# Developing Mathematics in East Africa

BALÁZS SZENDRÖI

This article describes the personal journey of its author[1] over the last eight years to help strengthen mathematics, primarily pure mathematics, in East Africa.

## The beginning: work in Maseno

It all began in 2010 with the word "quiver". A year earlier, I had applied to be a mentor in the LMS MARM project, responding to not much more than an internal urge to do something exciting. One aspect of MARM is that it acts as a kind of match-making service, aiming to find common points of interest between African mathematics departments and prospective mentors. This is not always an easy task. But after an earlier proposal with no clear links to my interests in geometry and algebra, which I decided not to respond to, I was sent another application, from a place right on the Equator in Western Kenya I had never heard of. The list of specialisms of members of staff included Operator theory, PDEs, as well as "quivers". While my work has nothing to do with the first two topics, it has a lot to do with quivers; but it was an odd choice of word, referring to a relatively narrow area of formal algebra, though with links to many other subjects. The person behind this smoking gun turned out to be David Stern, a recent PhD in my field, who had moved to Kenya and taken up a lectureship at the Maseno University following a much stronger urge to do something really exciting. It was clear then that there was common ground, and thus a MARM partnership was established; and with that, a journey for me to Africa.

Together with my graduate student Ben Davison, I paid several visits to Kenya, gave lecture courses on elementary and algebraic geometry and knot theory, and conducted heated discussions with local colleagues on teaching methodologies, the balance of research and teaching, and many other subjects. We hosted in Oxford some of the talented Masters students David was working with at the time; we helped one on his way to a US PhD position. Contacts were established with other Kenyan institutions: the University of Nairobi, the country's oldest and largest, though not necessarily its most innovative, and the dynamic Strathmore University, a Christian private institution with the soft-spoken, highly regarded statistician John Odhiambo as its Vice Chancellor.

I was impressed by the honesty and openness of many of the lecturers and students I met, as I tried (often unsuccessfully) to remember their names. Due to the hospitality and resourcefulness of David and his colleagues, I had the opportunity to visit some of Kenya's beautiful places: lakes, extinct volcanoes, rainforests and the savannah with its non-human inhabitants, carnivores as well as herbivores. But first and foremost, I began to understand better the difficult conditions under which our colleagues in Africa work. The lack of resources is a problem; as is the relative isolation, including distance and cost of travel between, and even within, countries. But the main difficulties arise from the very large teaching and administrative loads that they carry.

## Intermezzo: the rapid expansion of University provision in Africa

A campus in the town of Maseno was established in 1990 as a constituent college of Moi University; it became an independent university 11 years later. It soon established its own satellite campus in a nearby town, Bondo; around the time of my first visit, from Bondo Campus arose Jaramogi Oginga Odinga University of Science and Technology. Two branchings within a decade or so on the tree of Kenyan universities — almost exponential growth. Indeed, while in 1980 Kenya had just one public university, in the early 2000s it had six and now it has over twenty. The number of students multiplied even faster. The pattern is replicated elsewhere (though not everywhere) in the region: in the same time span, Ethiopia went from two to eight to over thirty and Tanzania from one to five to eleven public universities.

The consequences are easy to imagine. All these universities need Principals, Deans, Departmental Heads, as well as qualified lecturers teaching different fields of mathematics. Education is in massive demand all over Africa[2], and the mathematical sciences are reasonably popular; calls on service teaching further increase the need. But at the moment supply, especially quality supply, is completely unable to keep up with this demand: there is a huge capacity gap. Addressing this gap is perhaps the most important challenge facing anyone interested in the development of mathematical sciences on the continent.



The 2016 Nairobi Workshop in Algebraic Geometry

**Mentoring a research group: algebraic geometry in Nairobi**

During one of my early visits, I met two ambitious algebraic geometers at the University of Nairobi, Jared Ongaro and Damian Maingi, both with recent PhDs from Europe. In 2013, we agreed to combine forces to organise a summer school in Mombasa that attracted around 40 Masters students from the region. This became the starting point for a long-term collaboration, with yearly workshops on Algebraic Geometry involving a varied group of participants from the region and elsewhere. Laura Costa from Barcelona and Gavin Brown and Miles Reid from Warwick became long-term partners. The LMS helped with MARM and Scheme 5 grants; some senior participants have generously used their own grants while postdocs and graduate students were able to join using support from their departments. The 2018 workshop will be organized in collaboration with the Clay Institute.

Our main success has been to work with a changing cast of Masters students, who often choose their research topics from among the subjects discussed at a recent workshop. In the last few years, Masters dissertations have been written in Nairobi on toric geometry, Kontsevich's recursion for the number of

curves in the plane through a fixed number of points, the Hilbert scheme of points of a surface, and the Euler characteristic of the moduli space of curves, reflecting the interests of workshop speakers. After the initial discussions at the workshops, the presence of Damian and Jared on the ground is key to the successful completion of these theses. In 2016, the group graduated their first home-grown PhD, Ben Obiero, supervised by Damian; Ben remains a frequent attendee and speaker at our workshops. Some of the students are teaching at local schools and universities, while others embarked on international PhDs; one, with support from the Oxford Mathematical Institute and the Simons Foundation, is coming to Oxford to start his doctoral studies in October 2018.

**On to other foreign lands: work with EAUMP**

The 2013 Mombasa school in fact was the yearly edition of an existing series, the Eastern African Universities Mathematics Programme (EAUMP) Summer Schools. EAUMP is a network of five Mathematics departments, started in 2002 by the International Science Programme (ISP) of the Swedish International Development Cooperation Agency. Its members are the departments in Nairobi, Dar es Salaam in Tanzania, Makerere University in Kampala, Uganda, as well as the Universities of Rwanda and Zambia. For the 2013 edition, the School was reorganized, expanded from two weeks to three, and some other innovations were implemented, including a mini-project competition. The collaboration was judged a success, and I was asked to stay involved. Since then, we have co-organised a yearly three-week School in pure mathematics, on subjects as varied as Experimental Pure Mathematics, Functional Analysis and Homological Algebra; the 2019 edition will feature Algebraic Topology, including applications to Data Science.

One early lesson was how popular computer-based demonstrations and projects are at these events. Working with free software that the students can continue to work with is of course essential; SAGE or some variant is now a feature of most Schools. There are always technical challenges to implementation, but the pleasure on students' faces when a computation finally works is worth all the effort.

Core financial support from ISP has been central to the continuing operation of the Schools; CIMPA and the LMS-AMMSI Postgraduate Fund have also

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[2]According to a recent survey by the Pew Center, a Washington DC think tank, sub-Saharan Africans rate education as one of their most important concerns, second only to health care and well ahead of government efficiency, access to food, roads or energy.

been very helpful. More recently very substantial funding from ICTP, Trieste has allowed us to expand the invitation list from members of the five EAUMP departments to students from further afield, in particular recent AIMS graduates.



Some workshop participants at the Victoria Falls, 2017

Work with EAUMP has also allowed me to visit the other beautiful countries of the network, and to develop contacts with colleagues there. A workshop in 2017 in Zambia by the Victoria Falls remains a particularly memorable occasion, both for the amount of pointless topology (please read this in the technical sense!) I learned from South African colleagues, and the drenching we got when standing next to the Falls just after the rainy season.

### Branching out into new fields: applications

The funding landscape for development-related projects in the UK was dramatically transformed by Government's establishment in 2015 of the £1.5 billion (yes, you read that correctly) Global Challenges Research Fund, managed jointly by the Research Councils and learned societies to help address research challenges faced by developing countries. Pure mathematics is finding it difficult to tap into this source, as the research conducted has to demonstrate direct impact on Sustainable Development Goals[3]. The time seemed right to think creatively about what could be done in this framework.

Help came from the ubiquitous David Stern, whose interests include statistics and software development. In 2016, we successfully applied for a joint grant to implement a recently developed quantitative method to measure corruption risk in government contracting in developing countries. The aim was to bring together my contacts in political science

with David's project in statistics programming, in particular work on a new package R-Instat, and take this to an African audience. Together with Elizabeth David-Barrett, a corruption expert, we ran workshops at AIMS Tanzania in 2017 and AIMS Ghana in 2018, with local mathematics students, DfID and World Bank experts, and others; we have invitations to take this work elsewhere. More recently, we also started a small project that aims to use data to help smallholder farmers and farmers' cooperatives, by investigating the effectiveness of certain low-cost innovations.

### Epilogue

Mathematics remains in a difficult condition on the African continent, from early education through schools to universities and beyond. In higher education and research, the capacity gap mentioned earlier remains a fundamental challenge. Students on international PhD programmes have a good track record of returning to Africa, but the numbers are small. Local PhD programmes are being developed and should be helped, but there is a shortage of qualified advisors and the quality of the output remains very variable. Perhaps more innovative solutions should also be tried, such as "sandwich" PhD programmes with substantial time spent both in Africa and in the North; such an approach can work, but currently appears very difficult to fund in the UK on anything like the scale it is needed. "Hybrid" PhD programmes, an idea of David Stern, could also be tried, where research is combined with teaching innovation and other aspects of professional development. But one thing is certain: improvements will only come from continuing engagement — external help combined with internal drive to bring about much-needed changes.



### Balázs Szendröi

Balázs Szendröi is Professor of Pure Mathematics at the University of Oxford, a member of the AIMS-South Africa Council and a Trustee of the charity Supporting African Maths Initiatives (samicharity.co.uk)

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[3]This point deserves a longer discussion. One can certainly imagine scenarios, say involving cryptography or robotics, where aspects of algebraic geometry become relevant to development challenges. But the basic point remains: pure mathematics, and especially training in pure mathematics, appears difficult to include in GCRF applications given the way the calls are currently configured.