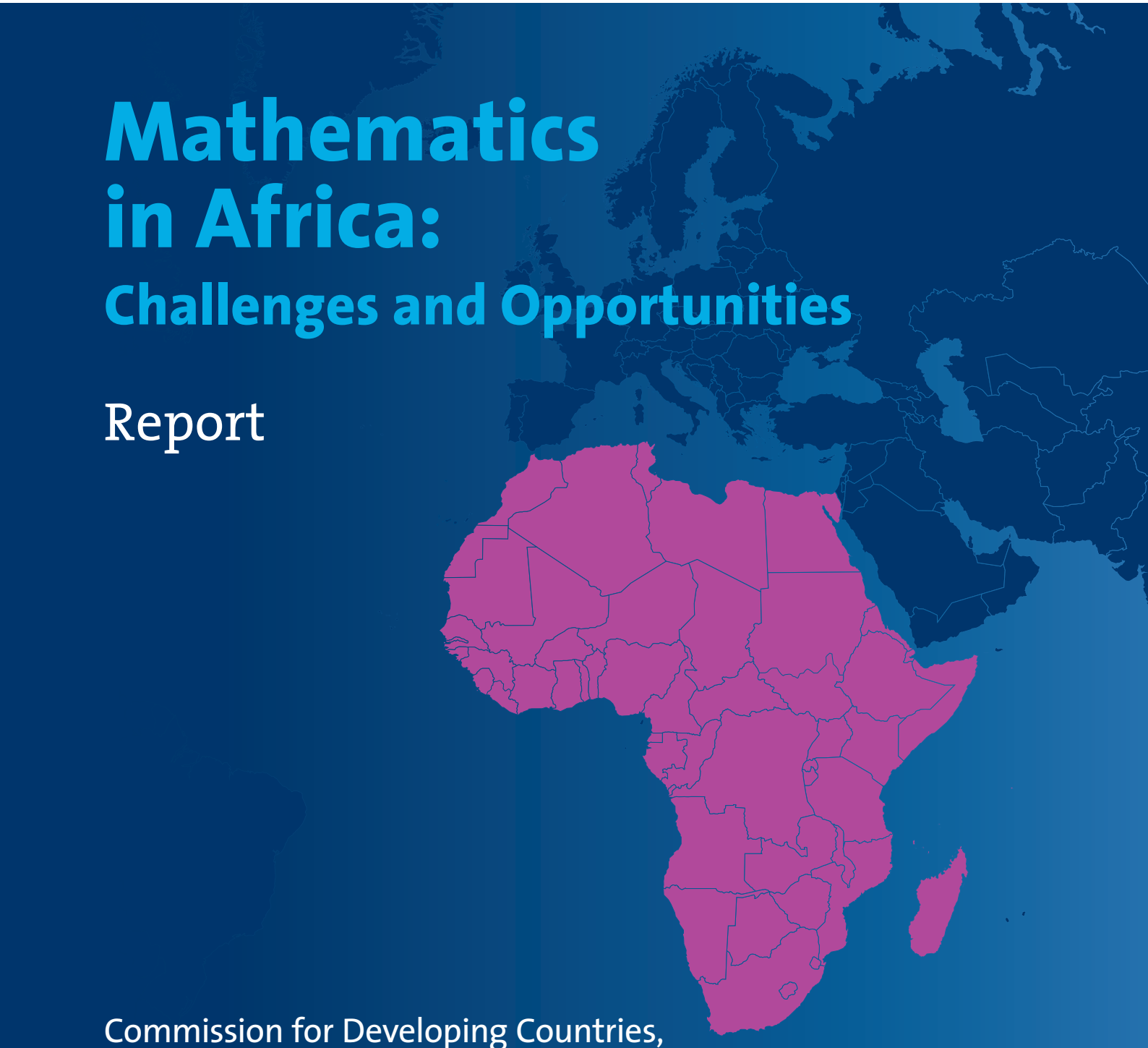
Mathematics in Africa:

Challenges and Opportunities

Report



Commission for Developing Countries,
International Mathematical Union

Mathematics in Africa 2014
A Summary Report

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1. Introduction

This document is intended as an addendum and update to the report "Mathematics in Africa: Challenges and Opportunities," prepared for the John Templeton Foundation by the International Mathematical Union in 2009. The 2009 report can be found at:

http://www.mathunion.org/fileadmin/IMU/Report/Mathematics_in_Africa_Challenges__Opportunities.pdf

While there have been instances of remarkable progress since the 2009 report, such as the Africa Mathematics Project supported by the Simons Foundation, the majority of the challenges outlined in that earlier document still remain. This update, in fact, will serve to highlight several of the same central themes expressed in 2009 and to cite additional recent evidence of their relevance. It is supplemented by six country "Snapshots" in Appendix I, which offer more detail about the main themes. This is followed by Appendix II, which summarizes projects or competitions recommended by our advisors as supportive of the African mathematics enterprise.

Some of the leading mathematicians who contributed to the 2009 report were again generous enough to contribute to the current updating. The IMU expresses its gratitude to them, and to the original contributors whose views have been so valuable in gathering important information.

2. The Templeton Report: Summary

Because of the continued relevance of the Templeton report, we offer by way of introduction a brief summary of its major points.

A continent of contrasts

The 50-plus nations of Africa exhibit huge variability in size, population level, wealth and culture. Not surprisingly, these variations are also seen in educational development, including mathematics development. Yet while African countries differ from one another in many features, they are broadly similar in key issues that concern our advisors – institutional and national conditions that help or hinder mathematical development. From their reports, it seems clear that these conditions are virtually the same throughout the continent. These include:

- Low numbers of secondary school teachers and mathematicians at the master's and PhD levels. With few professors to train the next generation of leaders, countries cannot meet the growing demand for mathematicians with advanced, up-to-date training.
- Professional and geographical isolation, which limits opportunities to advance professionally
- Low salaries, a poor public image, and shortage of mentors
- Record numbers of students clamoring for a college education
- Deficient and outdated infrastructure, instrumentation, and teaching materials

Overall, the story of mathematical development in Africa 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.

What is needed

In brief, African nations need more support for those who wish to become educators and researchers in mathematics, and more collaboration among institutions and people seeking to make this happen. Necessary steps include:

- Stronger 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 rewarding mathematics-based careers

Levels of research

One measure of mathematical strength is the number of PhD holders. For the whole of sub-Saharan Africa, according to 2009 estimates, this number is smaller than 2,000, and may be closer to 1,000. Another measure of research output is mathematical publications; while North Africa's share is highest, at about 0.87% of world output, the shares for the rest of Africa are extremely low: for Southern Africa 0.39%; for West Africa 0.08%; for Central Africa, 0.03%; and for East Africa, 0.01% of world output. Differences in research publications are also wide, with a sampling from MathSciNet ranging from 370 in Egypt and 334 in South Africa to 3 in Benin and 0 in Ghana.

Primary and secondary school mathematics

Both primary and secondary level mathematics education are weak in most 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, which has increased crowding

in the primary schools and brought a drop in quality. Large class size prevents teachers from interacting with students, attending to those who need special attention, or practicing learner-centered techniques. One result is that few students reach the secondary level. In some sub-Saharan countries, less than 10% of the secondary age population is enrolled in school; in the rest for which figures are available, only South Africa and Swaziland have gross enrolment ratios greater than 50%.

Education level of secondary school teachers

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. While such degrees and diplomas give an impression of specificity and uniformity, official requirements are not always met in reality. This is often due to inherent bottlenecks and the incapacity of governments to provide the necessary training resources. In some cases, stringent requirements actually worsen the situation. For example, teacher shortages are often eliminated *artificially* by a process of "inferior substitution": that is, surplus teachers (in other subjects) and temporary teachers are assigned to teach mathematics, even though they are not qualified to do so.

Identifying and tracking gifted students

The purpose of identifying exceptionally gifted mathematics students is to ensure that mathematically gifted learners reach their maximum potential to the benefit of their countries as well as themselves. Unfortunately, in sub-Saharan Africa there are few systems for identifying gifted mathematics students – apart from the traditional examinations and competitions such as the Olympiads – and no systems for tracking them once identified. Such systems, were they available, might make a small but concrete contribution to mathematical development of African countries.

Weaknesses and strengths at the tertiary level

There are many causes of weakness in African mathematics, but underlying them is the pervasive scarcity of skilled teachers at all levels. Those few students who arrive at the university aspiring to a career in mathematics find daunting and pervasive problems. These begin with camped learning spaces, where students jostle for room in classrooms originally built to hold 30 or 40. Today several hundred students are assigned to that same room, jammed elbow to elbow, balancing on windowsills, or standing along walls. Subject matter often focuses exclusively on traditional branches of pure mathematics such as algebra, geometry and analysis, especially in francophone countries, where little attention goes to applied, multidisciplinary, or industrial mathematics. Outdated lecture-style teaching invites little participation or group learning. Teaching maps poorly with student needs, and the outdated curriculum is not in sync with career realities.

The faculty experience

Excessive teaching loads demoralize faculty as well as students. Professors have too many students, no time or incentive to pursue research, and inadequate salaries. They

seldom have teaching assistants to lessen the load. One consequence of the poor teaching conditions is that they institutions are unable to fill faculty slots. Just as teaching does not map well with students' career needs, it does not fit well the needs of Africa, where faculty have a low public image and are often blamed of being irrelevant for the STEM-based careers of modern day.

Centers of excellence and regional networks

Increasing numbers of research centers are a symptom of strength for African mathematics. Most centers have outreach programs, some of them significant, while maintaining a strong single base. Our advisors agreed that it is more cost-effective to optimize these existing centers than to build additional ones.

Even with these centers, many countries have a mathematical enterprise that seems adequate for the nation as a whole, but is weak at each individual institution. This weakness is in some cases mitigated through collaborative networks of institutions at the national or regional level. Some of our advisors feel that webs of dispersed but related networks can be an effective response to the particular problems of Africa, pooling resources, linking those with similar interests, and overcoming isolation.

Building for the future

In response to the question "What must be done to develop Africa's future?", the responses of our advisors can be summarized as follows: "Train the young well and teach them good practice."

Among encouraging signs that this has begun were more national mathematics competitions and participation in Pan African Mathematics Olympiads. In addition, more African countries have strengthened their Internet systems, allowing better access to journals, problems, and online courses.

An encouraging trend is the desire to educate more students within Africa, lessening the brain drain that has plagued many institutions. Those who study and then work at home are best positioned to train people in their own institutions and regions, build relationships with other institutions, understand local problems, and become educational leaders.

Conclusion: Meeting the need

Advisors to this report, all of whom have long experience in the research and training conditions of Africa, uniformly point to educational improvement as the overwhelming need facing the mathematics enterprise today.

They suggest several approaches to this need:

- Direct support for the mathematical enterprise, which is primarily the responsibility of national governments;

- More forceful steps by the mathematical community to promote government support, including educational campaigns, more active public speaking and lobbying, and programs that demonstrate the value of scientific research;
- Strengthening successful existing mechanisms, most notably regional training and research networks;
- Inviting more donor support for postgraduate study, which is relatively low-cost and high-return;
- A parallel step, also relatively low in cost, is to provide fellowships and career training for faculty, most of whom have little or no support for the research or advanced degree work necessary for a strong mathematics community.

Partnerships in the form of regional networks have already developed in response to the distinctive geographic challenges of this immense continent, and our advisors have endorsed this path as much by their actions as by their recommendations. Most of those who presently live in Africa are themselves involved in regional networks, some of them as founders and leaders. The concept is supported as well by those who are part of the Diaspora, and who share the dream of a stronger mathematical enterprise across Africa.

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The remainder of this report has been prepared as an update of the 2009 Templeton report in anticipation of ICM 2014, hosted in August by Seoul, Korea.

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3. Anglophone Sub-Saharan Africa

This section was compiled under the leadership of Prof. Joseph Mugisha of Makerere University, Kampala, Uganda. In addition to Prof. Mugisha, the following mathematicians volunteered to serve as our panel of advisors:

- Dr. Emmanuel Kwameh Essel, Department of Mathematics & Statistics, University of Cape Coast, Ghana
- Dr. Mercy Kasima, University of Malawi, Zomba, Malawi.
- Dr. Juma Kasozi, Department of Mathematics, Makerere University
- Dr. Henri Laurie, Department of Mathematics & Applied Mathematics, University of Cape Town, South Africa
- Dr. Wilson Charles Mahera, Department of Mathematics, University of Dar es Salaam, Tanzania
- Prof. Godwin Christopher E. Mbah, University of Nigeria, Nsukka, Emugu, Nigeria
- Dr. Simegne Tafesse, Mathematics Department, Haramaya University, Ethiopia

This update will consist of a brief consensus overview comprised of nine points drawn from the group of contributors. Some of the points will be followed by one or more

recommendations, while some describe challenges for which no solution is suggested. In Appendix I is a selection of "Snapshots" submitted by these same advisors from Sub-Saharan Africa to provide additional detail. The consensus points, as well as the Snapshots, are broadly consistent with the more detailed body of recommendations in the 2009 Templeton report and should be read in the context of that report.

Screening tools and procedures
Few countries in Africa have screening tools or procedures to identify exceptionally talented mathematics students. In addition, there are few or no career development opportunities for these students.

We have studied other countries in Europe and the U.S. where universities have put in place programs for summer schools where both disadvantaged and talented high school students are identified and exposed to interesting career possibilities in mathematics. These students interact with undergraduate, graduate, and postgraduate student mentors. Such programs have succeeded in attracting a large number of talented students into mathematics. This idea can be adapted to the needs of Africa. AIMS in South Africa uses a similar strategy, but targets students who have completed the bachelor's degree.

Career development
We need to find regional summer school programs to expose students to different environments and explore varying real-life problems in different regional settings. And we must create new teacher education programs in mathematics to improve teaching methods and move away from the rote blackboard presentation of solutions toward expository methods that interest students in problem solving.

Linkages and networks
There are few mathematical linkages or networks between universities in Africa. 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.

It is desirable to establish programs that coordinate training within universities in the region to better leverage the various scattered specializations. This requires funds for tuition, upkeep, research, and supervision. It should be noted that training a mathematics PhD in an African university costs far less than it does outside Africa, so that it represents a high-return investment in capacity. The second advantage of intra-African programs is that comparative salaries and expenses in African countries are similar, so that students are more likely to return home and continue teaching after finishing their degrees than they are when educated in the U.S., Canada, or Europe.

Brain drain

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. This brain drain can be reduced by the suggestion above to strengthen training opportunities within Africa. This helps maintain connections through networks of supervision and teaching opportunities, thereby improving chances that participants in advanced degree programs will eventually find rewarding careers in their home institutions.

Governments lack research funds

Most governments (with the exception of South Africa) do not award research funds, 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.

Few employment opportunities

Most African countries have few employment opportunities for mathematics graduates. Several measures can help develop more:

- 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. The IMU, through its CDC, might be effective here in offering a limited number of competitive scholarships.

Combating institutional isolation

Most respondents cite advantages in fostering linkages between institutions in Africa. In particular, networks help link scattered and isolated mathematicians, reduce duplication of research, and reduce costs in staff training.

Most respondents feel that the IMU could supplement the efforts of some existing networks, such as AMMSI, EAUMP, and Southern Africa Master's Program in Mathematical Modelling, perhaps by funding a limited number of training slots in order to increase the numbers of mathematics graduates.

Weakness of journals

Many regional and local journals in Africa lack support and readership, and fail to thrive. Only a few countries, like Nigeria, have local journals in mathematics.

A need for local staff

There is need to find funding for training staff for careers at local universities and within the region. Despite ongoing concerns about the brain drain mentioned earlier, experience has shown that staff who are trained partly in their home country and partly through 'sandwich' periods abroad tend to remain in their home country upon completion of training.

4. North Africa and Francophone Sub-Saharan Countries[1]

Among African countries, those of North Africa are relatively advanced in mathematics, due at least in part to their governments' broad commitment to research and education at all levels, and to the sustained support of nearby southern Europe.

Farther south, francophone Africa, reflecting its colonial past and continued support from the world-wide *francophonie,* is also relatively advanced in secondary and tertiary mathematics, but its strength in pure math is not matched by activities in applied fields. This limits the ability of students to envision career opportunities in mathematics beyond teaching.[2]

A brief history of reforms

Such a situation reflects not only the colonial heritage of these countries, but also the injection of new France-inspired reforms into African countries. Unfortunately, feasibility studies were not done for any of the countries to determine whether the reforms were culturally appropriate. Also, the reforms were not geographically coordinated. For example, France decided to introduce "modern mathematics" in 1960; Morocco promptly introduced the program in 1962, while France itself did not act until 1969.

With the reform of the 1960s as background, it is not surprising that African countries were hesitant to integrate the more recent LMD (License, Master, Doctorate) reform adopted in the framework of the Bologna Process launched in 1999. It took an ultimatum by the European Union to persuade francophone countries to act. In this ultimatum, the EU warned that beginning in 2015 it would not recognize any diploma obtained in a country that lacked LMD reform. At first, only in North Africa did countries comply with the reform, beginning with Morocco in 2003, followed by Algeria in 2004 and Tunisia in 2006. By now, almost all the francophone African countries have responded as well, but again have incurrent problems due to cultural and economic environments as well as the lack of logistic ability to incorporate the mandate.

[1] This section was contributed by Prof. Nouzha El Yacoubi, AMU Vice-President (North Africa), University Mohammed V-Agdal, Rabat, Morocco. It has been edited somewhat for length.

[2] This introduction, adapted from the 2009 Templeton report, is reiterated by Prof. El Yacoubi for the current report.

The LMD reform aims to modernize learning and teaching by using information and communications technology (ICT) to prepare and deliver courses. The content of mathematics courses is provided through the Internet, allowing students to study first by themselves before attending "face-to-face" courses. These courses are designed to assist in accessing, interpreting, understanding and using information, as well as to develop thinking skills, initiate problem-solving, and encourage creativity. Traditional lectures are eliminated, and a new evaluation process is introduced, consisting of ongoing evaluation of students in groups of 25 or less. Faculty and staff are expected to use ICT, especially for on-line student registration, exams, and evaluations.

In brief, the LMD reform requires new behaviors, attitudes, learning environments, logistical materials, and funds. Many or most of these factors are missing in francophone African countries, which has hampered implementation of the reform. Other problems slowing the LMD reforms are aversion to change by teachers and students, overcrowded classrooms, inadequate technology, and poorly qualified staff. Therefore few of these countries experience the expected benefits of reform, including updated curricula and skills, smoother accreditation and evaluation procedures, and mobility for students, teachers and researchers.

As the European Union has become aware of these numerous problems, it has launched several programs of assistance. North Africa has benefited from such assistance and motivated its policy makers at all levels. This has generated national support programs like the Education Emergency Program in Morocco (2009/2012), supported by the World Bank, which raised university budgets by 40 percent.

In North Africa, the adoption of the LMD has been important in allowing universities to move closer to the level of the European universities, where the reforms have met with success. However, despite policy makers' desire to invest in education and innovation, many challenges must still be overcome. North African countries are evaluating their first period of LMD reform to judge how effective it has been. Morocco is ending its first decade, and changes for improvement are expected for 2014/2015.

Other important questions include:

- Are incoming students prepared to benefit from LMD reform and its positive changes?
- Did the higher education governed by the LMD reform succeed in
    - Developing thinking skills and problem-solving ability required by modern mathematics-based careers?
    - Encouraging undergraduate and postgraduate students to opt for mathematics-related STEM career opportunities beyond teaching?
- Are there sufficient national incentives to encourage applied research, technology, and innovation?

The introduction of the professional bachelor's and master's degrees (Licences Professionnelles, Masters Professionnels) could raise the value of mathematics

graduates to the labor markets. This will depend on establishing an efficient collaboration between the university and the users of mathematics. It is clear that mathematics plays a vital role in most of modern life, especially in key areas such as information and communication technology, medicine, economics, finance, demographics, planning, nanotechnologies, and genetics. Without relevant effective training and research in the mathematical sciences (pure and applied), however, it will not be possible to build the knowledge base and capacity needed to help the continent achieve sustainable socioeconomic growth.

Primary and secondary education in francophone countries also face numerous problems: mandatory enrollment increases, shortages of mathematics teachers (sometimes one mathematics teacher per school in rural areas), unqualified mathematics teachers (in Niger, in 2010, 90 percent of primary and part of secondary schools used contractual teachers lacking professional qualification), little professional development for mathematics teachers, large classes (70 to 100), poor didactic materials, and few ICT resources for mathematics courses.

Some better news is that almost all francophone African countries have launched a decade-long reform, beginning around the year 2000 and including efforts to restructure primary and second education. Primary education has benefited in particular from special financial support from the UNESCO-funded program Education for All (EFA).

Teacher training and development

After 1980, low public budgets in sub-Saharan francophone countries forced the reduction or even elimination of funding for teacher-training programs and recruitment of fully qualified teachers. During the decade 1980-1990, in the framework of "Pedagogy by Objectives," it was decided to harmonize mathematics programs throughout francophone African countries. Mathematics books were edited for teaching exclusively in those countries to avoid the kinds of cultural differences that could hold back reforms (for example, in North African countries, many mathematics courses in primary and secondary schools were "arabized" at that time). Between 1995 and 2005, a special effort was made by governments to create or renew the teacher training centers, and the helpful book "Training by Skills" appeared in 2004. But even though training of mathematics teachers was pledged by many institutions, they did not reach the goal of providing enough qualified teachers. Some countries were obliged to employ physics and even economics teachers to teach mathematics. (For more details see the EDIMaths 2011 report.)

Since independence, North African countries have been able to provide somewhat more teachers than needed for primary schools, and almost the number needed for secondary school. Because the quality of the teachers is more important than the quantity, training reforms have been launched, such as the National Charter on

Education (1999 in Morocco), recommending a new emphasis on continuing professional development that features alternating periods of training and employment. Morocco was the first francophone African country to implement the LMD reform and the first to offer new teachers the kind of training planned within that reform. In 2008, the High Council of Education declared that no progress had been made in the teacher training strategy, however, and suggested that the country should stick to international standards. Ensuing reforms have been more successful, including the CPGE (Classes Préparatoires aux Grandes Ecoles). This was introduced in Morocco, followed by Tunisia and Algeria, to train students holding a mathematics baccalaureate for two years, after which they can register in engineering high schools in their respective countries or in France.

It should be underlined that while this teacher training policy was successful in Morocco, Tunisia, and Algeria, other francophone African countries were held back by the shortage of qualified mathematics teachers. Fortunately, initiatives have been introduced to provide a critical mass of qualified mathematics teachers for the secondary schools. Reports on training mathematics teachers in five countries of the sub-region – Burkina Faso, Cote d'Ivoire, Mali, Niger and Senegal – were presented during the first CANP (Capacity and Networking Program in the Mathematical Sciences). CANP was created by the International Commission on Mathematical Instruction (ICMI), in collaboration with EDIMaths of UNESCO; CANP's first meeting was held in September 2011 in Bamako. But the shortage of fully qualified academic staff, and the low quantity and quality of qualified teacher-students remain deplorable.

As for professional development, even in North Africa, it is proceeding in a sporadic manner, often during the summer in a face-to-face manner. This training is of great importance for improving and updating mathematics knowledge and skills as well as teaching techniques. Workshops on special topics, such as the integration of ICT into teaching and learning, introduction of new topics, and exchanges of teaching tool kits should be regularly organized in collaboration with the Ministry of Education, associations of teachers, and mathematical associations. Unfortunately, distance training, which would surely have great value, is not really developed or operational.

Efforts to popularize mathematics in school

In the francophone countries, mathematics is not a popular subject. Indeed, mathematics clubs and journals are generally absent. In some countries, mathematics games like Kangaroo and Math for Jean are sometimes organized, but they have only sporadic financial or logistical support. Some programs to encourage scientific innovations at the university level have been launched, but without substantial outcomes in mathematics.

There is, however, support for National Mathematics Olympiads and Pan African Mathematics Olympiads. Morocco, Tunisia, and Algeria have attended the International Mathematics Olympiads since 1983; they were joined by South Africa 10 years later, and

then by Nigeria, Benin and Cote d'Ivoire, with Senegal as observer. The IMO planned for South Africa in 2014 – for the first time in Africa – is likely to attract more African countries.

It is important to popularize mathematics among the African students at an early age, when many may otherwise become convinced of its difficulty. Indeed, TIMSS reports have confirmed that poor performance by some examinees rather than lack of talent is a result of their negative attitude toward the subject. Now that mathematics is compulsory and a pre-requisite for admission to senior secondary scientific and technological courses, it is hoped that students will develop a more favorable attitude towards mathematics and that this will improve their performance. Even attending international assessment tests like TIMSS and PISA could popularize mathematics in schools, although among francophone countries only Morocco and Tunisia have attended regularly.

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 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% for boys, except in a very few countries where almost all girls of primary school age are enrolled at schools. But there is a substantial drop-out among girls at the secondary school level, due to socio-cultural (early marriage) and financial reasons, institutional barriers, and poor performance. In upper secondary school, only about 17% of students enrolled in Sub-Saharan Africa are girls, so that only a few have the opportunity to be enrolled in any scientific classes; among that population very few choose mathematics. The best registered percentage for enrollment of girls in mathematics at that level is about 30%, a percentage that decreases with grade level. By tertiary level it is about 10%.

As for achievements, the TIMSS reported that between 68% and 90% of African boys and girls in grade eight failed to reach the low international benchmark in mathematics (IEA, 2003), and unfortunately no significant progress was registered in TIMSS 2007 or TIMSS 2011. In terms of mathematical ability, many studies have reported that girls and boys are equivalent when they enter kindergarten. By the end of fifth grade, however, girls have fallen some standard deviations behind their male counterparts. In the TIMSS 2011 report, for example, girls in Tunisia performed as well as boys until 4th grade, but by 8th grade the gender gap clearly favored boys.

Among other factors identified in contributing to gender differences are negative socio-cultural attitudes, required household tasks, a gender-biased curriculum, poor didactic materials, lack of school dormitories, lack of sponsorship, low motivation, unqualified teachers, lack of encouragement and financial support from parents, low confidence, poor exam performance, and parents' attitudes toward boys' vs. girls' abilities.

Accordingly, a series of special projects were launched to promote increased enrollment of African girls in science, mathematics, and technology, and to encourage African women to embrace scientific and technological careers. These programs have been launched by UNESCO, the African Union, the World Bank, NEPAD, and others.

The ratio of women teaching mathematics at the tertiary level in Africa also remains very low, and the proportion of African women holding PhD in mathematics is around 17% for francophone Sub-Saharan countries. It is higher for North African countries but does not exceed 30%.

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.

It should be noted that the expansion of student enrollments did not occur at the same pace in all the sub-regions of sub-Saharan Africa; it was much faster in French-speaking countries mainly due to the admission policies in these countries which make it possible for anyone holding a secondary school "baccalauréat" to enroll in university.

In English-speaking countries, university enrollment is subject to rigorous selection based on criteria likely to promote quality of education, in particular the capacity of classrooms and laboratories and the level of teacher/student ratios. In Kenya for example, less than 10% of the secondary school graduates are admitted each year to the six public universities. Mathematics studies in higher education should increasingly be defined according to the ability of graduates to create jobs and to use existing and emerging opportunities for lifelong learning. It is also noted that research capacity is concentrated in a very limited number of countries.

In Anglophone countries, distance education has helped not only to extend access to higher education, but also to improve training opportunities for students living in rural areas and for women. Unfortunately, the development of distance education has not reached the francophone countries, with a few exceptions in North Africa.

The World Conference on Higher Education (WCHE) may have marked a significant step in the development of higher education worldwide. Like other regions of the world, sub-Saharan Africa did agree to set up the necessary strategies and mechanisms to ensure an effective follow-up to the major recommendations of the conference.

Postgraduate mathematics

At the postgraduate level, the accredited mathematics faculty who teach at the master's level select candidates from those pre-registered on-line. The final size of such classes depends of the mathematics laboratory in charge of the master's program, the availability of full professors, and external partners. This makes it difficult to determine the size of such classes, but it is possible to say that North Africa is providing mathematics masters within the LMD reform, benefiting from international programs that allow mobility, and from researchers themselves. In most of the other francophone countries, mathematics masters are organized with strong external scientific assistance provided in particular by France, Canada, and increasingly by some qualified professors living abroad (e.g., in the framework of TOKTEN in Mali).

Mathematics research

Mathematics research is more active in North Africa than in the francophone sub-Saharan countries, albeit oriented primarily toward pure mathematics. Nevertheless, sub-Saharan countries have benefited for two decades from substantial support to develop mathematics research. Indeed, in addition to African governments and their higher education institutions, several regional and international organizations contributed significantly to the follow-up to the World Conference on Higher Education in sub-Saharan Africa.

Some progress has been seen in developing mathematical research in that manner in Africa -- not really enough to let African mathematics research be recognized for quality because of the small number of publications in the reviewed journals. But at least some PhDs have been co-supervised in the framework of North-South and even South-South partnerships. In addition, there has been progress in developing applied mathematics, even in North Africa. Equally urgent is the need to reach out from mathematics to the other sciences, especially the life sciences, social sciences, engineering, telecommunications, renewable energy, finance, demography, and the humanities. In order to contribute to the economical and social growth of countries and to contribute to labor market demands, mathematics education must create new partnerships with the other sciences and better prepare students for the mathematics-based careers of the future.

Conclusion

Mathematics education is currently facing numerous problems at all levels in Africa, despite the strong mobilization of governments and international support. The rise in primary-level enrollments has brought an increase in the secondary education population as well as a problematic increase in the tertiary education population – without being matched by teaching resources, adequate learning environments, or logistical and financial support. Likewise, LMD reform (License, Master's, Doctorate), implemented to modernize and improve higher education, often generates new pressures on staff, teachers, and students before they are familiar with the mechanisms of reform or able to enjoy the promised improvements.

Perhaps the most important need is better training and professional development of mathematics teachers, particularly at the secondary level. This can be augmented when ICT is integrated and developed in the teaching/learning of mathematics from secondary school on, and when e-learning and distance training become an integral part of professional development. At the university level, there must be incentives for excellence and the institutions must be given all means to produce creative students with the analytical and problem-solving skills demanded by employers.

The IMU, through the ICMI and in collaboration with UNESCO, has taken a productive step in forming the CANP (Capacity and Networking Program in the Mathematical Sciences). Indeed, organizing EDIMath where country reports are given and professional training are provided over a two-week period, should generate fruitful exchanges and greater energy to advance the profession. EDIMath might be more effective if run as a mathematics development project (South-South) for at least three years, with countries that have been more successful in teacher training or development letting other countries benefit from their experiences. The Open Distance Learning (ODL) of South Africa is one example of a successful program, and the CPGE's Maths Agrégation in North Africa is another.

5. Networks

Since the 1990s, both African and international funding agencies have noticed the success of research and education networks to extend the reach of expertise, partnerships, and infrastructure in a variety of fields, including mathematics. Agencies have encouraged further development of networks, and Africans have responded with a growing population of them, including CARI, GEONET, GIRAGA, RAMA, RAGAAD, PDE Modeling and Control, and RAMAD. Described below are several networks at various stages of development and scale, from national to pan-African.

Ethiopia

In Ethiopia, the universities are theoretically networked by linking regional and old universities with new ones, largely for the purpose of solving problems of curriculum

reform. However, in practice it has proven difficult to create a system of fruitful and extended networks, mainly because of the problems that plague almost all the universities: shortage of staff and resources, lack of motivation and dedication, heavy teaching loads, and lack of incentives and financial support to make reforms.

One of the more successful collaborations is that between the Addis Ababa University mathematics department; the East African Universities Mathematics Program (EAUMP), a partnership of the East African region; Uppsala University in Sweden; and the International Science Program of Sweden (ISP).

In general, Ethiopia has found many potential advantages of forming or joining networks of neighboring countries in Africa, including:

- Experience sharing
- Staff and student exchange
- Research and training collaborations
- Motivating mathematicians

Such networks can help mathematics education grow stronger by simultaneously addressing problems that exist in individual countries and in Africa as a whole. A chronic disadvantage of networks for many countries is the cost of implementation and operation.

Much can be done by partners in Western Europe, the USA, and other regions to help enhance mathematical network development. Such efforts can:

- Encourage and support international and national conferences, training, and workshops in Africa
- Encourage and support mathematical research at school and university levels
- Provide scholarships for postdoc training and educational visits to countries with strong mathematics programs
- Support mathematics departments with equipment and literature
- Strengthen postgraduate programs in the country
- Enhance accessibility of international mathematical journals at universities for post graduate programs especially

Ethiopia is also a member of Strengthening of Mathematics and Science Education (SMASE), supported mainly by the Japan International Cooperation Agency (JICA) and based in Kenya. This organization covers many African countries.

Simons Foundation: Africa Mathematics Project

In 2013, the Simons Foundation awarded the first grants for its new Africa Mathematics Project, designed to nurture and accelerate high-level mathematics research in sub-

Saharan Africa. The three awardees will receive five-year grants to support graduate students, conferences, international exchanges and other research efforts.

According to David Eisenbud, former director of mathematical sciences at Simons and a creator of the Africa Mathematics Project, the program chose sub-Saharan Africa for its first awards because the region has pockets of strong mathematics researchers who lack resources and could potentially benefit from small but long-term investments in their research.

The three groups receiving grants are those of 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. The research teams have established collaborations across Africa, as well as in the United States, Singapore, Canada, and several European countries.

Ezome is the only researcher in his field in Gabon, said Dr. Eisenbud, and his collaborator Patrick Rabarison of Madagascar is in a similar situation. Both researchers studied in France, together with four members of their research group who have not yet returned to Africa. “The Simons Foundation funds will help us to develop research in our own universities,” said Dr. Ezome. “One of our objectives will be to be able to advise African PhD students in African universities.”

AMMSI

The African Mathematics Millennium Science Initiative (AMMSI), 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 Program Office, under Program Director Wandera Ogana of the University of Nairobi, oversees overall coordination. Prof. Ogana and the Regional Coordinators constitute the Program Committee whose function is to plan and implement activities of AMMSI.

The mission of AMMSI is to nurture the next generation of African mathematicians and mathematical leadership. Its activities include:

- Research in mathematics and its applications
- Training and education in mathematics and its applications
- Linkages and networking to enhance capacity
- Outreach and public education, to raise general awareness in mathematics
- Enhancing the availability and use of ICT in teaching and learning mathematics

Current activities
AMMSI is currently involved in the following activities, which have been ongoing since 2005.

Postgraduate Scholarships
These are partial scholarships, each up to €1,000, awarded annually to enable students who are sub-Saharan African nationals to pursue postgraduate studies in mathematics and its applications, at any university in Africa. They are designed to strengthen mathematics learning and culture by supporting the training of postgraduate students in African institutions. To date this project has supported more than 250 students who have completed their MSc or PhD degrees and, in some cases, published their research findings in reputable journals. At present the total funding of €20,000 is provided by the Commission for Developing Countries (CDC), a commission of the IMU.

LMS-AMMSI Conference Grant
The aim of this program is to provide postgraduate students with opportunities to interact with their academic seniors, meet potential mentors, and gain experience in making scientific presentations. Requests for support are made by the meeting organizers, through AMMSI, while the individuals to be supported are identified by meeting organizers. The London Mathematical Society (LMS) provides about £8,000 per year to cover travel expenses to meetings held in Africa, which are approved by AMMSI. The project has so far supported more than 100 postgraduate students.

Past activities
Additional activities that have been supported in the past, but suspended due to reduced funding, include *Research/Visiting Scientist Fellowships,* supported from 2005 to 2008 by the Mellon Foundation; four *Conferences,* supported from 2005 to 2009 in different AMMSI regions; an international *Mathematical Biology Workshop* (6-10 December 2006, in Nairobi, Kenya); and the *Symposium on the African Woman and Mathematics* (29-30 November 2008 in Maputo, Mozambique).

Planned activities
With adequate funding, AMMSI plans to maintain or initiate the following activities:

- Postgraduate scholarships
- Visiting/research fellowships
- Support for organization or attendance of conferences
- Support for regional interdisciplinary research involving mathematics and/or its applications
- Outreach activities to promote mathematics, particularly among girls and women.

Contact: Program Office: "Administrator" <ammsi@uonbi.ac.ke> or "Administrator" <ammsi.africa@gmail.com>. For further details visit the AMMSI website at http://www.ammsi.org.

Mentoring African Research in Mathematics (MARM)

MARM is designed to promote mentoring relationships between mathematicians on other continents and sub-Saharan African colleagues, together with their students. It aims to promote collaboration in mathematical research and in mathematics education, create joint research projects, and cultivate longer-term partnerships between institutions in Africa and those elsewhere. To date 14 partnerships have been established. MARM is a partnership of the London Mathematical Society (LMS), which provides most its £40,000 budget; the IMU; and AMMSI.

African Institute of Mathematical Sciences (AIMS)

AIMS was established in 2003, near Cape Town, South Africa, as a center for education and research. It was sponsored by six universities: Cambridge, Cape Town, Oxford, Paris Sud XI, Stellenbosch, and Western Cape. Postgraduate students were recruited from across Africa to a program that seeks to:

- Promote mathematics and science in Africa
- Recruit and train talented students and teachers
- Build capacity for African initiatives in education, research, and technology

In 2007, it expanded by acquiring two buildings and converting them into the AIMS Research Center, where tutors and visiting researchers are housed.

More recently, AIMS expanded into other African countries as a network under the framework of the Next Einstein Initiative (NEI). It second campus was opened in Senegal in 2011, and the third campus in Ghana in 2012. In February 2014 the fourth campus was inaugurated in Cameroon, and a fifth is scheduled in 2014 for Tanzania. In all, the NEI plans to expand the AIMS network to 15 centers throughout Africa by the year 2023. The slogan of the Next Einstein Forum is "Connecting Science to Humanity," and its mission is to provide a global platform for scientists to share their work and encourage young African scientists by opening avenues for partnership both at the individual and institutional levels. AIMS has also launched an Industry Initiative to help bridge the gap between academia and industry through the introduction of relevant curriculum, job and internship opportunities, and industrial research opportunities.

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Appendix I: 'Snapshots' of individual countries

The following vignettes are intended to provide further detail about the current situation of mathematical research and education in various African countries.

Ethiopia

Ethiopia is making a determined effort to improve both primary and secondary school education in mathematics. For instance, all first-cycle and second-cycle primary school teachers (Grades 1-4 and 5-8) must be diploma graduates, and high school (9-10) teachers must have a bachelor's. For university preparatory classes (11-12), the Ministry of Education has begun to train teachers for a master's degree. In addition, the Ministry has recently revised mathematics textbooks.

At the same time, progress in learning continues to be limited by continuing problems, such as sporadic distribution of materials to rural schools, low levels of teacher motivation and preparation, societal problems, and overcrowding. By one informal count, the ratio of mathematics teachers to students is 1:280 in primary school and 1:120 in secondary school.

Screening, tracking, and employment

There is no organized screening system as such for gifted mathematics students. Nor is there a way of tracking highly talented math students to assure their entry into top-flight universities with strong mathematics departments. In general, there is no way of identifying talented students in mathematics except by the results of formal examinations. There are at least some educational career opportunities for highly-talented math students in education, although those who score high marks are likely to seek positions in engineering.

New interest in applied topics

At the university level, optimization seems to be strongest topic in applied mathematics, with additional interest in differential equations. Problem-solving applications and research activities generally are only beginning to take hold, however, because university mathematics has traditionally focused on theoretical topics on the assumption that the only career for math majors would be in teaching. Given this history, even the first baby steps in applied areas are to be applauded.

Some challenges that hinder development and application of mathematics and mathematics education in Africa are:

- Lack of emphasis on the part of university administrations
- General view in society of mathematics as a difficult subject
- No encouragement for research as part of a mathematics education
- Lack of training about the practical applicability of mathematical concepts
- A general shortage of PhD holders and professors in the universities and in the country as a whole
- Lack of mathematical facilities, equipment, and literature
- Heavy staff teaching loads

- Lack of research collaboration among mathematicians
- Low salaries

There are, however, several conditions that favor development of mathematics in the country and region. They include the establishment of new universities, which will generate mathematics graduates, and the "70-30" educational policy of the country, which mandates that 70% of the total students joining universities be placed in science and engineering departments that employ mathematics staff. In addition, more expertise is needed by the nation in applied mathematics for fields such as physics, chemistry, statistics, biology, computer science, and engineering.

Given these needs, the Ministry of Education supports the training of more bachelor's and master's graduates at higher skill levels both in the country and abroad. Most of the bachelor's graduates study for a master's inside the country, while most master's graduates go to India for their PhD study. In addition, expatriates are recruited, mostly from India, to work at the university level.

There is much the IMU can do to contribute to these efforts. Helpful steps include support for research at the school and university levels to better understand the primary obstacles to sound mathematics education. At the same time, there are urgent needs for facilities for conferences, workshops and training; a system of networks to encourage exchange of ideas and enhance collaborative research; staff and student exchanges among universities; and support for staff to attend conferences, workshops and trainings. Additional needs include support for postdoc training abroad, scholarship opportunities for staff, better equipment and literature, scholarships for talented mathematics students, and capacity building for mathematics departments.

Ghana

Ghana has relatively strong programs in teacher education and mathematical physics, and strong development in primary and secondary education. Areas of specialization include optimization, differential equations, and mathematical physics.

The teacher-student ratio in primary schools is about 1:130, and in secondary schools 1:70. The required qualification for mathematics teachers at the primary level is a post-secondary teacher training certificate, and at the secondary level a bachelor's degree.

Career opportunities for mathematics graduates are mostly limited to teaching in schools and higher-education institutions. Initiatives to encourage mathematics students include distance learning centers to upgrade non-degree mathematics teachers and a mandatory PhD program for all university mathematics lecturers. Challenges include a loss of talented mathematics students to other professions, given the lack of opportunities in mathematics.

Malawi

Mathematics remains a challenging subject for many Malawian pupils, especially in secondary school. Based on student performance in national examinations, the pass rates in mathematics have been lower than in many other subjects.

There are some efforts to improve the teaching and learning of mathematics in schools. The Strengthening of Mathematics and Science in Secondary Education (SMASSE) project holds in-service training of teachers during holidays to increase competence in teaching mathematics and science.

Malawi also takes an active part in academic and professional associations in southern Africa. The Southern Africa Mathematical Sciences Association (SAMSA) and the Southern Africa Association for Research in Mathematics Science and Technology Education (SAARMSTE) are examples. In 2012, both associations held their annual conferences in Malawi.

The Malawi Institute of Education is currently reviewing the secondary school curriculum. The aim is to narrowing the gap that exists between secondary school and first-year undergraduate mathematics courses, as evidenced by the poor performance of first-year university students in mathematics.

Through funding from the African Development Bank, a bridging course in mathematics and science is being organized by the University of Malawi (Chancellor College and the Malawi Polytechnic) and Mzuzu University, with the hope of retaining many students, especially female students, in mathematics and science.

At the university, first-year mathematics classes are characterized by large class sizes with limited resources and few qualified staff. Many students do not return from oversees PhD or MSc studies, or leave for better remuneration and working conditions. Student numbers in mathematics courses have dwindled sharply in recent years.

The qualified personnel who have returned from their studies, together with locally trained teachers, have embarked on postgraduate programs with the aim of educating staff that would ultimately join and teach in the University of Malawi and other institutions. For example, the Department of Mathematical Sciences at Chancellor College of the University of Malawi has, since October 2012, revived the two-year MSc program in pure and applied mathematics. This program produced six graduates between 2004 and 2007, all of whom joined teaching staff in various universities, and five of whom later completed PhDs in South Africa. The program was shelved for lack of teaching staff when most of the pioneering faculty had left. The department also runs an MSc program in biostatistics, which started in October 2010 and has already produced 11 graduates. Currently the biggest challenge is inadequate teaching staff and lack of scholarships for students. The department is working on identifying and seeking support for adjunct or visiting professors.

The Department of Mathematics at Mzuzu University has run an MSc program in Information Theory, Coding Theory and Cryptography since 2004, and it has so far produced 25 graduates, six of whom have proceeded to do PhDs (including some in pure mathematics) in Europe and South Africa. A number of them have joined private and public university colleges as teaching staff.

Nigeria

Nigeria, like South Africa, has high-quality university education in mathematics, both pure and applied, with viable research centres. Nigeria also has strong secondary and elementary mathematics education, again of similar quality to that of South Africa. The teacher-student ratio in primary schools is 1:35 and in secondary schools 1:100.

The qualification needed to teach mathematics in primary schools is a certificate in education; in junior secondary a junior secondary certificate; and in senior secondary a bachelor's degree.

There are no commercial or specialized career opportunities for talented and well trained mathematics students.

South Africa

In general, South Africa shows weakness at the primary and secondary levels, but considerable strength in post-secondary mathematics.

At the school level, achievement is inadequate, with a low number of students going on to university with a mathematical background over the last 20 years. Rural mathematics education in South Africa is very poor.

The target values for the teacher-staff ratio in primary schools is 30 students per teacher, and in secondary schools 25 students per teacher. In practice, however, the ratio may be much higher in poorer schools. Many of the best schools, with good teacher-student ratios, are private schools.

The normal qualification to become either a primary or secondary school teacher is a three-year diploma. Bachelors degrees are not required, and many mathematics teachers do not have a bachelors degree.

All teachers are represented by the large South African Democratic Teachers' Union, and there is also an association for mathematics teachers (AMESA).

Talented mathematics students are identified by mathematics competition essays. There are also some programs to support the educational progress of talented mathematics students, but these talented students are not accelerated in schools.

Despite the poor situation of both primary and secondary education, South Africa has a large number of PhD students and university staff in mathematics, as well as an active research community. One reason is the availability of state funding for research and conferences, and long-term historical connections with universities abroad. The availability of funding is a strong draw to eager students in neighboring countries, who have little local public support. This is actually a problem from the country's point of view, in that the population of South African mathematics majors at both ordinary and honors bachelors degrees is very small.

Another worry for South African mathematics is a demographic one – the expectation that many aging senior staff will retire over the next five years. This is expected to have a negative impact on both the mathematical research and instruction.

At present, mathematicians in South Africa show leadership in the areas of cosmology, topology, algebra, numerical analysis, and continuum dynamics, with many departments of mathematics and applied mathematics. There is a distinct separation between pure and applied mathematics, such as occurs in Morocco, Nigeria, Egypt, Senegal, Ghana, and Botswana.

South Africa takes part in both the Southern Africa Mathematical Sciences Association (SAMSA) and the Southern Africa Association for Research in Mathematics Science and Technology Education (SAARMSTE).

There are opportunities for mathematics careers both in industry and in academia. Opportunities for the improvement of mathematical development and training include special payment and bursaries for teachers in schools and bursaries for the fourth year at South African universities (honors).

Tanzania

Students in Tanzania achieve below-average results at all levels of mathematics, as evidenced by the results of students who participated in the 2011 and 2012 national examinations (http://www.necta.go.tz)

The Tanzania Ministry of Education is considering the recruitment of additional teachers, and preparations are in progress to purchase essential books.

The regional, NORAD[3]-financed MSc in Mathematical Modelling (http://www.maths.udsm.ac.tz) has stimulated the growth of mathematics capacity in universities in the region, but unfortunately the financial support of NORAD is being discontinued. The MSc in Mathematical Modelling has graduated over 50 MSc in various applied mathematics fields, and most of them are now employed as faculty and staff in the region of southern Africa. The program has brought International professors who

[3] The Norwegian Agency for Development Cooperation, http://www.norad.no/en/front-page

have trained future leaders and improved the quality of dissertations. The program has not only benefitted staff members who are training at universities, but has also resulted in research work and joint supervisions which have identified strengths and weaknesses of mathematics departments in the region. Some efforts for continued MSc support include CIMO, the Center for International Mobility, of Finland, which offers training support for MScs and PhDs in mathematics for Uganda , Rwanda, Tanzania, Zambia, and Ethiopia (http://www.maths.udsm.ac.tz/cimo).

Areas of specialization are not well developed in Tanzania. A blend of pure and applied mathematics is typical, due to different training at different stages. This creates discontinuities in specializations, and detracts from the meaning and development of expertise as it does in Ethiopia, where there is little distinction between pure and applied mathematics.

Uganda

The East Africa University Mathematics Program (EAUMP), initiated in 2002, has received funding from ISP[4] and SIDA[5] for the last 10 years and is aimed at training university staff in pure mathematics. Seven PhD students have graduated from the program – though not all studied pure mathematics because of low interest in the field – and more than 50 MSc students have graduated. The network also offers annual algebra schools hosted on a rotating basis by member countries. The program also offers support to purchase basic equipment like projectors, computers, and essential textbooks. The beneficiary countries have expanded from Uganda, Kenya and Tanzania to now include Rwanda and Zambia. Areas of specialization include biomathematics, insurance and financial mathematics, numerical analysis, and some blended pure and applied mathematics.

Because of the relatively small number of staff specialising in pure mathematics, mentoring in pure mathematics topics has been a problem. The African Mathematics Millennium Science Initiative (AMMSI), in conjunction with London Mathematical Society, has supported a Mentoring African Research in Mathematics (MARM) scheme that has proven helpful. Since 2008 it has provided a pure mathematics mentor to teach an intensive three-week course for MSc students and to co-supervise research projects. Follow-up scholarships for graduates of this program are limited to those who proceed to a PhD in pure mathematics.

There is a low application rate for graduate studies in mathematics (both MSc and PhD) because all applicants must pay for the programs and no state research fund is available for senior staff to attract research students to Uganda. The effect of making state funding available can be seen in Ethiopia, where public grants attract a relatively high number of admissions to MSc in mathematics (up to one hundred students annually). In

[4] International Science Program (ISP), Sweden
[5] Swedish International Development Cooperation Agency

Uganda, low student numbers and lack of state funding have led to a high drop-out rate, very low completion rate, and limited attraction for bright students in Uganda.

The employability of mathematics majors after higher education is not ideal. Mathematics majors in many universities in Uganda are rare as employment is difficult. Universities have fixed faculty positions and students don't see where they can be employed with a graduate degree. Some students get jobs as teachers, but there are limited industry positions available for mathematicians.

The salary of a graduate teacher is about $130 a month, which is not attractive, so that many students switch to alternative programs that offer a better prospect of employment after university.

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.

There has been an increase in research in biomathematics, with an average of 10 students per year opting for an MSc in this area with a completion rate of 50%. This is still hindered from further growth by the lack of research funding.

The small population of graduate students contributes to a low publication rate, unnoticed research output, limited conference attendance, inexperience in supervision, and limited connections with universities abroad.

Conditions in primary and secondary school are not strong enough to attract many students to the subject. The teacher-student ratio in primary school is 1:200, and in secondary school is 1:150. Primary school teachers in Uganda are required to have only a two-year diploma, though secondary school teachers require a bachelors degree.

There is no system of education that tracks highly talented mathematics students to ensure their entry into university for mathematical development. This is because mathematics is not seen as offering a reasonable, well-paying career, and most talented students eventually join a more promising professional career, such as engineering, business, or finance.

The job of popularizing mathematics is undertaken by the Uganda Mathematical Society, whose membership is drawn from all mathematics users in the country. The Society holds an annual mathematics contest (at primary, secondary and university levels) where winners are given prizes at the annual general assembly of the society. It also hosts an annual mathematics teachers conference before the association's annual

general meeting, at which the problems affecting mathematics teaching at all levels of education are discussed.

The best students in the mathematics contest are selected to represent Uganda at the PAMO and IMO. Uganda sent participants to the 2012 IMO in Argentina. Screening to identify talented students is done through National Association for the Education of Gifted Children, in conjunction with the Gifted Foundation from the UK. Then the selected gifted children are gathered into a gifted program every year in Uganda.

Some steps that have been suggested to build a strong mathematical community in Uganda include increasing the number of government-supported student enrolments into universities and increasing the salary of science staff, including mathematicians, by 30%. Salaries have changed little in recent years compared to those of other civil servants.