# Mathematics for Sustainable Development (MATH4SDG): A Capacity Building Project in Uganda and Tanzania

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**Abstract**

Mathematics for Sustainable Development, MATH4SDG, is a capacity building project funded by the NORHED II programme under the Norwegian Agency for Development Cooperation (NORAD) involving the mathematics departments at the University of Dar es Salaam (Tanzania), Makerere University (Uganda), and the University of Bergen (Norway). The project aims to enhance mathematics education and research in Tanzania and Uganda. Central to MATH4SDG is 11 PhD-students, with four in secondary mathematics education and seven in applied mathematics and statistics. All PhD-students are supervised by both Norwegian and local supervisors. Another component involves outreach to schools and research collaboration workshops with local industry and governmental organizations. By aligning university mathematics programmes with the needs of these stakeholders, graduates become more attractive to employers and the workforce benefits from a strong foundation in mathematics and its applications thus aiding in the digital transformation for sustainable development. MATH4SDG contribute to educating much needed schoolteachers and enhance the proficiency in mathematics.

***Keywords***: Mathematics; Capacity building; Applied mathematics; Secondary mathematics education; Outreach

# 1 Introduction: The Significance of Mathematics

As part of achieving the overall aim of MATH4SDG to increase general mathematical lit

The Italian philosopher, physicist, and astronomer Galileo Galilei is in the 17$^{th}$ century referred to as stating that mathematics is the language in which God has written the universe (Maddy, 2011). In the subsequent centuries, we saw tremendous scientific development leading to the industrial revolution, and more recently the digital revolution. During this development, mathematics evolved and confirmed its role as the language of the sciences. However, in 2015 UN estimated that more than half a billion children in schools were not achieving the needed proficiency in reading and mathematics. The problem of illiteracy is most profound in developing countries. Globally there has been little progress in the percentage of trained primary school teachers, around 64% in sub-Saharan Africa. In the 2019 progress report on the UN's 2030 Agenda for Sustainable Development (United Nations, 2019), the UN states that there is a need to harness science, technology and innovation with a greater focus on digital transformation for sustainable development. To achieve this, the need for mathematics becomes even more important as numeracy is also mentioned explicitly in Target 4.6 in the Sustainable Development Goal 4 (SDG4), Quality Education (United Nations, 2015).

Mathematics lies at the foundation of most subjects in the natural sciences, technology, economics, health, and the social sciences, hence it is taught at all levels of education and universities worldwide. With the ongoing digitalisation of our societies, the inflation in data availability and the acknowledgement that many previously qualitative fields are getting more quantitative, basic knowledge in data science, including artificial intelligence and machine learning, has become important generic knowledge expected from university graduates in many fields. In Norway, most of the technical and natural science studies at the largest universities are now being reformed to reflect this.

Globally the world recently faced a huge health crisis with the COVID-19 pandemic causing deep social, economic, and political crises. Mathematicians were contacted globally to use mathematical models to do projections and explain the dynamics of COVID-19. Africa is in addition plagued by several health problems such as vector-borne diseases, HIV, and Ebola. Malaria has continued causing morbidity and mortality in the East African region. The role of mathematics in health matters cannot be over-emphasized. Climate change

is another concern globally. It has caused and continues to cause many negative impacts such as floods, droughts, bushfires, cyclones, etc., thus affecting agriculture, water availability, the ecosystem, etc. The role of mathematics in the development of science and technology is acknowledged globally.

In response to this, Mathematics for Sustainable Development (MATH4SDG) is a capacity building project running 2021-2026 funded with 20 million NOK (approx. 2+ million USD) by NORHED II, the Norwegian Programme for Capacity Development in Higher Education and Research for Development under the Norwegian Agency for Development Cooperation (NORAD). It is a collaborative initiative involving the mathematics departments of the University of Dar es Salaam (USDM, Tanzania), Makerere University (Uganda), and the University of Bergen (UiB, Norway) (https://math4sdg.w.uib.no/). The overall aim of MATH4SDG is to increase the general mathematical literacy in Tanzania and Uganda and develop and strengthen the capacity in postgraduate training and research in mathematics in these countries. This includes the education of 11 PhD candidates. MATH4SDG has therefore executed a research programme in collaboration with colleagues within health and medical institutions in the three cities, focusing, e.g., on the epidemiological modelling as well as initiated activities to strengthen secondary mathematics education in Tanzania and Uganda. Three outcomes are defined as follows:

- Better mathematical research at the two African universities,
- Updated and relevant educational programmes in mathematics and mathematics education, and
- Higher visibility of the departments.

Below we will describe the various activities in MATH4SDG, particularly the projects done by the 11 PhD students, which form a core of MATH4SDG. Next, we describe outreach activities and finally some evaluation of these activities.

# 2 The 11 PhD Students

## 2.1 Four students in Mathematics Education

Good mathematics schoolteachers are essential to trigger interest and learning of mathematics for the next generations thereby contributing to the development of proficiency in mathematics. At the two African universities, education of primary and secondary school teachers takes place at their respective Schools of Education. For this reason, four PhD projects were allocated to secondary mathematics education in the following areas:

Makerere University: Two male students. One (Ssali et al., 2025) is focused on the application of Problem-Based Learning (PBL). The Uganda Ministry of Education and Sports (UMoES) promoted the inclusion of PBL compentencies such as critical thinking and problem-solving, creativity and innovation in the new competence base school curriculum starting 2020 (UMoES, 2019). Therefore, this project implements PBL in some schools and evaluates upon this. The other PhD student (Gaanya et al., 2025) is implementing Mathematics for Sustainable Development (Math4SD) projects as an attempt to adhere to the inclusion of the cross-cutting issues in Uganda's new curriculum (UMoES, 2019) at the lower secondary level. The cross-cutting issues are attached to the three categories of the Math4SD perspectives such as environmental awareness, diversity and inclusion, and socio-economic challenges.

University of Dar es Salaam: Two female students. One (Boki, 2025) works within the area of technology application in schools, particularly how technology can be used in classes that frequently suffer from lack of teachers. In Tanzania, the shortage of teachers is severe and persistent. In the year 2022/2023, Tanzania faced almost 66% shortage of mathematics and science teachers as 70,327 teachers were needed, but only 23,647 were available (Mosenda, 2024). Another PhD (Kihaga et al., 2025) is focused on the challenges of teaching and learning in large classes, which is a common phenomenon in Tanzania due to, e.g., higher demand for formal education, shortage of human and physical resources, pupils repeating years, and national

economy (Shukia, 2020). In fact, Tanzania's secondary schools have up to 70+ students in a single classroom, contrary to the national benchmark of 40 students per teacher (Mazana et al., 2020).

## 2.2 Seven students in Applied Mathematics

As stated above, there is a greater need for more knowledge and training in the field of data science, which is an emerging multi-disciplinary field. This will create professionals with knowledge and skills on how to collect data from various sources, organize data into information, and interpret the data. In East Africa, like other Sub-Sahara countries, data science is a young field. Thus, there are challenges in recruitment, training and retention of data scientists. Consequently, there is a demand in building human capacity in this field, which is a research field of the mathematicians in Bergen.

Makerere University: Two male and one female student, two of whom are working in mathematical statistics. One student is working with random matrix theory: Dimensionality reduction in the presence of missing values and outliers. Another with Computational Mathematics, Data Science, Partial Differential Equations, Reconstruction, and the third with Dynamic Ensemble modelling of Reserve Risk in General Insurance.

University of Dar es Salaam: Three male and one female student, all in applied mathematics. One works with Mathematical Modelling of the Effects of Vaccination, Water sanitation, Education programme and Treatment interventions on the Transmission Dynamics of Typhoid. The second one is working on the evolutionary dynamics of Antimicrobial resistance using a data-driven modelling approach; the third one on transmission dynamics of brucellosis with interventions; while the fourth one works on the transmission dynamics of two-strain TB model, with drug-sensitive and drug-resistance to treatment.

# 3 Outreach

As part of achieving the overall aim of MATH4SDG to increase general mathematical literacy in Tanzania and Uganda, the project also participated in several outreach activities aiming to improve the teaching of mathematics in colleges and schools. These were to complement the work done by the 11 PhD students. These activities have been carried out in various regions in Tanzania and Uganda in collaboration with the Mathematical Association of Tanzania (MAT) and the Uganda Mathematical Society (UMS). The project did workshops on, for instance, the use of GeoGebra, an interactive geometry software, for high school mathematics teachers in Tanzania and Uganda. These activities focused on motivating teachers and introducing them to new teaching methods and technologies. In Tanzania, MATH4SDG has managed to train more than 600 mathematics secondary school teachers and has visited 30 secondary schools to motivate and inspire students about mathematics. Also, two workshops have been organised on alignment of university mathematics research and education with industrial needs.

Collaborative research has been achieved between industry and academia (mathematics research) i.e. within various research institutes and government authorities involved in medical research, weather forecasting and climate modelling, among others. Through these workshops, it has been possible for the PhD students and some staff members to present their research and to show the relevance of mathematical modelling in solving real-life societal and industrial problems.

# 4 Lessons Learnt and Recommendations

MATH4SDG had a midterm evaluation where three project coordinators were interviewed and a questionnaire was sent to all the participants with 49 respondents: 4 project coordinators (the co-authors), 29 other academic staff, 4 admin/finance management staff, and 12 students. 33 from USDM, 8 from Makerere, 8 from UiB. Some of the findings are referred to below.

## 4.1 Progress and impact

Traditionally, mathematics is a male-dominated sector in Tanzania and Uganda. Women are under-represented among the academic staff of the mathematics departments at the higher learning institutions in Tanzania and Uganda and in the areas of applications of mathematics. Therefore, the project aimed at recruiting at least 30% female PhD students. The project is therefore proud to have one female southern partner coordinator and one other woman in the steering committee working with the didactics part of the project. The recruitment of 3 female PhD candidates (of 6) in Tanzania and 1 female PhD candidate (of 5) in Uganda is therefore an important achievement. One of the female PhD students has been supported with a babysitter for longer travels. Besides, the project collaborates with Uganda Women in Mathematics Association, Tanzania Women in Mathematics, and the Eastern African Network for Women in Basic Sciences. The project has been providing annual support to the Science Camps for high school girls organised by the partner institution in Tanzania. Makerere has implemented affirmative action to boost female admission in general, and this is expected to also play a positive future role for the interest in mathematics.

The collaborative partnership impacts the quality of new or revised study programmes in several ways. The partners have organised common workshops to revise academic courses. They organise exchanges of students and study visits, so the students get exposure in areas they are not conversant with.

Scholarship and Research Visits to Bergen: The 11 PhD students were granted full scholarships: fees, stipend, book allowance and laptops. Female PhD candidates receive special allowances. Most students have been to Bergen twice, for periods of at least two months. They receive joint north-south supervision that has an emphasis on the quality of the publications. Furthermore, students have acquired new computational skills.

Some of these students had never been outside their countries and gained very valuable personal experiences on top of the academic achievements. An additional benefit for them is access to the university library in Bergen, which continues and is renewed after they return home. In particular, the four PhD students in mathematics education visited Norwegian secondary schools and observed mathematics teaching as part of their stay in Bergen; and subsequently wrote a paper comparing Norwegian school teaching with Uganda and Tanzania. They also presented their work to Norwegian secondary mathematics teachers at a seminar as part of a master's programme for in-service mathematics teachers.

Conferences: Several staff and students have received support to attend conferences, workshops, and extended visits abroad. MATH4SDG organized its first conference "The African-Nordic Conference in Mathematics", at Makerere University in August 2023, where the eleven PhD students were among those who presented papers. The students have also attended other conferences/workshops, and some students have won awards for their presentations.

## 4.2 Sustainability beyond the life of the project

Most results from the project are sustainable and will last. For instance the curricula reviews will have impact on future generations of students, and the publications produced are adding to the body of knowledge internationally. This includes the implication of the teaching interventions done both as part of PhD studies and outreach activities. Also the established networks, with both industry and among the partner institutions, are something that can be build upon in the future. Finally, the University of Bergen is one of the original partners in the CoRE-MATH, an Africa-Europe Cluster of Research Excellence under the collaboration of African Research Universities Alliance (ARUA) and The Guild of European Research-Intensive Universities, established in 2024 (https://www.the-guild.eu/africa-europe-core/index.html). MATH4SDG is now connected with this network, which may also likely yield other future projects.

## 4.3 Some challenges in the project

The 11 PhD students are followed closely by their local supervisors and co-supervisors at the University of Bergen. There were challenges in developing a suitable supervision culture partly due to geographical distances. These challenges were overcome through communicating expectations. In addition, Mega-Supervision was developed among the PhD students in education, where all four joined with their Norwegian co-supervisor and several of the local supervisors for joint sessions in which the students took turn in giving feedback to each other's drafted papers. The students are supposed to have publications in reputable journals, but many experience very long review processes, which is very frustrating.

Although MATH4SDG so far appears to be successful, the project is also limited to two African institutions in two different countries. Although the project will likely have impact, much is yet needed. Implementing changes in school systems lacking resources, particularly teachers, and with other teaching traditions is not something that is fixed through one project, but we hope that at least it is a move in the right direction.

# 5 Conclusions

The project is ongoing and on track. One respondent to the survey expressed that it is a main strength of MATH4SDG that is has a strategic focus on strengthening higher education and research capacities in developing countries. In addition, by supporting local institutions to produce higher-quality graduates and more inclusive, impactful research, the project aids in building a competent workforce, hence lays a foundation for sustainable development. Other respondents said the strengths of the project are highly experienced project leaders who constantly follow up on the progress and the commitment of the supervision team with north-south supervision. Also, the high competence of the PhD students recruited, and the capacity built at the PhD level that can take lead in their home countries and improve quality of staff, are found to be important strengths. Students themselves highlighted the collection and analysis of data as strengths, and academic staff emphasised that the project is improving the research environment within their institutions. Furthermore, the outreach to the schools and schoolteachers, and the opportunity to travel to different countries and get to inquire about their education system for learning purposes are mentioned as strengths of the project. In addition, the visits to Bergen had an impact on Norwegian students as well as academic staff learning about mathematics teaching outside of Europe. International collaboration and networks, such as those fostered by the Core-Math (https://www.the-guild.eu/africa-europe-core/innovation-technology/innovation-technology-old/Mathematics.html) network under African Research Universities Alliance (ARUA, https://arua.org/) and The Guild (https://www.the-guild.eu), are crucial for amplifying the impact of and synergies between individual projects like MATH4SDG beyond their initial scope.

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