathematics is a subject for boys.

- Improving initial teacher training, Teacher training initiatives must change to increase priority in mathematics
- Existing teachers must be reinforced with improved knowledge and practices. In-service training should follow recommended guidelines. (Walter & Briggs, 2012)
- More textbooks are needed but must be the right textbooks and teachers must be correctly trained in working with them.
- Technologies should be utilized to help teachers gain access to ideas, models, materials and tools.
- International assessments such as PISA22 and TIMSS are less relevant for countries far below international norms. Training for tests which are not suited to the learning needs of the specific population may be a barrier to progress. Regional and national assessments may be more beneficial.
- Self-learning technologies can be a useful supplement, particularly where adequate teaching is lacking.

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