International Clinics on Infectious Disease Dynamics and Data

The ICI3D Program (www.ici3d.org)

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Rationale

Reducing infectious disease burden will help unlock Africa's human potential. Mathematics and simulation are essential tools in infectious disease control, enabling decision-makers to explore control policies before implementing them, interpret trends, and predict emerging threats. Currently, developing countries with the highest burdens have the least capacity to analyze and combat infectious disease risk. We train international cohorts of junior researchers to conduct integrative research in infectious disease dynamics and to communicate their questions, methods, and findings across disciplinary boundaries. Through this project, we aim to jump-start Africa's ability to address its infectious disease problems and engage with the global research community.

Funding

The ICI3D program was developed with funding from the National Institute of General Medical Sciences of the US National Institutes of Health under award number R25GM102149. This grant has now ended, and the program that funded it no longer exists. We have pieced together funding from the US National Science Foundation, World Health Organization, and SACEMA to keep the Clinics running in the short term but are **seeking long-term, sustainable funding**. The full annual budget (including administrative costs) is approximately $250,000.

Approach

The ICI3D program is structured to provide maximum interaction between American and African researchers from the full spectrum of research disciplines engaged with processes that affect infectious disease dynamics – including mathematicians, statisticians, computer scientists, disease ecologists, sociologists, demographers, and medical, veterinary, and public health epidemiologists. This is accomplished through two complementary workshops – the Clinic on the Meaningful Modeling of Epidemiological Data (MMED), which has been run since 2010 and targets primarily quantitative scientists, and the Clinic on Dynamical Approaches to Infectious Disease Data (DAIDD), which has been run since 2012 and teaches modeling principles and aspects of study design for dynamic systems to researchers with little or no background in mathematical modeling. In addition, the International Disease Dynamics and Data (I3D) Research Scholars Exchange Program fosters close interaction with the most promising MMED and DAIDD graduates, ensuring they have the support they need for further development of their research careers and providing a mechanism for allowing them to complete research publications in close collaboration with ICI3D faculty.

Recruitment: We solicit applications for both Clinics via a request for applications sent to public health schools, governmental health agencies, mathematics and ecology departments, and via our own professional networks. Applicant selections are made by consensus of a faculty review committee, accounting for essential and desired applicant characteristics as well as gender balance and our desire for participants with diverse professional and geographic backgrounds. We have been successful at recruiting high-quality, diverse cohorts (**Table**, under Outcomes).

Evaluation: Our program evaluator runs two feedback sessions during each Clinic that are closed to the faculty. These sessions focus on identifying potential modifications to better meet participants' needs during the current and future Clinics. Participants also complete an anonymous written survey rating each session, providing finer-scale detail to support future improvements. Participant feedback has led to major improvements in clinic content, organization, and pedagogy through the years.

Program Components

Overview of the MMED clinic: MMED comprises an interwoven series of interactive lectures, computer tutorials, faculty research talks, research formulation exercises, participant poster sessions, one-on-one mentor sessions, live participatory coding sessions, group projects, and an interactive outbreak simulation and investigation exercise.[1] Most sessions are run with the full group; however, some parallel sessions are offered to ensure there is sufficient common ground for participants with different backgrounds (**Track A** for mathematical modeling background; **Track B** for backgrounds in epidemiology, statistics, medicine, or other empirical research). Sessions transition gradually from hands-on exercises to research practice. The diverse pedagogical approaches ensure participants access to multiple means of learning and stimulate lively interaction amongst participants and faculty (**Figure** below).

MMED focuses on engaging participants in modeling projects that use infectious disease data to grapple with practical questions in a meaningful way. The Clinic illustrates techniques for integrating mathematical models with data to interpret experimental, observational, and surveillance data and to plan future studies. We teach participants to use data to inform the construction of transparent models of appropriate complexity to answer a scientific question. We balance training in mathematical modeling with sessions on study design, data curation, data analysis, logistics, ethics, and scientific communication. Several Clinic sessions focus on clear communication with stakeholders. We use interactive, iterative communication exercises in a group with diverse cultural and academic backgrounds to practice effective oral and verbal communication.

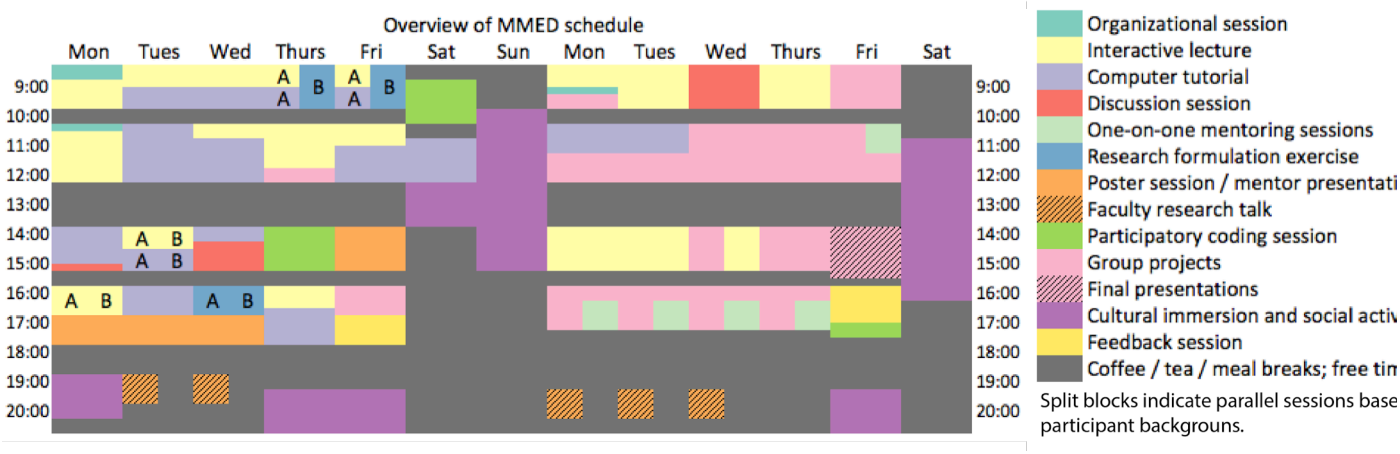

Figure. MMED schedule, broken down by pedagogic categories.

Participants integrate the above content during group project work on active research questions that is begun in the second week of the Clinic and culminates in a project report due 6 weeks after the end of the workshop. The research questions addressed can be posed by Clinic faculty or by participants, and each group consists of 4-6 participants with different backgrounds, paired with 1-2 Clinic faculty. We require that each project group include participants from both Africa and elsewhere to foster international collaboration. Example topics addressed by recent MMED working groups include:

- *What impact would using measles vaccine outside the cold chain have on outbreak response in the Democratic Republic of Congo?* (in collaboration with and using data from MSF)
- *Could rising active tuberculosis incidence in Madagascar be explained by a hidden HIV epidemic?* (in collaboration with and using data from the Malagasy Ministry of Public Health)
- *What intervention scenarios will permit Kenya to meet the 2030 target for elimination of canine rabies?* (in collaboration with and using data from the Kenya Medical Research Institute)

Each year, some groups focus intensively on skills development in an area outside their prior training. For example, past groups without experience in data collection (e.g. mathematicians and computer scientists) have conducted an outbreak investigation (including questionnaire design and data entry, cleaning, and analysis) of a real-time epidemic simulated among course participants.[1] This type of cross-disciplinary immersion is essential for training young scientists to work effectively across disciplines to solve emerging problems.

Project groups present oral reports at the end of the Clinic and submit a written report 6 weeks after the workshop. The group project reports are then reviewed by 2 faculty members (or relevant external reviewers) in a mock peer-review process. Some groups go on to pursue peer-reviewed publication of the project under faculty guidance.[2-4]

Overview of the DAIDD clinic: The DAIDD clinics target public health researchers and population biologists with a good grounding in classical statistics and experience with data collection but little or no knowledge of dynamical systems theory or infectious disease modeling. This clinic provides a conceptual foundation for integration of dynamic modeling approaches into empirical infectious diseases research, and assumes less technical sophistication (e.g. scientific computing skills or formal mathematical training) than is expected of participants in Track B of the MMED clinic. The overall objectives for the 1-week program are that participants will leave with

- An understanding of dynamic principles and their role in the epidemiology of infectious diseases
- A familiarity with diverse modeling frameworks
- Guided experience with construction of simple models
- A conceptual framework for fitting models to data
- Experience creating a model world to address a research question
- A set of identified resources for continued learning

In addition to interactive lectures, discussions, and computer labs that provide an introduction to the fundamental concepts and methods in infectious disease dynamics, a major component of DAIDD consists of guiding participants to develop from their research interests a well-defined research question that can be addressed using a data-driven disease model. Various components of this process focus on the concept of a "model world", which we define as an abstraction of a focal research system that has a fully specified set of assumptions and rules, with the minimal sufficient complexity necessary to address the research question (model world exercises are also in Track B of the MMED curriculum). Such components include:

- **A Collaborative Model World*:*** An instructor facilitates a session where the group chooses an example research question, and collaboratively works through the process of abstracting the focal research system into a model world and then producing a model diagram that describes the populations of interest (state variables) and the processes (transitions between states) reflected by the model.
- **Individual Model Worlds:** participants then repeat the exercise individually as an overnight assignment, producing a model world and a model diagram to address their own research question.
- **Model Telephone:** An exercise focused on clear interpretation and communication of models and their assumptions, using a version of the game "telephone". In groups of three, participants pass their model diagrams to another group member, and then write a verbal description of the model they have received. These descriptions are passed to the third group member, who attempts to recreate the diagram based only on the verbal description. Each student then compares the description and the new diagram to their original diagram, giving them an opportunity to evaluate where communication broke down. The group then discusses lessons learned and revise their diagram and description for increased clarity.
- **Individual research plans:** During independent work sessions later in the week, participants develop a preliminary research plan, suitable for use as a framework for developing a grant or dissertation proposal by working closely with peers and Clinic faculty. Building on the components described above, each participant develops a research plan that includes: a focal research question; a description of a model world; an accompanying diagram; identification of appropriate modeling frameworks and discussion of their assumptions, advantages, and limitations; discussion of quantitative approaches to both study design and data analysis; and identification of potential collaborators.

Overview of the I3D Research Scholars Exchange Program: The I3D research scholars exchange program allows the most promising researchers among MMED and DAIDD graduates to spend 6 weeks (minimum) completing a research project with a member of the ICI3D faculty. During the 6-week exchange program, visiting research scholars are fully integrated into the lab group of the supervising faculty member and carry out a research plan tailored to the scholar's background and the proposed project. All I3D scholars give an oral or written report on their work at the end of the 6-week project period and are required to submit a final written report after returning to their home institution. In most cases, the final written report is in the form of a manuscript formatted for submission to a journal agreed upon by the scholar and the supervising faculty member. I3D scholars are also encouraged to give conference presentations on their work.

Outcomes

Capacity Building: ICI3D provides advanced training to individuals across career stages, with participants including undergraduate and graduate students, researchers, professors, and officials at governmental and international health organizations in Africa and worldwide. By providing **scientific and communication training to both early and mid- career participants**, the Clinic strengthens the global

capacity for infectious disease control and prepares future generations to better respond to emerging threats.

Collaboration and Continuity: To promote continuity amongst Clinic participants and help generate exceptional LMIC researchers and professionals, our **mentors program** provides an opportunity for the most promising African MMED participants—those with both strong research potential and effective communication skills—to return to the Clinic and engage on a deeper level, helping new participants through the learning process. We promote **sustained international collaboration** via continuation of group projects after the workshop with faculty guidance; such projects sometimes lead to publications with participant and faculty from multiple countries.[6-10] To encourage **long-term collaboration between participants and faculty**, promising participants can be nominated to apply to work with faculty from another continent on a project of their proposal via our International Disease Dynamics and Data Research Scholars Exchange Program (I3D; funding ended 2016 but we are actively seeking continuing support). Finally, we actively train and recruit new workshop faculty to **ensure long-term sustainability of the program** and promote professional growth of the most promising former participants. To date, 6 former participants have served as workshop faculty for the MMED or DAIDD clinics (typically after multiple years as successful MMED mentors).

Research Outputs and Pedagogic Material: While ICI3D is primarily a training program, **peer-reviewed publications** have resulted from MMED group projects and I3D exchange visits.[2-6] At least 4 additional publications have been submitted and are currently undergoing peer review. Faculty collaborations emerging from the program have also resulted in publications focused on both research[7-11] and pedagogy.[1] Lecture slides and computer labs are hosted online via public (and, for confidential data, private) repositories and promoted for wide use amongst our networks. As of MMED 2017, all lecture materials are made available through the open access and fully citable ICI3D Figshare Collection.[12]

Table. Summary of ICI3D Program participants, 2012-2017. Participants are broken down by sex, race, and institutional location (Africa or North America). The program has had 328 unique participants during this timeframe.

	MMED							DAIDD						2012-2017
Based at African Institutions	2012	2013	2014	2015	2016	2017	Mentors	2012	2013	2014	2015	2016	I3D	Total*
Total	**32**	**21**	**20**	**40**	**38**	**38**	**16**	**3**	**4**	**4**	**8**	**8**	**6**	**216**
By sex														
Male	22	14	10	21	26	22	8	2	2	2	4	4	4	**131**
Female	10	7	10	19	12	16	8	1	2	2	4	4	2	**85**
By race														
Black	23	13	13	33	32	33	8	3	3	3	6	8	5	**169**
White	7	7	4	3	5	2	4		1	1				**29**
Other	2	1	3	4	1	3	4				2		1	**18**
Based at North American Institutions	2012	2013	2014	2015	2016	2017	Mentors	2012	2013	2014	2015	2016	I3D	Total
Total	**5**	**8**	**8**	**9**	**9**	**8**	**1**	**13**	**13**	**13**	**15**	**15**	**5**	**112**
By sex														
Male	2	4	4	2	3	3		2	7	6	4	6	3	**40**
Female	3	4	4	7	6	5	1	11	6	7	11	9	2	**72**
By race														
Black	1		1		2	1		1	2	3		2		**12**
White	2	6	7	7	5	6	1	9	6	2	12	11	4	**75**
Other	2	2		2	2	1		3	5	8	3	2	1	**25**

* Totals in this column may not equal the sum of 2012-2017 columns due to single inclusion of repeat participants.

Cited References. Authors are color-coded as MMED participants and MMED faculty.

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