



Article title: Education-based grant programmes for bottom-up distance learning and project catalysis: Antimicrobial Resistance in Sub-Saharan Africa

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Education-based grant programmes for bottom-up distance learning and project catalysis: Antimicrobial Resistance in Sub-Saharan Africa

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Abstract

International development and aid are often conducted through the allocation of funding determined by decisions of non-locals, especially in the west for those in the global south. In addition, such funding is often disassociated from local expertise, therefore providing little long-term developmental impact and generating distrust. This is particularly true for conservation, as well as environmental and educational programmes. We hypothesise that by granting local people the educational tools and the necessary funding to develop their own projects through the use of an applicant driven peer-review approach, it is possible to relocalize the decision-making process to the programme participants, with the potential to generate and select more relevant projects with developmental outcomes of higher quality. Here we created an online curriculum for antimicrobial resistance (AMR) education that was followed by 89 participants across Ghana, Tanzania, Nigeria, and Uganda. We then created an open research programme that facilitated the creation of eight *de novo* projects on AMR. Finally, we organised an applicant-driven grant round to allocate funding to the “Neonatal Sepsis in Nigeria” project to conduct a pilot study and awareness campaign. This work opens perspectives for the design of frugal educational programmes and the funding of context-specific, community-driven projects aimed at empowering local stakeholders in the global South.

Introduction

Antimicrobial Resistance (AMR)

Harmful bacteria cause more deaths per year worldwide than either AIDs or Malaria(1). For most of these bacteria, effective antibiotic treatments are available. This has been true since the advent of penicillin, and the following decades uncovered many more antimicrobials capable of saving human life. However, globally bacteria have become resistant to many of our most effective and widely available antibiotics. This resistance is not yet adequately studied or monitored, with problem areas in the global south especially comprising the overuse of antibiotics in food crops and livestock, and their overspill into water sources and effect the local environment and peoples, and allowing for spread of resistance, constituting a *One Health* problem. Natural selection of antibiotic-resistant strains in these antibiotic rich environments gives an advantage to new and emerging resistant strains in rural and urban settings globally, as well as clinical settings where antibiotics are more commonly used and required for medical treatment(2). Soon this will inevitably lead to an antibiotic shortage.

LMIC contextualised by AMR

Low and Middle-Income Countries (LMICs) bear the highest burdens of infectious diseases with potentially the least resources, and also have limited data on the epidemiology and burden of antimicrobial resistance(3,4). A 2017 WHO report highlighted the gaps in information on pathogens of major public health threats. The report also emphasised the lack of high-quality data and how it limits our ability to assess and monitor trends of resistance worldwide (5). Congruent to earlier reports, the laboratory identification of AMR and bacteria still rely on the use of substandard phenotypic techniques coupled with poor laboratory information management systems seen mostly in LMICs such as within Africa. Aside from this, other barriers such as a poor diagnostic infrastructure, limited staff capacity and training as well as questionable quality management systems compound the problems of tracking down resistance (6,7).

The COVID-19 pandemic has underscored the importance of new paradigms for testing and researching infectious pathogens. The use of pathogen genomics has provided information to scientists in record time to help guide public health strategies. Hence recent efforts in Nigeria saw researchers use sequencing to study and characterise sequence types (ST) for AMR bacteria causing hospital-acquired infections. Datasets collected were made available to their AMR National Coordinating Centre (NCC) in an effort towards overcoming the current knowledge and fragmented data gap. Gains made by countries in Europe in the fight against Antimicrobial Resistance have largely been due to the availability of data at several levels and education which is mostly absent in LMICs (8). Therefore, in the face of growing global health threats, where individualism is a danger to gains made, LMICs particularly those in Africa are optimistic about initiatives that aid their developmental agenda in strengthening existing but weak or non-existent infrastructure to tackle health threats like AMR.

Education and grass root project creation programmes

There has been efforts in the past to improve the infrastructure of LMICs, especially in Africa, however the majority of these programmes have been initiated by projects coming from a western nation with control over project management at all levels(9). This has recently begun to change, with an emphasis towards projects that give natives project ownership and motivation, creating sustainable projects without outside interference.

Therefore, similar to this emphasis on bottom-up –as opposed to top-down– change, a concept of “smart people before smart cities” has become dominating sentiment, with the creation of opportunities for residents, in particular educational ones, being a priority that must go hand in hand with infrastructure improvements (10). This capacity building in people and facilitation of independent work therefore must take priority and allow for new decentralised teams on the continent to work on global problems using their own motivation and methods. This has been shown to be more effective at fostering long-term change(11).

Online learning and capacity building are a priority over travel

During the COVID19 pandemic, international programmes of educational support were encouraged to make educational resources available online and disseminated locally where possible. This has shown to work well in some settings such as high schools (12) as well as within new online infrastructure such as the open source and African built “Voltschool”(13). Similarly the funding granted for these international programmes can be more efficiently spent on capacity building rather than on flights. Prior to this study, the researchers conducted another study focusing on an agile funding allocation scheme to projects determined by applicants (14). Following this scheme, here we used the travel spending funds towards a microgrant allocation to allow the applicants to determine a project within their cohort that should receive seed funding for capacity building beyond education, as well as motivate their own ideas with *de novo* project creation.

Goal of study

Just One Giant Lab (JOGL) is an NGO for collaborative science. In partnership with Hive Biolab, Kumasi, Ghana, University for Development Studies (UDS), Tamale, Ghana and Mbeya University of Science and Technology (MUST) Tanzania, and with the support from the Microbiology Society, JOGL hosted a grant round to catalyse project creation by participants in response to the need for increased capacity building and a focus on education organised a virtual training series on Antimicrobial Resistance (AMR). We also provided a training on the use of an AMR tracking app “microBIS.io” for a pilot result. The goal of the workshop was to build the capacity of university students and laboratory technicians on the latest trends in AMR screening and testing, as well as increase AMR stewardship and empower them with the resources to become agents of change in reversing the spread and negative effects of AMR in Africa.

Methods

All participants in the AMR workshop were invited to join the “Africa against AMR Community” space on the JOGL collaborative network platform(15,16) as well as a special

Africa AMR channel within a community workspace on instant messaging service “Slack”(17) to enhance networking and collaboration.

The project team developed a curriculum to cover important aspects of microbiology, AMR, and innovative approaches to tackle the challenge. Finally, at the end of the programme a grant round was conducted.

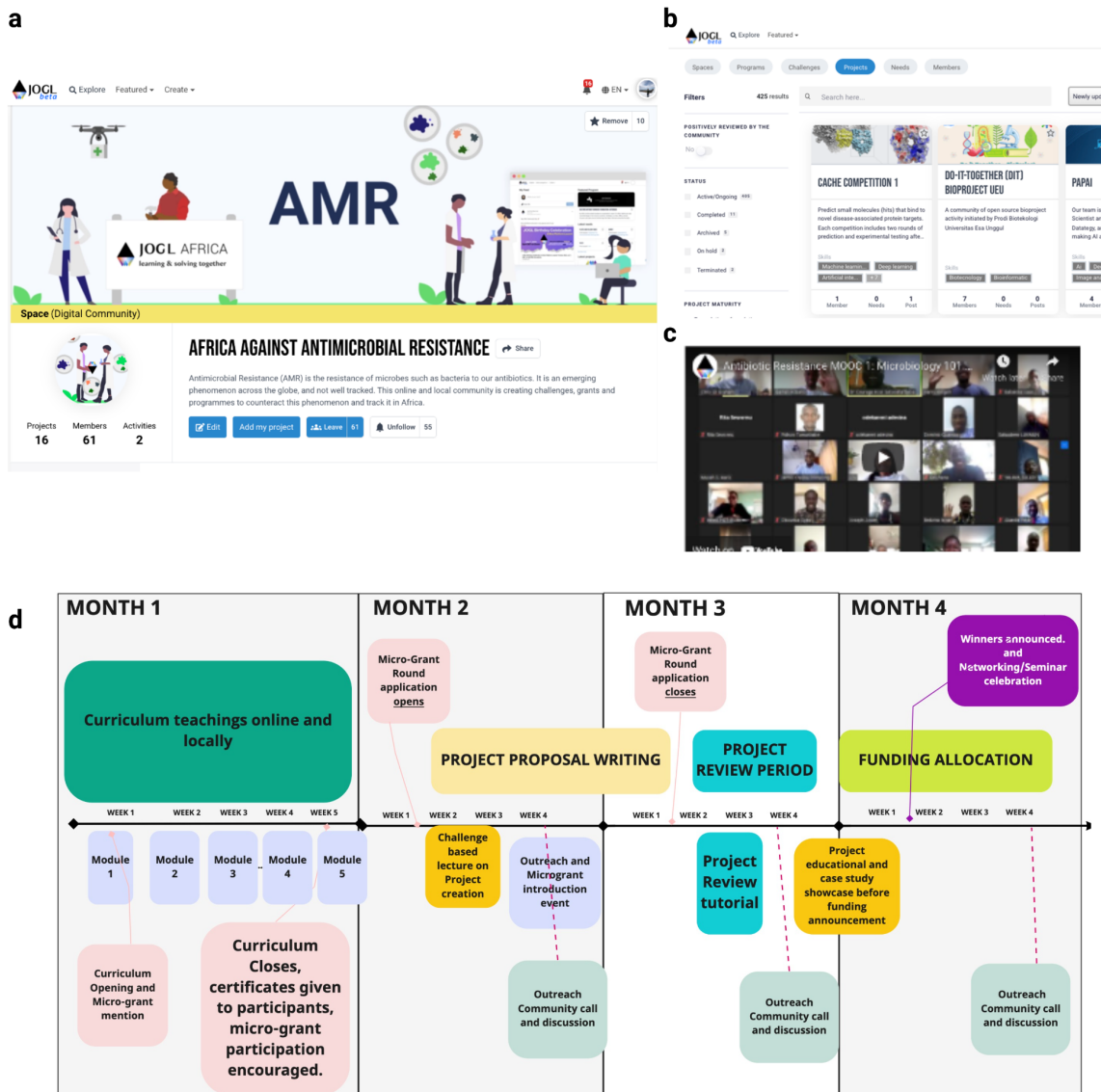


Figure 1. Online Project creation and Networking. **a.** Program page in the JOGL social innovation network used to allow for project creation in an open-source accessible website **b.** project search and display function **c.** Videos of modules were recorded and displayed on the platform. **d.** Timeline of initiative

Geotagging and Surveying

Geotags of the coarse-grained information (town level) participant locations were pulled from the JOGL website and converted using Geo-Coder(18,19), and the names and identifiable

aspects of members were removed before geotagging. Upon signup to the platform, consent is given for location tracking, in the user terms and conditions.

Outreach and Recruitment of Participants

Participants were contacted through social media channels such as Twitter, Facebook, and LinkedIn to advertise a free curriculum and grant round, in addition to on our constructed site. Existing media accounts with 4000+ followers allowed for sharing between individuals through connections.

Curriculum

The course was composed of two parts - an online workshop series and onsite practical sessions. Each lecture was created one week ahead of schedule. The online workshop consisted of five modules delivered as weekly Zoom webinars from the 21st September to the 19th October. These sessions were recorded and the videos were uploaded on YouTube(20). Practical sessions on microbial identification and sensitivity testing were scheduled for interested participants in Kumasi, Ghana (Hive Biolab), Ghana, and Mbeya, Tanzania (MUST). The details of the curriculum can be found in the supplementary information.

Online Web-space

For presenting the modules within the “Massive Open Online Course” (MOOC), and the grant review round, we used a citizen science and project creation network called “Just One Giant Lab”(14,16). This allowed participants to create their own projects in addition to taking part in our syllabus available here(15). The social network aspect in a focused programme allowed for sharing and openly disseminating the curriculum internationally. These were all created with the help of the design team at JOGL.

Local collaborator selection

Coordinators of the programme local to Ghana and Tanzania were found through the JPIAMR portal for collaborator finding, as well as through existing shared contacts. They were reached out through email and the collaboration was initiated at the grant writing stage, with further participants and partners invited after the grant award by our funders.

Administration

Administration was conducted first through a google form (**Supplementary Data 1**) for the collection of emails. The resulting email spreadsheet, which included demographic information, was then used to liaise for the rest of the course.

The grant round leveraged the JOGL interface to facilitate contact with applicants. Using the JOGL application programming interface (API), applicant data was collected so that anyone who joined the grant round were then emailed with any updates through the course of the endeavour. Administration within the consortium of collaborators between MUST, University of Warwick, Hive Biolab and JOGL was conducted over Slack channels, emails and zoom meetings with no in-person meeting.

Network of skills creation

Similar to Masselot et al(16), participants filled in their professional background, skills and employment status on signing up to the JOGL platform. In order to better understand how skills were related across participants, we used a network approach to assess similarity between skills and got further insights about the global diversity of the community. In this network approach, each declared skill is a node and the considered skills as linked if they co-occur in a participant. Links are then weighted by the number of participants they co-occur in. Gephi 0.9.3 was used to represent the network in **Fig3**, its modularity algorithm was used with default parameters to compute communities.

AMR in Africa Grant Round

JOGL organised the 'AMR in Africa Grant Round' to support one research, innovation, or education project tackling AMR in Africa. The call for proposals ran for one month, from November 18th to December 18th 2021. We used a proposal template as attached (**Supplementary Material 2**) with a focus on the antimicrobial resistance outcomes to encourage a formal application approach, then used the following format for administration. (**Fig2**) Applicants were required to mark at least four other applicants, therefore giving a democratic and local outlook on the most relevant and innovative solutions by curricula through experts and existing creators. This followed a community review methodology as used in the OpenCOVID19 programme 2020-2021(14).

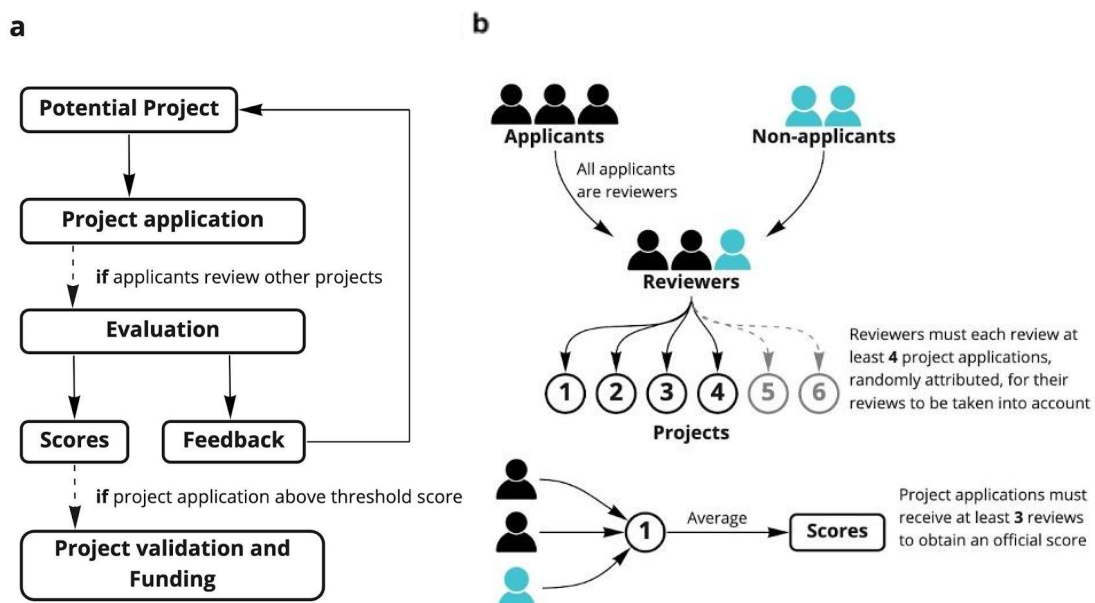


Figure 2. Grant Application process.

a. Flow of community review and grant application **b.** applicants review one another allowing full scalability. (Adapted from Graham, Landrain and Santolini et al 2022)(14)

Results

Background of Participants & Trainers

The virtual training attracted 89 participants across the African continent from diverse backgrounds such as laboratory technicians, students, researchers, and innovators (**FigS1**). More than 50% of the participants were undergraduate students, while the other 50% comprised lab technicians/scientists, postgraduate students, and teachers/lecturers also. Most of the participants came from Ghana, Tanzania, Nigeria, and Uganda as per details filled in the application form. The results of the form indicated our shared connections were greatest in Ghana, Nigeria, Uganda, and Tanzania as visualised in **Figure 3**. This is likely as our collaborating partners were from Tanzania and Ghana, who also shared the opportunity within their networks, notably from a range of cities across the aforementioned countries (**Fig3a**). The distance between participants, normally inhibitory to practical or in-person instruction, was overcome using online teaching and community building. The community leveraged through the creation of a curriculum was that of a network of participants with some relevant skills already (**Fig3c**) who could complement each other's strengths during project creation: those with more experience with open science in general, creating a community of open science advocates (including JOGL staff) (pink), but also project developers (orange) and biologists (green and blue), with some having multiple of these skills, indicated by degree of connection between groups. Most notably synthetic biologists who joined the grant and education programme had the most experience in open science.

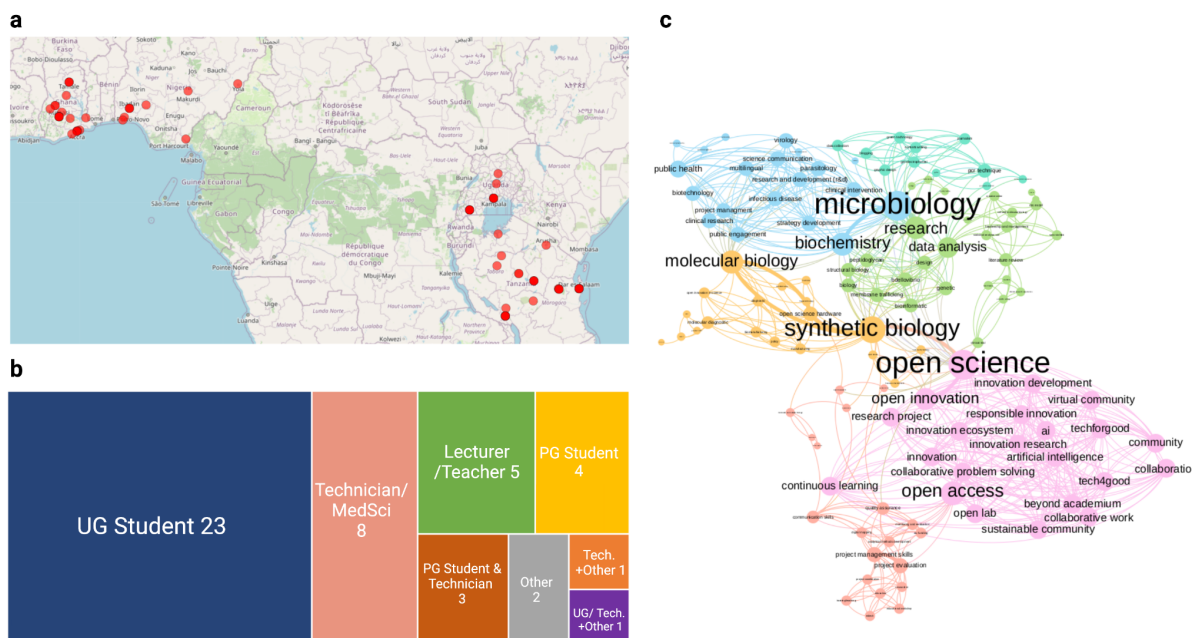


Figure 3. Location and Profession of participants of virtual curriculum in Africa

a. Locations derived from geocoded data from form input. All participants are shown as red dots by city, with intensity indicating number of participants from the region. b. A visualisation of the professions who filled in the post curriculum form. c. Network of skills in the cohort of participants. Skills are connected if a participant has both of them in their profile. The thickness of connections indicates number of participants sharing two skills and the size of nodes indicates the number of neighbouring nodes. Gephi 0.9.3 was used to represent the network. Colour indicates the community, assessed using modularity.

Post-Course Participants Survey

The overall feedback shared by the participants in a post-workshop survey was positive (Fig4). Roughly 98% of the survey respondents rated the workshop 4 or 5 (1-5 scale) (Fig4a). Similarly, over 93% of the respondents indicated that the training had a high positive impact on their current work (ratings of 4 or 5) (Fig4c). Of the modules taught during the online sessions, less specialist introductory aspects such as MOOC 2, MOOC 3, and MOOC 1 (Supplementary information- Methods and notes) were deemed to be of the highest relevance to the participants trained. Importantly, there was a large number of applicants who continued to apply for the grant round in AMR project creation, suggesting curricula are a positive means for *de novo* project creation and onboarding (Fig4b).

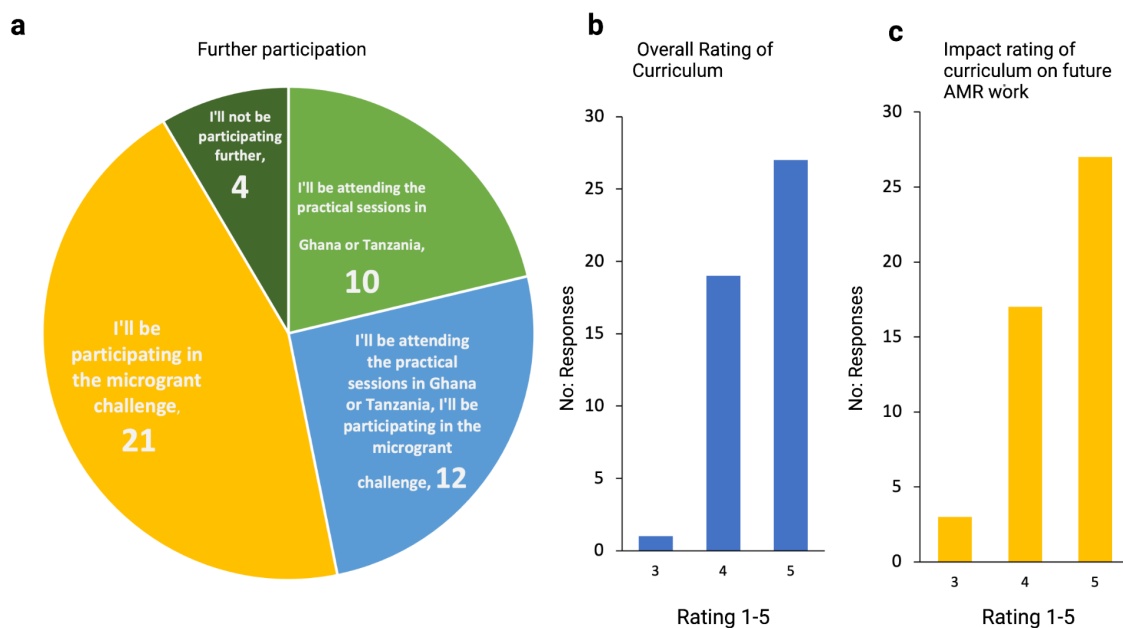


Figure 4. Participant feedback of pre-grant curriculum.

a. Participation, practically, in grant challenge or no further participation. b. Rating of curriculum, (1-5) according to participant feedback c. impact of programme on future work.(1-5)

Some participants shared additional content about their experiences during the five-part online training:

“I had ‘locked’ myself but the course now opened my mind. It woke me up to see the ever increasing challenge of AMR.”

“The training was well organised, precise and straight to the main point.”

“The modules were very relatable to my work and also improved my knowledge on AMR”

“It was lively at all times and encouraged participatory discourse”.

They also made some suggestions for improvement, some of which have been captured below:

“You may please consider a session to educate non-specialists because, I am not working with a medical institution and having difficulties engaging fully”

“Engage more stakeholders for example political policymakers and other African country health ministries”

“Involve practical sessions for participants from other countries outside Ghana and Tanzania”

“I think you are doing a great job but I think what needs to be improved should be the technical aspect of it because we lost connection at a point during one module.”

Participants’ comments on modules they found relevant (related to informational content and not developmental or project-related content) may be due to the fact that the workshop was dominated by undergraduate students and early career lab technicians, who identified concepts they could apply in their day-to-day work. However, the modules on antimicrobial stewardship and digital mapping are equally relevant in developing additional leadership, coordination, and digital literacy skills required for the next level of careers. Comments in particular on ministerial and governmental cooperation to improve outcomes and network are particularly significant changes that future programmes could integrate.

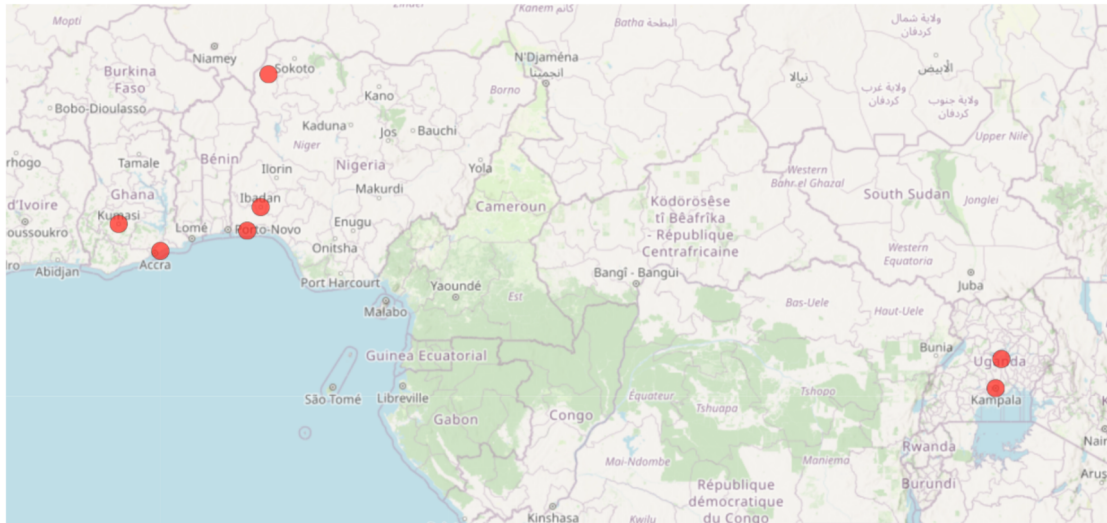
In summary, the AMR workshop and curriculum as a means to build new projects were carried out to a satisfactory level with future iterations likely to alter the curriculum based on sign-up and topic interest, based on the team’s experience organising and delivering the programme, and the feedback received from the participants (**Fig4**). There is a great potential to scale the workshop and its associated activities to reach more students, young professionals, and general science enthusiasts in Africa due to its mediation through online platforms.

Grant and Project creation outcomes

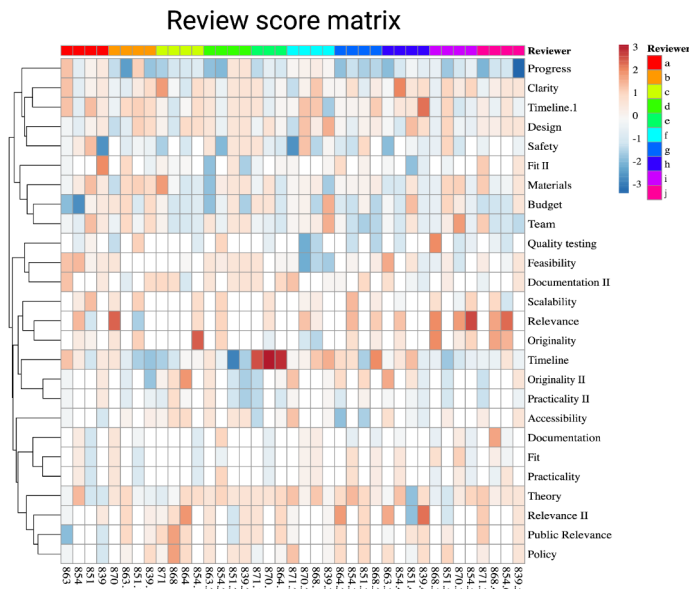
After the curricula, in total eight projects(15) applied to the grant round from a subset of the curriculum takers, but also from individuals who saw the grant round advertised in their

network, with a geographical distribution similar to the participant distribution (**Fig2/Fig5a**). In order to ensure fairness after submission and review and prevent gamification, the reviewers' scores across the questions in each form were normalised to their overall average review mark across their five reviews using the community review method. The distribution of scores per question shown by the heatmap indicates independence of questions asked in the form, and allowed for detection of odd reviewer behaviour (14). (**Fig5b**). The winning team with the highest average review score for the 1000 euro grant was "Neonatal Sepsis in Nigeria" (21). The other seven teams that applied to the grant, or formed as a consequence of its existence were encouraged to apply to later or other grants. As a result of the programme there is still an active community of collaborators on the community "slack" channels whom conduct meetings on science policy on a monthly basis in preparation for future programmes, and this initiative acted as a catalyst for its community growth, we are currently writing collaborative grants with many of the participants. This shows that with little organisation and a small prize pot, a significant collaborative output can be achieved with micro-grants if accompanied by training and encouragement.

a



b



c

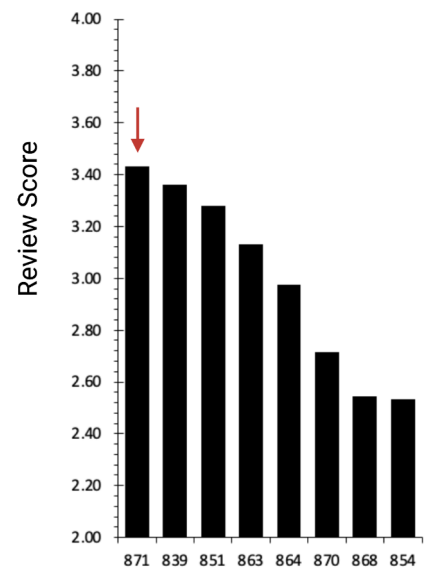


Figure 5. Project catalysis and scoring by applicant-based peer review.

a. Location of new projects created (18), **b.** Review behaviour as visualised by heatmap of scores per question Red to Blue, high scoring to low scoring respectively, determined by Z score **c.** Review score rankings by applicants. Winning project is denoted by a red arrow.

Network building and community science considerations

In addition to the projects created, by creating a community internationally through the web, the collection of information for database related programmes can be improved. A collaborator who took part in the education aspect of the programme, asked participants working in hospitals to gather data of location, and resistance of bacterial strains, which allowed the team to begin the creation of an antimicrobial resistance location database.

Further success in reaching out to participants would allow an international map, and service not possible in on the ground programmes . We have supplied a sample of this data (**Supplementary Figure 1**). In future programmes, such communities can be leveraged for similar community science outputs such as data gathering.

Fostering of collaboration among organisers and participants

Some of the participants met virtually for the first time because of the project. Throughout the development of the courses and practical sessions, there has been exchanges of good practices among participants who are from different countries and continents. The high level of collaboration shown throughout the project paved the way for future joint proposal writing for a bigger grant to curb the menace of AMR worldwide, and an active online science sharing community. Some participants have networked during the workshop and we hope this project provided the right platform for early career scientists in AMR to share their experiences with one another to tackle issues of AMR in Africa.

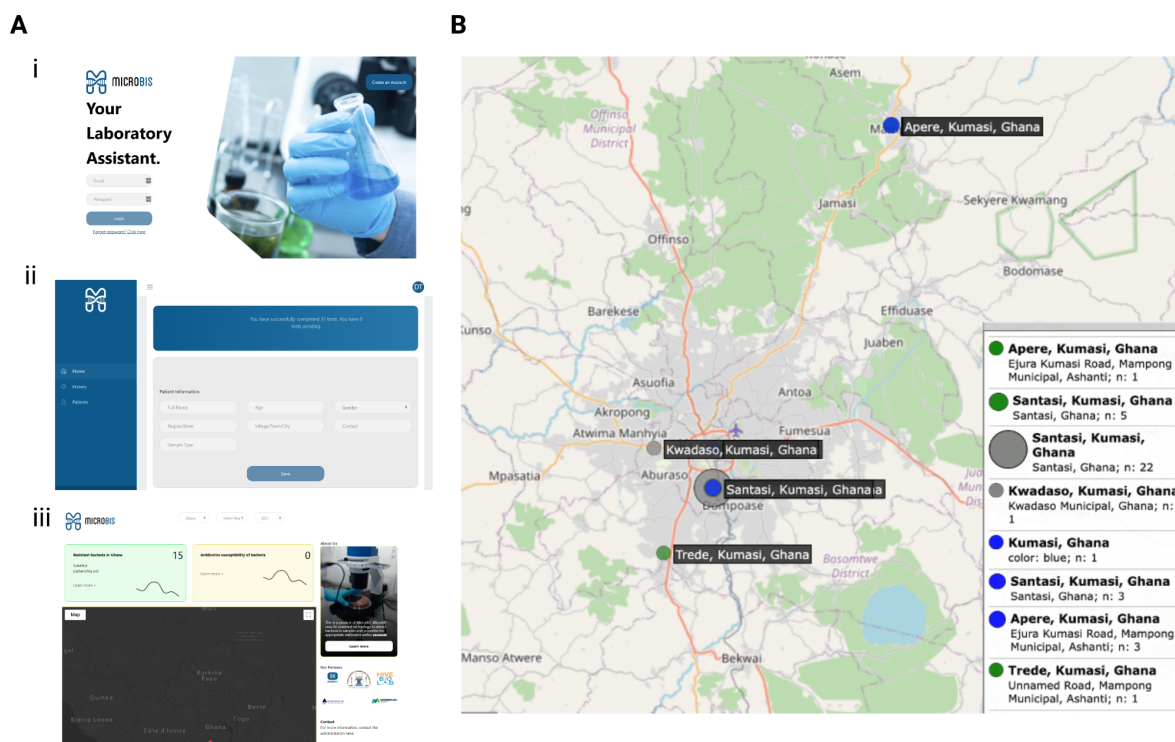
Conclusion

Through the use of a local network of contacts and the “Just One Giant Lab” web platform, we were able to create an online curriculum for AMR and deliver this to a diverse audience based predominantly around Uganda, Nigeria, Tanzania and Ghana. We hosted a program fostering the creation of eight *de novo* projects and organised a community review round that funded one project selected by applicants and participants of the online curriculum. As such we performed a hybrid model of online curriculum and grant allocation, working with local partners and participants as community drivers, with democratic and local values upheld by decisions of applicants themselves. This method could help foster development in a cost-efficient manner and at an international scale. to. This programme and its scale would not have been possible in person due to travel costs, yet it allowed for capacity building with an educational program as well as local project creation and curation. This technique opens perspectives to design frugal approaches allowing to locally empower individuals in context-specific project catalysis and educational programmes for the global south.

Acknowledgements

The facilitators for the workshop were Prof Courage Kosi Setsoafia Saba (University for Development Studies, Ghana), Dr Linda Salekwa (Mbeya University of Science and Technology, Tanzania), Dr Beverly Egyir (Noguchi Memorial Institute for Medical Research, Ghana), Harry Akligoh (Kumasi Hive and Duplex Bioscience LBG, Ghana), Chris Graham (University of Warwick, UK & Just One Giant Lab), and Gameli Adzaho (Just One Giant Lab). Dr John Moat of University of Warwick also made inputs into the content of one of the modules. We thank the Microbiology Society for the International Development Fund grant (GA002608) and IFD for funding JOGL Africa.

Supplementary Information



FigS1. Antimicrobial resistance strain tracking in Africa.

A Microbis app, a web based antimicrobial tracking system. **B** Location Data from preliminary study, Blue = Tryptophan resistant strains, Green = Not Tryptophan resistant, Grey = Unknown

Methods Notes

MOOC1 Microbiology, Bacteriology 101, and Antimicrobial resistance

The session started with an introduction of the AMR education project and its associated activities. Information was also shared on the various engagement platforms created. Led by Prof Courage Saba and Chris Graham, the module was focused on the basics of bacteriology and antimicrobial resistance. Some of the concepts covered included types of bacteria and microorganisms, cell biology, DNA, and AMR patterns. A key learning point was the realisation that AMR was on the rise in the food industry, especially in animal production. Farmers in northern Ghana for example were cited to be administering antibiotics to poultry and livestock, including cattle, to treat infections. The module further highlighted the ‘one

health' concept, the inter-relationships between human, environmental and animal health, known as 'one health'. This concept explains why salmonella has a high-cross contamination pattern passing through waste water, food, and humans, and develops resistance to antibiotics. The session concluded with a discussion on the challenges associated with developing new antibiotics for current and future infections.

MOOC 2: Techniques involved in identification of microbes

The session exposed participants to different techniques of isolating and identifying microorganisms. The lecture was delivered by Dr Linda Salekwa of Mbeya University of Science and Technology in Tanzania. She mentioned soil, air, and water as examples of media from which microbes can be isolated. These media influence how the microbes can be isolated. Some of the identification techniques discussed include direct observation, gram staining, biochemical tests, serological assays, and molecular techniques. The importance of microscopy for direct observation was highlighted. The session further explored different types of media to culture microbes classified based on composition (simple, complex, synthetic and special) and roles (selective, differential, elective and enrichment. Also the lecture included a lesson on various techniques used to culture and quantify viruses. Most of the questions asked centred on the practicality of using the various techniques discussed to successfully isolate and/or identify microbes.

MOOC3: Sensitivity testing/antimicrobial susceptibility testing

Chris Graham facilitated the third session focused on AMR sensitivity testing. Additional topics covered included minimum inhibitory concentration (MIC), disc-based sensitivity testing, creating do-it-yourself (DIY) labs for microbiology, getting materials, blood defibrination and storage. The session further covered AMR screening techniques, quality control, and working with EUCAST guidelines (22). The discussion on integrating DIY techniques into microbiology was particularly relevant as many of the participants work or study in low-cost settings where equipment is limited. Tips were shared on DIY approaches to benchtop and bunsen work, media autoclaving (hotplate, microwave, boiling media, sterilising water), low-cost incubators, and low-cost microscopy.

Mooc 4: Antimicrobial Stewardship

The fourth module, which was in two parts, covered antimicrobial stewardship. In the first part Dr Egyir introduced antimicrobial stewardship as a set of actions that promote the responsible use of antimicrobials. She stressed 'responsible use' is very important in the era of COVID-19 due to increased prescriptions and use of antibiotics, a risk factor in AMR. Core elements of antimicrobial stewardship such as hospital leadership commitment, accountability, pharmaceutical expertise, tracking, reporting, and education were highlighted in the talk. Benefits and challenges of stewardship programmes were covered. Dr Egyir concluded with recommendations for reducing AMR in hospital settings including reducing inappropriate antimicrobial prescription, using narrow-spectrum antibiotics, giving treatment using appropriate guidelines, increasing knowledge on antibiotics and AMR, investing in data monitoring and analytics, and raising awareness on AMR. Following this, Gameli Adzaho

gave a talk on fighting AMR through social and behaviour change communication (SBCC). He introduced the socioecological model, and explained how it can be used to analyse individuals' and groups' antibiotics usage behaviour. He further explained how the behaviour change framework works in determining priorities for an intervention. Delving into SBCC campaigns, the keys described were: analysing the context, setting objectives, identifying the audience, choosing a strategy, selecting a theme, developing key messages, and creating an action plan.

MOOC 5: Digital mapping and MicroBis

Harry Akligoh delivered the final lecture on digital mapping and the microBIS (<http://microbis.io>) platform. He shared that digital mapping concerns the art and science of using digital technology in collecting data. He went on to give use-cases of how mapping biomedical data could contribute to positive public health impacts. Harry went on to introduce microBIS, a platform that serves as a digital laboratory assistant, developed by his team in Ghana. A demo of the platform was subsequently given. Key features of the system include algorithm-based bacterial identification and AMR mapping. The platform provides data security and fast accessibility to information through the dashboard. For IP purposes the data is owned by people who contribute to it.

Practical Techniques for Microbial Identification and Sensitivity Testing

Following the successful online workshop series, the Hive Biolab team organised two rounds of practical sessions from 20th to 21st November and 27th to 28th November 2021 for selected participants in Kumasi, Ghana. The goal of these practical sessions was to give people the opportunity to perform some of the techniques they learnt about in the online phase. Some of the topics covered were bacterial identification, medium preparation, culturing, and sensitivity testing with discs. They also had the opportunity to explore the microBis platform practically.

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