Report on Training and Capacity Building at SACEMA: DST/NRF Centre of Excellence in Epidemiological Modelling and Analysis, Stellenbosch

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EXECUTIVE SUMMARY

Following the review of SACEMA in February 2009, and the Management Board's Response in March, attention was focussed upon the increased importance of truly multi-disciplinary training at SACEMA, in the light of the dearth of qualified researchers in modelling, and the recognition that training must include coursework, a greater biological component, and more practical, clinical or laboratory experience. Attention was also focussed on the urgency of an effective outreach strategy to attract more South African (especially black) students. However, staffing at SACEMA was totally inadequate and the Director already over-burdened. Therefore I was engaged to come for a month as training consultant to evaluate SACEMA's whole training component and report on ways to build the right kind of capacity for the future.

One week was spent at AIMS evaluating the MMBD Clinic. Observation, discussion with participants and written student responses all combine to confirm that this is in many ways an excellent model for the kind of regular training exercise that is needed. Three weeks were spent interviewing students, staff, supervisors and associates of SACEMA. Overall impressions are of high quality, well-motivated students, good student-supervisor relations, and some excellent work being done. Those I talked with (especially students and supervisors in UKZN and Wits) seemed genuinely pleased at the opportunity to discuss well-being and progress. Some problems emerged, some immediate solutions were proposed and even implemented, and useful conclusions drawn for future action on the deeper problems. This monitoring and evaluation exercise must be ongoing, and so much more in connection with training, such as the planning and organization of coursework and outreach. For this, joint action with partners in capacity building is essential, and the staffing at SACEMA has to be urgently addressed.

Some major recommendations

- Bring together the admirable and promising capacity building ideas and initiatives at Stellenbosch (biomathematics) and at UKZN (biostatistics), making maximum use of established expertise and existing strengths. Prepare a joint proposal for adequate funding, emphasizing the strategic importance of a truly interdisciplinary epidemiology (and ecology) at this point in South Africa's history.

- Simultaneously, pursue vigorously the timely vision of an integrated Graduate School of Epidemiology at Stellenbosch University, which can work with SACEMA to bring the clinical and the mathematical into sustained healthy engagement, thus providing

the much-needed focus for crucial, country-wide, inter-disciplinary training needs.

- Appoint a Deputy Director (Training) at SACEMA, who should (ideally) be an inspirational teacher and researcher with administrative skills, tasked with over-seeing training and capacity building, monitoring progress, organizing workshops, internships, outreach, research initiation courses, and targeted short courses. Pending such appointment, engage short-term consultants to evaluate student progress, perhaps every six months, and give early warning of personal or work problems, assist with appropriate networking, and advise on coursework and other needs.

- Cultivate the fruitful and highly-valued association with Rutgers/DIMACS, holding regular one- to two-week workshops after the highly successful MMBD pattern, bringing together a diversity of students and inspirational mentors from Africa, North America and elsewhere, taking account of the critique and suggestions in Part 1 of this report.

- Build on the success of "Research Days" at Stellenbosch, encouraging more interaction between isolated students, and more opportunities to talk about their work, critique/support each other, and widen their perspectives. Hold "Mini Research Days" in UKZN and WITS, and also more Departmental seminars and colloquia, and encourage student "Journal Clubs".

- Design initiation courses for MSc students, in research methods, concepts in biology, etc. In cooperation with all involved Universities, invite SACEMA students to attend regular modules of relevance, as advised by supervisors, and also mount special short courses to meet needs.

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Prologue

Tony Davies, professor emeritus in occupational health at Wits University, opened a talk surveying the long and sad saga of 20th century inquiries into health and safety in South African mines with a fragment from a poem by Edna St Vincent Millay:

> "Upon this gifted age, in its dark hour,
> Rains from the sky a meteoric shower
> Of facts ... they lie unquestioned, uncombined."

He went on: "Perhaps, after decades of meteoric showers of facts on occupational lung disease in mines, one must turn to poetry in order to move the South African mining sector and government to fulfil their responsibilities in this regard. But what shall be the theme? ... Should we go for visual imagery and attempt to describe the graph of autopsy data showing TB in black South African miners, its red line climbing steadily, ominously, decade after decade?..."

The human tragedies associated with disease in Africa and elsewhere continue to appal our sensibilities and drain our resources: TB, malaria, trypanosomiasis, leprosy, cancer, cholera, polio, bilharzia, and many other lesser, more localised or shorter-lived epidemics (will swine-flu be short-lived?). Looming over all, and interacting with them all in complex ways, is the great pandemic of HIV-AIDS. Red lines, for all the sub-narratives of "good news" picked up and emphasised by governments and media, are still "climbing steadily, ominously, decade after decade."

Epidemiology, in its full richness as a truly multi-disciplinary – even trans-disciplinary – scientific enterprise, has the capability to become the most effective response of "this gifted age" to some bleak realities confronting Africa, a true light-source for "its dark hour". The scientific infrastructure and the technical resources are there, if we will rise to the challenge, develop capacity in each of the separate disciplines, and bring them together into fruitful collaboration: the public health professionals and policy-makers, the biologists, mathematicians, statisticians, health economists, the clinical epidemiologists and the quantitative epidemiologists.

That is the reason that SACEMA came into being, and the task has become increasingly vital over the last three years. The careful collection and structured sorting of genuine data from that "meteoric shower of facts", is one great, skilled, task, to be carried out by highly-trained clinicians and health workers of various kinds at various levels. And the modelling and analysis – the "questioning, combining", analysing of that data, with the only tools that are serviceable for the job: biology, mathematics, statistics, and computing science, is another great task. But the two activities cannot be separated – each informs the other, or both are nearly useless. Yet, so much of the data is sequestered, inaccessible, untapped, for various reasons. *Other valuable data is released to northern-hemisphere institutions boasting high-powered multi-disciplinary teams promising quick publications*. Talented African biomathematicians, biostatisticians and bioinformaticians exist, but are isolated from each other and from the clinicians, the public health institutions and the data-collectors, so are often fixated on theory. And training initiatives directed toward genuine engagement with the biological realities are rare, remain detached from each other, and struggle for adequate funding.

Thus, the sustained, thoughtful conversation between these parties (all now well represented in South Africa) essential to setting out seriously to solve some of the biggest problems facing the country and the continent, is simply not taking place. And one of the keys to making this conversation happen is the subject of this report: effective multi-disciplinary training in meaningful epidemiological modelling.

Background

The NRF Centre of Excellence in Epidemiological Modelling and Analysis (SACEMA) was established in 2006 on recommendations to the DST by a panel of experts that such a facility was critical to understanding the dynamics of disease transmission, in particular HIV and TB but including others and their interactions. Mathematical and statistical modelling in quantitative epidemiology was largely missing from the South African skills base with relatively few local mathematicians or statisticians being drawn into them. Thus SACEMA was established, with the following mission statement:

"To establish, within South Africa, a leading research centre of excellence for quantitative modelling of the prevalence and management of disease in and transmission among hosts. The Centre will focus on the major health issues in Africa by:

- Developing the necessary human capacity and infrastructure to advance epidemiological modelling and analysis;
- Placing an initial emphasis on research into the epidemiology, control and management of HIV/AIDS and TB, extending this to malaria and other diseases as additional staff and funding become available;
- Providing a firm scientific basis for health policy and planning locally and nationally."

A review of SACEMA was held 16-18 February 2009, to access SACEMA's performance from its inception in 2006 to June 2008. The report, by an international panel of three, highlighted the importance of training as a major part of SACEMA's activities, and recognised "the enormous difficulties encountered in recruiting qualified researchers" and "the consequent shift of emphasis in favour of training" at SACEMA. The report made certain recommendations relating to training: (a) urgently recruit a researcher who would over-see post-graduate training and relieve the Director of some administrative responsibilities, (b) explore remote mentoring possibilities, (c) offer targeted courses for SACEMA students to receive inter-disciplinary training, and (d) develop internships for SACEMA students with practising biologists to gain biological insight. Two recommendations of the report relate to outreach: (e) expand the successful undergraduate workshop ('epi-intro week') by offering internships to high school and undergraduate students to work with SACEMA students, (f) devise an effective outreach strategy to attract more South African (especially black) students.

The SACEMA Management Board responded as follows (abbreviated):

(a) Rather than appoint a senior scientist whose role should be "primarily research", it was suggested that the incumbent be a highly skilled teacher with sound experience in student supervision, who would focus mainly on capacity development. The provision and evaluation of high-level supervision for 30 MSc and PhD students (most off-site) and the organisation of local and international courses, will be a full-time job.

(b) Video conferencing facilities may not be feasible, but SACEMA will consider making use of the University's Division for Interactive Telematic Services for distance mentoring.

(c) Many students recruited by SACEMA are indeed in need of a more solid grounding in the basics of biology and medicine and in the general philosophy underlying mathematical modelling of biological data. However, the provision of a wide variety of focussed short courses in biology and mathematics is not feasible with current staff and funding. What is required is much broader-based teaching support from an established institute of higher learning. In this regard it is encouraging to note that, when the Review was discussed at the March meeting of the SACEMA Management Board there was a very positive response from the University of Stellenbosch, which has recognised the need to provide sound

epidemiological training in South Africa. The Vice Rector for Research and the Dean of Sciences lent their weight to the idea of establishing a Graduate School of Epidemiological Modelling at the University of Stellenbosch. Such a school will have a positive impact on SACEMA in terms of training and capacity development as students will be exposed to expertise in Mathematics, Statistics, Biology, Medicine, etc. It will also assist SACEMA in attracting more South African students into the mathematical modelling of diseases. Meetings are being set up to discuss the practical issues involved in putting this idea into real effect.

(d) Offering internships to high school and undergraduate students will be investigated through existing national structures, e.g. The South African Mathematics Foundation.

At the time when these issues were being discussed, I was approached by the Director with regard to coming to SACEMA to evaluate the whole training enterprise and assist with giving direction in capacity-building. It was ultimately agreed that I would attend the AIMS/DIMACS Clinic on Meaningful Modelling of Biological Data (hereinafter referred to as the AIMS Clinic, or MMBD Clinic) for the week beginning 11 May, and then spend three weeks in Stellenbosch, with visits to the University of KwaZulu-Natal (UKZN) in Durban and the University of the Witwatersrand (WITS) in Johannesburg.

Purpose of consultancy

Within the parameters of my stay outlined in the previous paragraph, I was given complete freedom to pursue my enquiries, and enjoyed the willing cooperation of SACEMA staff, students and associates. My brief was simply to observe and assess both the training Clinic at AIMS and the daily working life of SACEMA students, talk to whomsoever I wished: staff, students, supervisors, researchers, associates, board-members and stake-holders, and at the end to report on the current state and propose future directions for SACEMA's training activities, with regard to the first of its mission statement objectives:

Developing the necessary human capacity and infrastructure to advance epidemiological modelling and analysis;

and the second of the NRF Review's key performance areas :

Education and Training – capacity building through masters and doctoral programmes, post-doctoral support, etc.

Modus operandi and acknowledgements

Background documents helpfully provided by the SACEMA Director Prof John Hargrove and the Research Manager Ms Lynnemore Scheepers included the NRF Review and the SACEMA Management Response, and lists of SACEMA staff, current students (with their institutions, supervisors and projects), past students who have completed studies, participants in the AIMS Clinic, SACEMA research areas and publications, submitted publications, and conference presentations. An exercise to compile, check and up-date all email addresses and telephone numbers was undertaken with the Research Manager, to whom I acknowledge my indebtedness for her help.

In addition to attending and observing the sessions of the AIMS/DIMACS Clinic, some twenty people were interviewed fairly informally at the Clinic during the first week. In the subsequent

three weeks thirty-six people associated with SACEMA were interviewed more formally, and at greater length (often an hour or more). In particular, twenty SACEMA students discussed with me their backgrounds and goals, personal experiences and professional training. At Stellenbosch these discussions usually took place outside, if the weather was good, in the very congenial and relaxed garden setting of the Stellenbosch Institute for Advanced Study, where privacy and complete confidentiality could be preserved. In between I was able to informally observe students at work and interacting, discussing their work with peers or supervisors, and I attended a couple of seminar presentations.

I visited the Stellenbosch Mathematics Department and talked with Prof. Ingrid Rewitzky, Head of Division, Mathematics, who has played a vital role in launching the Biomathematics initiative at Stellenbosch. The Director and I had lunch with the Vice Rector for Research, the Dean of Science and the Deputy Dean (Research) of the Faculty of Health Sciences and Head of Clinical Epidemiology. I was able to spend time with Dr Brian Williams before he flew back to Geneva, and to accompany him and the Director on an informal tour of the Kayamandi Township, assessing it for possible involvement in community health survey and other projects, in association with the Desmond Tutu Centres. Dr Alex Welte visited briefly and found time amidst a hectic schedule to discuss many things with me over lunch. Dr Jeremy Lauer of WHO, associated with SACEMA as a CIDA project consultant, passed through for a few days and gave me some valuable time. I take this opportunity to express my thanks for the warm hospitality of AIMS and SACEMA, and their Directors Fritz Hahne and John Hargrove, and also for the generosity of all those who gave me their time and shared their experiences and expertise.

In the final week I visited SACEMA's other "hubs", with travel and accommodation ably organised by the Administrative Officer, Ms Natalie Roman, to whom I am grateful. I travelled first to Durban and spent a full day interviewing five students and five supervisors. This included Prof. Glenda Matthews, who efficiently organized the timetable and spent much of her day ushering and introducing people to me. Prof. Delia North, Head of the School of Statistics and Actuarial Science (SSAS), kindly provided a comfortable room for interviewing, and others in the Department were very welcoming, even to baking excellent cakes for tea-time. I was glad to able to discuss a number of issues at some length on the phone with Prof Salim Karim, Pro-VC (Research) and Director of CAPRISA. And I was delighted to meet four old students, colleagues and friends, from the University of Zimbabwe, convened in the tea-room after lunch. Both Glenda and Delia were extremely hospitable and went out of their way to meet and entertain me on the first evening (the finest of fish, appropriately, in a memorable restaurant overlooking the yacht-basin), give me lunch, and get me through atrocious traffic conditions back to the airport. Again I record here my gratitude to them, their colleagues, and all those who gave time and communicated their ideas and feelings in interview.

Another day was spent in Johannesburg, in the School of Computational and Applied Mathematics at Wits, interviewing four students and two supervisors: Dr. Alex Welte (with whom I had already talked in Stellenbosch) and Prof. David Sherwell, who, with the warm assistance of Ms Dorinda Bowes, kindly organized a room for me, fully supplied with tea, coffee and biscuits, and took me to lunch, together with Alex Welte, doctoral student Tom McWalter, and an old student, friend and colleague of mine, Dr.Temba Shonhiwa, from Mathematics. It was fortunate, in one sense, that a number of students and supervisors were unavailable, as time with each would have been much shorter. I have since been able to obtain written responses from some of these. My timetable was ably organized by Edmore Marinda of the School of Public Health at WITS, and I once more take this opportunity to thank him, Dorinda Bowes and David Sherwell for their assistance and hospitality, as well as all who gave of their time and their thoughts in interviews.

Part 1 of this report will focus on the AIMS/DIMACS Clinic, assess its effectiveness and draw lessons for future training exercises. Appendix 1 collects some retrospective verbal comments

on the Clinic from the interviews with SACEMA students. A Questionnaire was sent to all student participants of the Clinic, on many aspects of their training histories and experiences, including the Clinic. Ten responded in some detail. Question 3 focussed on the Clinic, and the responses are collected in Appendix 2, which includes their responses to Questions 1 & 2 on goals and backgrounds to help interpret their views in context.

Part 2 of this report will widen the scope to SACEMA's training and capacity building as a whole. Responses to the wider scope of Questions 4—7 of the Questionnaire are collected in Appendix 3. Appendix 4 lists people interviewed while Appendix 5 contains, as a case study in coursework for modelling, details and evaluations of the regional Masters Programme in Mathematical Modelling that was successfully run for a decade 1995—2007 at the University of Zimbabwe. The remaining Appendices 6, 7 and 8 contain transcripts (confidential, and not to be taken as verbatim) written up after interviews.

PART 1: Report on the AIMS/DIMACS Clinic on *Meaningful Modelling of Biological Data*

Organization and style

I found the "welcome pack" symbolic of the overall style of the workshop – a pad of blank paper and a pen … The openness and flexibility of the programme ("on the website, but might change anytime"), combined with the constant injunction to "think about the data", was impressive and conducive to creative thought and fruitful, reflective interaction. The students certainly appreciated the thrust of the clinic, well-expressed by the title, and they unanimously welcomed the opportunity to "think together about real data", and "play around with real data", in ways many said they had never previously experienced.

The flexibility placed a burden on Juliet Pulliam in particular, as coordinator and master-of-ceremonies, for some discipline is always required. But I think she managed her challenging task admirably, and only one person seemed to think there could have been less time-watching and control. A student accolade:

"Julie was amazing and I was very impressed by how easily she adjusted to continually changing conditions…"

Although regret was expressed by some that the large upstairs computer laboratory was not accessible, it seemed to me that the venue, with its accessibility to coffee, dining-hall, lounge, and specially-placed computers, worked ideally for the number of people, which itself seemed ideal for the kind of close interaction the workshop aimed at. (No impersonal tiered lecture-theatre; no elusive rooms separated by long corridors.)

Most people dispensed with name-tags very quickly, to my dismay, especially as there was a large community of AIMS students at meals to confuse my memory! One or two people expressed the wish that a list of participants had been issued; I was glad to have one sent to me in advance by Lynnemore Scheepers, Research Manager at SACEMA, and found it invaluable.

Group dynamics

I thought (and students generally agreed) that the mentors (or faculty) were accessible, approachable, encouraging and often inspirational. Sometimes (for me who started knowing almost nobody) it was hard to tell who was mentor and who was student. This was a positive feature of the learning community, assisted by the fact (possibly designed?) that some of the "students" invited from elsewhere in Africa and from the US were more mature. A number of students have expressed a desire to sustain the relationships and budding collaborations that were built up during the clinic, and suggested that old and new participants might be fruitfully combined at subsequent Clinics/Workshops. One person commented sadly that the first DIMACS Workshop attracted some African-American students who have not returned. Some helpful selection criteria for future invitations should emerge from this report.

Generally the students appeared to be highly motivated, and they interacted well, with a few exceptions. The group-work around computers was particularly productive, especially where this brought US and African students together, for the backgrounds and skills were often quite

different. While the groups were not designated in advance, there was some encouragement by mentors to resist natural groupings of like-minded students with similar backgrounds. Where groups were well-mixed, this paid off handsomely, and participants expressed mutual appreciation. Some felt they learned more this way than in any other aspect of the workshop. Some expressed regret that they did not get to know others well enough during the week to be sure of sustaining active collaboration afterward. It would be good, in future planning, to find ways to encourage such mixing, in both programmed group-work and informal times. A student commented:

"Integration of the American & African students didn't happen throughout the workshop partially because of the free-for-all nature of group work and partially because of a lack of ice-breakers at the beginning."

Pedagogy

Overall, it was impressive how much of the up-front presentation proceeded by asking questions, displaying a shared understanding that the best kind of education and training, especially for young would-be researchers and modellers, is not about learning the right answers, but learning to ask the right questions, or (better), to ask *good* questions: in this case, primarily about data, but also about theory, about the philosophy of modelling, and about the human community realities behind the data. For a presenter, asking well-timed and nicely-judged questions is an excellent way of ensuring that the answer, when it comes, is highly valued, remembered and internalised. But this naturally devours time. There were occasions in this clinic when presenters showed some frustration at the silence following a question, and certainly the responders tended to be the same people. This will always be the case by the nature of things, but some solutions to bear in mind for the future are:

(1) Build the silence in, so that everyone is aware that they are being given time to think, not merely wait for an answer from someone else. This also allows freedom for different cultural styles to operate. Here is useful advice from someone skilled in inter-cultural communications:

"*If you are chairing a meeting and you want to stop [those from one culture, or gender, or those with more individualistic or aggressive style] from dominating and give [those from another culture, or gender, or style with different norms of group-interaction] an opening,, the trick is to slow everything right down and deliberately create silences and spaces within which [those of the second group] feel more comfortable about talking and expressing themselves*."

(2) Place the participants in groups at the start – preferably at different tables, and designate (say) two minutes for group discussion followed by brief report-back. This helps to draw out contributions from people sympathetic to a more consensual style of debate. The extra time involved will usually be amply rewarded.

"If people are in groups and we can try to create some kind of group identity then the less confident ones may be more likely to express themselves. It probably depends on allocating people to the groups rather carefully."

Appreciation was expressed by many students of the way the SACEMA Director, John Hargrove, set the tone of the clinic in his two presentations opening the first two days, and introduced the main issues:

"What I enjoyed most was John setting the tone by insisting on relevance to reality, and meaningful grappling with real data."

John emphasised aiming at simple but "meaningful modelling," using more data and less parameters, seeking insight into "what's really going on here." He did it again later with a fresh "midnight" insight communicated the following morning, giving a feel for doing lively, cutting-edge research by fresh, community-sensitive, data-driven thinking. Brian Williams continued the development of this theme. Bringing his vast experience and his own inimitable and inspirational style of provocative questioning, he succeeded in arousing animated discussion on a number of occasions, insisting on people thinking in fresh and bold ways. His gift for turning formal presentation into informal, almost Socratic, interaction is a model to be emulated at all levels of training.

Other mentors contributed in this way, notably Steve Bellan, and Jonathan Dushoff. It is an open secret of successful research and learning communities that such people, even when not actually presenting, can change the learning atmosphere and invigorate discussion, by sitting in the audience, interjecting apt remarks and asking challenging questions. This informal style of mentoring – the mentor as role-model and catalyst for thinking critically and creatively – is of enormous value, and such mentors are to be sought, courted and cherished. Conferences and training clinics should, in their planning, place as much value on the quality of mentor-in-the-audience as on the quality of presenters.

It was one of the strengths of the workshop that students were expected, and given time, to apply the ideas presented to real data in pre-prepared spreadsheets. Brian Williams was also, I understand, largely responsible for the huge amount of work put into these. This group-work with spreadsheets was universally acclaimed by students as enormously eye-opening – many had never done anything like it before: actually "playing with parameters to see what happens to the fit, hence which parameters do what, and which may be ignored, which are most significant." (I confess to feeling some surprise that this was new to so many, as this seems to me central to what "modelling" is about, given the technology. But perhaps I underestimate the difficulties of incorporating this effectively into training.) At any rate, similar resources (even the same ones, until new data can be incorporated) will be essential for future training exercises. Such detailed interactive resources are naturally time-consuming to prepare in advance, but should be integrated into training at all levels.

A common response from students during the Clinic was: "I have learnt to look at data in a new way!" "This is the first time I feel I have seen what modelling really means!" A later written comment from a US student:

This workshop in my opinion did it the right way... theory and formal lectures on how to do certain things, followed with hands-on practice. I don't think you can really learn something unless you do it for yourself.

The presentations of more technical issues, such as statistics and differential equations, had mixed receptions. This was largely due to the great differences in background of the students. While talks were mostly well-paced and the key ideas well-explained, presenters were often unsure about what they could assume and what pace was appropriate, with such a diverse group. Broadly speaking, the American students were stronger in statistics and the African students were stronger in mathematics. There was also a diversity of experience with different software programmes. On this, however, most students agreed that it was to their benefit to learn to work with alternative programmes, and to appreciate their relative merits. They also generally agreed that it was not too difficult to make the transition to an equivalent programme.

One solution to addressing the diversity would be to divide into parallel sections on occasion, offering students the chance to study areas of weakness. The value of this would depend on helping each student in advance to assess their needs and be clear about the levels of training expected and offered.

There is another possible solution. Some of the technical background needed for a training clinic could be collected beforehand in a short written course, with practical examples and helpful references and links, and sent to students for pre-clinic preparation. Alternatively, a pre-clinic structured coursework week might be mounted. This would make more time, in the clinic itself, with all mentors present, for what cannot be pre-packaged, and was by far the most valuable aspect of this clinic – the live interactions with inspirational mentors, and the group-work with peers. As a student put it:

"The first one week program can be run with one or two mentors to guide students and introduce the basic tools of the Clinic like programming, data, basic statistics. So the second week can be lots of discussion and presentations where all the mentors will join us…"

The diversity of people in this clinic may have been challenging for presenters, but it remains a thing to rejoice in, and I would urge that future planning incorporate diversity into invitation lists and into the structure of plenary sessions, more explicitly. The essence of meaningful modelling is its inter-disciplinary nature, which must be affirmed and celebrated. Here is a challenging suggestion from a participant: perhaps someone should prepare a talk on just that topic!

I appreciated that there was a mix of mathematicians, ecologists, statisticians, and epidemiologists. Perhaps a discussion of that outright, and how we all fit together, might have been very interesting.

Some presenters made constant and helpful use of two-dimensional graphical pictures, and bar-charts. I would suggest that more creative use of diverse kinds of visual representations and mind-maps would be good, since each distinct form can assist new insights. From my own experience, and from what students said to me during this clinic, presenters do well to prepare with an awareness that students are likely to evaluate the session with questions such as these:

What was the main goal, and the main conclusion? What was the big idea? What do I recall vividly? Did they make simple things sound difficult? Did they make exciting things seem boring? Will this training intervention change my behaviour?

The big ideas

The outstanding lessons of this clinic, cited repeatedly by students, were appropriately related to the theme: *linking* biological data to mathematical theory by an interactive *thinking* process. Indeed, these lessons are largely to do with the philosophy of modelling, which many students seemed to have encountered for the first time in a thoroughly practical form. That mathematical/statistical theoreticians and clinical data-collectors should be constantly talking seems obvious, but it clearly requires constant re-emphasis. Carefully collected and relevant data helps to design meaningful models, which in turn suggest improved data-collection methods. The interactive linking of theory and data was beautifully symbolized for students by those spreadsheets. Some of the big lessons and memorable insights are encapsulated by the following, all spoken/quoted during the clinic, by presenters or students:

"Let's try to figure out what's going on here!"

"When you have a story – when you think you know what's going on, then try to pin it down with a model!"

"When you look at data from different theoretical perspectives you *see* different things!"

"When you've got a model, what do you do to this model to address *this* question?"

"How do you know when you need to make the model more complicated?"

"Fitting data, while necessary, is not sufficient!"

"You need to be irreverent toward the data!" "Data is always dirty!"

"The most important words in science are: 'That's funny!' But sometimes the anomaly demanding an explanation can be due merely to wrong data!" How do we distinguish?

"What's really important about modelling is what's unimportant!" (That is, over-complicated models can be intractable and even irrelevant.)

"All models are wrong, but some are less wrong than others!"

"Don't underestimate the value of even the simplest model!" (as a starting-point for thinking, as a tool for thinking; for beginning to get a feel for what parameters do and what parts of a model do what , and what can be ignored).

"Use only the parameters, merited by the data, that will help address the questions!"

Einstein: "Things should be made as simple as possible, but not too simple! "

Einstein: "The object of all science is to coordinate our experiences into logical structures."

The talks and discussions about epidemiological modelling on this clinic ranged widely enough for the omission of certain factors and ideas (either in current modelling practice or just in this particular clinic) to seem apparent to this observer. I list some of these tentatively (in no way as a criticism), in case any may be considered relevant for future discussions, training exercises, or indeed for possible incorporation in epidemiological modelling!

Mobility, emigration, rape and war, as possible significant influences, as well as the less quantifiable human values (moral, ethical, cultural, religious); the politicisation of data collection and release; stratification by criteria other than age; data analysis using collection units other than countries; analysis involving different logistic functions for various interventions.

Balancing professional & personal, number-analysis & human reality

This section will express views of a more personal nature, derived from my experiences of spending a week in the (impressive and up-lifting) AIMS environment, and of being part of the (generally happy) learning community constituting the modelling clinic. Firstly, I have never before felt so strongly the importance of integrating into academic and professional training issues of personal growth. Allied to this is the second perception, that a healthy and fruitful scientific community is usually a happy human community, in which there is both diversity and unity: diversity challenges while similarity supports. Postgraduate training, research and thesis-writing can be very lonely. Challenge and support are both necessary, thus neither is sufficient. Appropriate scientific community networking is of the utmost importance for a young beginning researcher, and this must be taken into serious account in planning training programmes of all kinds. Some obvious considerations: the physical environment has a

significant effect on any scientific meeting; the opportunities to mix and get to know each other are often at least as important to participants as the formal scientific programme; doing something (anything) together helps greatly in bonding and opening people to each other. The group work on this clinic was extremely profitable; but some students felt that time for that, and indeed for getting to know each other better was too short. The dinner excursion to the Brass Bell and the drumming evening were very much appreciated; an afternoon or even a day excursion together would have been welcome too. And the hidden, longer-term scientific benefits would more than justify the outlay. One US student wrote:

"*I would have liked to have had a better plan before leaving the workshop on an active collaboration. I think this was a goal of the workshop, and I think I will probably interact with the other N. American students and faculty to do this but I don't feel that I formed any working collaboration with African students. Personally, I think we could have had a bit more social interactions near the beginning of the workshop and really throughout... I think often in successful collaborations, it's really the friendships that are formed first, then the collaboration*."

I shall frame my third and final perception as an exhortation to myself. In modelling infection in a community, it is I myself, in my full humanity, not my computer, who is trying to understand what's going on in this community, consisting of humans like me.
The *raison d'etre* of mathematical modellers was well expressed by Alfred North Whitehead, about eighty years ago:

The paradox is now fully established that the utmost abstractions are the true weapons with which to control our thought of concrete fact.

But modellers are surely part of a greater transaction, also well put by Whitehead:

Nothing is more impressive than the fact that, as mathematics drew increasingly into the upper regions of ever greater extremes of abstract thought, it returned back to earth with a corresponding growth of importance for the analysis of concrete fact.

In our engrossment with theoretical abstractions, amidst impersonal oceans of data, we must hold on somehow to our awareness of the concrete human facts we are analysing:

- numbers, aggregates, populations, are people;
- a parameter representing (say) average number of concurrent partners is an abstraction of human issues like honesty, fidelity, loyalty, fear, betrayal, love;
- "having sex" is usually about giving and receiving expressions (sincere or affected) of love;
- money figures usually represent issues of human cost;
- graphs and statistics represent human drama, pain, tragedy and triumph.

This is not merely a pious reminder of the participation of mathematical modellers in wider humanity. Human empathy inevitably has positive benefits for meaningful modelling, and this insight must be integrated into training, by internships or other forms of engagement with the physical community in the raw, and also in learning to make sense of data. I quote John Hargrove, in explaining why the number 204 in one box of a spreadsheet is greatly diminished in the next column: "If you are pregnant at fourteen, your probability of being pregnant the next year is low." That number 204 actually stands for 204 pregnant 14-year-old girls studied in Harare in 1997. In justifying his statement, John gave a graphic and compassionate description of what it might be like to be one of those pregnant fourteen-year-olds, and what they had probably gone through. And he capped this with an unconsciously theological remark: "Mercifully, we have a small number in this box here …" Out of such an awareness of the meaning of individual items of data, together with the skills necessary to interpret what is happening in the bigger pictures, are meaningful models constructed.

A student wrote after the Clinic:

"*I think modellers have to start to work with people [who] are doing empirical studies or collecting data in populations. In this sense having Brian [Williams] and John Hargrove come for a few days was important to me, because it helped me stop looking at the data sets as abstract quantities that we were just working with, and start to appreciate were they came from and what it really represented and the difficulties associated with getting the data*."

Conclusion

It is clear to me that this Clinic was a resounding success from almost everybody's point of view, achieving its objectives and living up to its provocative title. There are lessons to be learnt and things to improve on, but there is no doubt that this is a model for the kind of training that will make all the difference to currently perceived deficiencies in modelling training. After the Clinic, I spent three weeks interviewing a wider caucus of SACEMA (epidemiological modelling) students at different levels, asking questions concerning their histories and needs and their opinions on appropriate training initiatives; the general response from those who had attended this Clinic, and those who had heard of it, was: "That is exactly what students need!"

PART 2: SACEMA Training & Capacity Building

State of health of the SACEMA community

Overall, my perceptions on the quality of training going on right now are not inconsistent with the Report of the NRF Review (which needs to be more widely and carefully read within the SACEMA community as well as by associates, stakeholders and funding agencies). SACEMA has been launched well, and is sailing with dignity and grace amidst some rough seas. The research output is healthy, the current students are impressive, and both they and their supervisors are largely content with their progress. But, from a longer perspective, there are grounds for deep concern about ever-present dangers of narrowness and irrelevance, in a field that must persistently strive for multi-disciplinary breadth, theory engaging with real data, mathematics engaging with biology. If SACEMA is to live up to its vision and its promise, the linked issues of staffing and training for the immediate future must be urgently addressed.

Coming as an outsider to the SACEMA community I lived within its embrace for four weeks, 11 May—5 June, and talked with staff, MSc students, PhD students, postdocs, supervisors, researchers and associates, first at AIMS in Muizenburg for six days, and thereafter based in Stellenbosch, taking a full day each in Durban and in Johannesburg. I give here my impressions, based on the experiences of this month, of the quality of life and work in the community, insofar as they relate to training. (That is, I do not presume to speak of the quality and direction of research *per se*.)

The Director, John Hargrove, is widely respected and appreciated as giving effective research leadership and institutional management, as well as presiding with great personal warmth over the SACEMA "family". A number of senior people with inside knowledge of SACEMA's history and activities described him as doing a great job against enormous odds. He has far too much for one person to do; specifically, in addition to the burdens of day-to-day institutional and research leadership, he is required to take responsibility for planning, funding and recruitment, as well as oversee the important training aspect of SACEMA. A successor will be hard to find, and the aim must be to back up the Director with a leadership team.

However, the current staff members are of high quality, and rapport is extremely good. Natalie Roman, the Administrative Officer, efficiently and cheerfully organized my remuneration and my travels, especially the intensive itinerary to interview in Durban and Johannesburg, with minimal hitches. The new Research Manager, Lynnemore Scheepers, is rapidly finding her way around the complexities, and has her finger on many pulses; she was extremely helpful to me, and is enthusiastic about creative ideas for targeted recruitment, and enhanced training initiatives. Both Lynnemore and Natalie are, however, required to do many things that a Secretary could ideally do, and, should one be added to the establishment, they could each be freed up to do more things commensurate with their qualifications and skills, especially the substantial additional work I will be urging in this report in connection with enhanced training and mentoring.

I was struck by the excellence of the senior team-members. Both Dr Alex Welte (part-time) and Dr Rachid Ouifki are impressive as Research Fellows, giving valued support to the Director and (by their students' accounts) excellent supervision. The recently appointment of Ms Nelly Biondi will bring great benefits to the community, as she is a well-trained member of that rare and valuable species: health economist. Health economics is essential for monitoring cost-effectiveness of projects, and comparing alternative strategies and proposals.

The quality of the students is also generally high. There are two postdocs: Dr Simon Childs (on the basis of a seminar I was able to attend) is doing research of high potential value; Dr Farai Nyabadza, while writing and publishing at a good rate, is appreciated by students as a willing and helpful supervisor, and was frequently to be seen in intense conversation with one of his three research students. The Centre in Stellenbosch has a very good working atmosphere, and an overall sense of happy community. A newcomer says "SACEMA is a very happy and productive environment," and a student from UKZN visiting SACEMA for Research Day says that the students in Stellenbosch appeared "so comfortable and cosy." Another student with wide experience loves the working environment and atmosphere, and the interaction with others: "You look forward to going to work at your desk, and you get a happy feeling when you arrive." I was aware, on an average day at the Centre, of some fruitful interactions between students, and also of animated discussions with resident mentors, or with inspirational visitors such as Brian Williams. Generally, the working environment and student-supervisor relationships seem to be happy and productive for the students at UKZN and Wits too.

Some common themes from my interviewing are the following:

The original inspiration for a career in mathematics/biology/statistics/modeling was often a teacher, sometimes a parent; once it was the influence of a train-driver father who enjoyed mathematics and managed to communicate this to his children. For one person, the experience of a baby with malaria was significant. Some came to love mathematics later, finding inspiration in a particular undergraduate course or project. Many cited the needs of their home countries: malaria in Tanzania, polio and leprosy in Nigeria…

Goals: "*Work in a research community* [usually in public health] *on community-based projects with the promise of achieving real change." "Build a Home-team in modelling!' "Contribute to my country and to Africa, to give back the gift I have been given, to teach them and make them realise that they can do more with their lives and also accomplish more."* Some students see their goal in limited, immediate terms only: *"Get my degree!"* Some leadership is needed in provoking students to ask challenging questions: What are the current burning topics worthy of investigation and investment?

Most students speak highly of their supervisors: *"He/she is a wonderful supervisor;" "She/he is a very good supervisor, giving you time, encouraging you to think for yourself, willing to discuss things with you."*

On the negative side: *"There are too few senior mentors with time to give." "I thought that going to SACEMA would help with mathematics skills, but a lot of the maths going on is not very relevant to me."* Some students (especially PhD students) would like to be kept aware of and involved more in management concerns. *"It would be great to have the chance to be actively involved in strategic thinking, solving the problems, contributing to shaping the nature of SACEMA". "We see things when they are implemented."*

The big problems for the immediate future

The staffing and training problems are inseparably linked, and the staffing situation at SACEMA is therefore crucial for rounded and well-mentored future training. A number of SACEMA associates agreed that the biggest problem is the missing "middle-age" senior cadre. Appointments of suitably experienced mentors and researchers to senior posts have proved extremely hard to make. This has to be seen in context.

"Training in epidemiology is in a desperate situation throughout the world," says Brian Williams, backing this statement up with shocking statistics on the two-thousand strong army

of people working for a major global health organization: only a handful know much statistics, and even fewer can be called real epidemiologists.

Margaret Ward (SACEMA Research Manager 2006—2008) states the problems very well, and points to ways to solve or at least ameliorate them:

"The teaching capacity in this area is a great problem in South Africa, and creating training opportunities is therefore very difficult for SACEMA. Similarly, the staffing situation at SACEMA is also impacted as there are hardly any qualified and experienced people to draw on locally. The only option is to draw on international skills and create some kind of efficient transfer mechanism to contribute to building up reasonable capacity in mathematical epidemiology in this country. The DIMACS interaction is one such successful way of doing this, but perhaps more is needed, and a full-time training post at SACEMA would be a great start to this. In addition, there is a lot of work to be done in sustaining that transfer of skills and translating it into a critical mass of local skills, and would need the dedicated attention of someone to create a local community of modellers through creating student and academic interest in the area. If SACEMA could employ someone to run the training initiatives but also the outreach component and be involved in the activities of the off-site hubs, that would be great."

A second major problem, recognized by most students and supervisors, impinges on the problem of staffing. This is the need for structured and targeted coursework, both for initiation to biological modelling, computing skills and research methods, in the light of the diverse backgrounds of incoming SACEMA students, and also for building the wider base of skills desirable for genuinely multi-disciplinary training.

There are serious gulfs in the health sciences generally, reflected institutionally in South Africa.

(a) On the one hand, mathematical modellers (gullible, big on ODEs and deterministic models, take data as simply given or else ignore it), and on the other, statisticians (playing with the data all the time with some scepticism – but often not enough scepticism, little idea of underlying mechanisms, think stochastic DEs are the way forward). The seriousness of this gulf is aggravated by the fact that some data is simply too little to say anything and some is quite untrustworthy.

(b) On the one hand, mathematicians/statisticians (hard, quantitative scientists, fixated on theory), and on the other, biologists, clinicians and health professionals (soft, qualitative scientists) who have no idea whether their strategies and proposals are statistically justified or valid according to best models.

(c) On the one hand, health economists (practical, hard-headed), and on the other, everyone else (little stomach for reality-checks on sustained costs or escalating costs).

Relative to these great gulfs, the old traditional polarization between two kinds of mathematicians may not look so bad (I was relieved to find myself easily accepted in the world of epidemiological modelling!) but it is there all the same:

(d) On the one side, pure mathematicians (Proofs? Re-think construction of model from scratch, don't just play with parameters! What about existence, uniqueness of solutions? Have you checked that conditions are really satisfied? How can we generalize these theorems? What else might this theory apply to?), and on the other

side, applied mathematicians (the mathematics treated as a "black box"— ready-made, all-purpose solver).

The perceptions of American students tend to confirm that these gulfs exist in the US also:

G. *I did my undergraduate training in Physics and Mathematics and am finishing my PhD in Ecology and Evolution of Infectious Diseases. My strengths are that I feel very comfortable with Math, and have a lot of experience modeling dynamical systems... however [my weakness is that] I have not integrated modeling with data, or used real data much.*

A. *As an epidemiologist/biostatistician I appreciate the value of the field, and I am interested in the application of biomathematics to public health data. However there is a gap between the mathematicians and the applied researchers that may still need to be filled. So far in my experience a team approach, including both mathematicians and epidemiologists has been the most productive.*

C. *My goal is to work in international infectious disease epidemiology with a focus on integrating field epidemiological (randomized control trials, observational studies, cohort studies) projects with mathematical modeling*

To mount a training enterprise that bridges these gulfs, and adequately reflects the richness of multi-disciplinary epidemiological studies without which meaningful modelling is impossible, is a demanding but unavoidable challenge for SACEMA. New appointments to design and oversee such an enterprise are essential. Some simple and immediate steps towards challenging students to interact with each other and broaden their training base are proposed in the section on "Building student community and mutual support." Some considerations of course-content and structure, together with a look at the logistical problems of mounting courses, appear in the section on "Coursework" below. And the need to incorporate some practical engagement with clinical, biological, and community-health projects is discussed in the section on "Internships."

Good students are rare: about four percent of applicants to SACEMA are regarded as acceptable. Outreach to both high schools and undergraduates will be of critical importance (see the section on "Outreach" below). But good students require good supervisors. There are some very promising post-docs and doctoral students, and a number of senior people I spoke to at UKZN and WITS expressed willingness to supervise or co-supervise more students. Some ideas for attracting international mentors are outlined below ("Solving the staffing/senior mentors problem"). In the short term, joint action with international individuals and groups, together with an "efficient transfer mechanism", will help towards building up local capacity in mathematical epidemiology, as the successful Rutgers/DIMACS interaction has demonstrated. But the most promising longer-term capacity-building prospects lie in the Biomathematics initiative at SU and the (still paralysed) Biostatistics initiative at UKZN, in conjunction with striving to realize the vision of a School of Epidemiology at Stellenbosch (see the relevant sections below).

Building community and student support

At Stellenbosch, there is a generally happy, productive atmosphere: *"Everyone with a problem can find help."* But for some the physical open-plan environment has its disadvantages in lack of privacy (the garden offers a partial solution in good weather!). Students based at the other universities can sometimes feel isolated.

At UKZN *"we are all friends,"* and the atmosphere in the department (SSAS) is very positive and friendly. I understand that the students I interviewed have individual offices close together; but: *"We do want to feel more a part of SACEMA."* Appreciation was generally

expressed for the SACEMA Newsletter, but some said they could get no response to "Contact-us"on-line. A doctoral student (maths and physics) said: *"I really need to talk to someone in biology, and also medicine."* A masters student said: *"It's difficult to find someone in the field"* [of multi-state modeling]; *"if I found someone I'd be willing to go and visit them for a month."*

Community life at WITS is by its nature less integrated, with widely separated departments, and big-city context. I discovered that two SACEMA students with much in common (one at CAM and one from SSAS /UKZN living of necessity in Johannesburg) did not know about each other, and I was pleased to bring about their introduction by David Sherwell. It was also pleasing to be able to put the UKZN student in touch with the local organizer of a student Journal Club in the School of Public Health.

Student interaction and opportunities to present/discuss work

Research Day(s) at SACEMA in Stellenbosch are hugely appreciated, but such opportunities occur too rarely for some students. Common student responses were: *"Interesting to see what everyone else is doing;" "It helped me to find the right people,"* [to communicate with]; *"I felt a big gap." " Some of us felt a bit intimidated on Research Day"* [biostatisticians amidst biomathematicians!] It seemed not to have crossed the minds of the statistics graduates who felt this way that the mathematically oriented students might have felt equally intimidated by the statistical sophistication of the UKZN statistics students. The inter-disciplinary nature of epidemiology must be more explicitly built into the design of Research Days, with the common understanding that everybody present is expected to feel challenged and to respond positively. The common focus and substantial intersections of the multi-disciplinary community must also be emphasised. There are, of course, creative tensions here:

"Research Days are well organized and most people get a lot out of it, but for best interaction you need more overlap in what people are doing."

Although "Research Day" has already been extended by natural demand to nearly two full days, there is much agreement that the exercise would benefit from more time (say 2 nights) and more informality, to allow for social interaction, networking and team-building. *"There should be more time to get to know others and to talk informally about each other's work."* The *"most important thing that happened"* to one student was meeting Rachid Ouifki, of whom he could ask questions in French! It is clearly very important that all supervisors are urged to attend and get more involved, both in organisation and on-the-spot mentoring, by apt questioning, challenge and encouragement.

Most students (and supervisors) responded enthusiastically (*"a wonderful idea!"*) to my suggestion of holding "Mini Research Days" at the other hubs (UKZN and WITS), and most would welcome more opportunities to present their work at departmental seminars or colloquia. This would encourage interaction between isolated students, and give more opportunities to talk about mutual problems in their work, critique/support each other, and widen their perspectives.

"It would help students who are good academically but haven't learnt how to present." "A regular 'Progress Meeting' would be good, where students can be honest and open and talk about their work." "Second year undergraduates should be invited" [as an outreach].
A senior person thinks that Mini Research Days at UKZN, WITS *"are a good idea for enhancing networking and collegiality; and the Director should make an appearance."*

One doctoral student suggested that: *"a retreat would be more useful,"* working over 3—4 days would demand commitment but *"could make a huge difference"*. Such a retreat could be

based around the question: 'Where are you struggling?' and would inevitably include some help on research methods and biostatistics.

At least two people suggested that the commitment and focus of (Mini) Research Days could be enhanced by offering prizes for best presentations, as they do at Post-graduate Research Days – now a successful annual event at both UKZN and WITS (I did not hear about anything similar at Stellenbosch). These are high-profile University events with media coverage, targeting sponsors and stakeholders. It is gratifying that SACEMA students were involved in presenting at each of the UKZN and WITS events, and in the organizing at UKZN.

Senior SACEMA associates expressed support for making more opportunities for student interaction and presentation of work. Prof Slim Karim, the Director of CAPRISA is positive about a Research Day for SACEMA students, with involvement of others too, being mounted at CAPRISA, jointly organized by CAPRISA/SSAS/SACEMA. David Sherwell has agreed that CAM could revive its Colloquia, with a special emphasis on the SACEMA students. Delia North and Glenda Matthews agreed that the Dept. of Statistics at UKZN could host regular seminars at which SACEMA students could be involved as presenters and participants.

"The SACEMA Seminar series [at Stellenbosch] *is excellent,"* providing incentives to *"improve presentation skills,"* and also a challenge *"to explain what you are doing and how you are thinking."*

The majority of students were positive about the prospect of (say) bi-weekly, informal, student-run Journal Clubs, for sharing difficulties, commissioning literature reviews or short presentations, etc. One student stated that CAPRISA and SSAS at UKZN "*had a successful [joint] Journal Club, basically in biostatistics,"* and offered to help to get one started again: *"It helps you not to be narrowed down too much."* Another said, of participation in such a club: *"I learnt not to just take published papers for fact! You have to also read the reviews and citations…"* Such a club would provide support and comfort*: "I felt overwhelmed at the beginning of my research—there were just too many papers to read."*

Cooperative working groups

There was a good deal of common ground here in what people said in interview.

[Experienced observer:] MSc students at SACEMA are mostly not well prepared, and they are uncoordinated, often working in isolation. *"It would be good for them to be working in groups on related themes, and ideally focussed on projects."*
[Supervisor/researcher:] *"It would be good for students to work in groups as teams around common projects."*
[Doctoral student:] *"It will be nice if [incoming masters students] are given group or individual projects to work on before engaging in their own personal research."*
[A masters student] likes the idea of cooperative grouping of MSc students, *"working in similar areas and (depending on nature of research) focused on a project involving a real community,"* from which data could be collected to support (or not) the theorising. At present students might simply take data from on-line sources such as WHO, and some confess to an uncomfortable ignorance about where those numbers come from and how to reckon with confidence intervals, etc..
[A masters student] responds enthusiastically that a project (especially a locally based hands-on data-collecting one, at, say, Kayamandi just outside Stellenbosch) would greatly enrich the MSc experience generally, and is eloquent about wanting to *"do the data-collecting myself.''*

The idea of involvement in a community such as Kayamandi as a pilot project for masters students to get hands-on experience of data-collection, demographic and health surveys, and to

work together on something in common, was strongly approved by Brian Williams, who outlined a possible strategy. Start immediately, getting MSc students involved in the community, using churches, clinics, and other contacts (such as musicians in the community). Within two to three months employ someone like Dirk Taljaard (Owner of Progressus, a research organization specialising in expertise requests) to run a systematic Community Health Survey (health status, demographic information, etc.) and have the MSc students integrated into it. Even if this doesn't lead to a funded Big Project, or mesh with what people like the Desmond Tutu centres are already doing, the experience and the data will be excellent for students.

If such involvement in the community did lead in the direction of a hoped-for Big Project, then application for funding would be made, and two people at SACEMA would be appointed – one to give intellectual direction, one to supervise on the ground. The training benefits that would accrue are immense. Perhaps something similar or on a smaller scale might usefully be mounted at UKZN and WITS, by identifying existing projects (or creating new projects) nearby, in which masters students could be involved.

One (more mature) doctoral student suggested that SACEMA should group into working sub-units. Some ideas "off the top of his head": a BED group, a stochastic model group, a micro-modelling group, a macro-modelling group. This would avoid situations of duplicated effort and wasted time, like two students searching for and downloading the same pdf file, which he had experienced. This would clearly facilitate communication, and help people keep up to date more efficiently with recent literature. If students start with diverging topics, it is hard to get together later and lots of opportunities for sharing common research and modelling problems are lost. Smaller units and common agendas are better for fruitful interaction between students, although one needs to seek constantly a balance between cooperative work and individual effort and initiative.

Library, data-base, literature pool, model templates

It is an important part of research training to learn how to source, read, criticize and cite literature, both on-line and in other forms. And in epidemiology, this must be extended to learning about access to data and the use, analysis and classification of data. This section brings together ideas for improving training efficiency in these respects.

A number of students at the Stellenbosch Centre voiced the need for better access to books, and urged the development of a SACEMA library. (Students have apparently been requested in the past for their suggestions for books, but nothing seems to have happened. Yet another symptom of understaffing?) The distance to the SU Library and the limited availability of relevant books meant much time could be wasted. There were mixed views on the efficiency of the inter-library loan system. Nobody at UKZN or WITS expressed concerns to me, but everybody would benefit from a central SACEMA stock of books, carefully selected, well-catalogued and available for loan, especially in view of the multi-disciplinary nature of the field, and the need to discourage narrow student development. The Library should also include as wide a range of student projects and theses as possible, as guidelines and models: *"I think access to past MSc theses is useful."*

Three related developments also seem advisable, adequately represented by the following pleas from researchers and students (and also obviously impinging on staffing!):

1. Central data-base. *"We need a Data Manager – a researcher who has particular responsibility to compile databases."*

2. Literature pool. *"SACEMA could store pdfs in a folder on its server, so anyone can post a good one for sharing with others."*

3. Model templates. *"There is huge potential for improving efficiency in dealing with ODEs, and the same could apply to stochastic DEs."* Possibly three-quarters of students at SACEMA use ODE models, and *"although it is a good thing to see how it comes from scratch"*, yet *"I think that with regard to scientific output it would make sense to work toward some sort of template, or root-model, from which people can start, and adjust it for their purposes."*

Access to data for meaningful modelling

The following paraphrases and distils what was said to me by a number of researchers/ supervisors:

"Access to data is a crucial issue; we need a whole new approach to the problem of persuading clinicians and public health people to make their data available for analysis. People with data will cheerfully give it to anyone who will promise to produce a published paper with their names on it, in a short time. So a high-powered team from, say, Imperial College, London, has access to South African data that SA researchers and modellers would love to have. Recruiting Statistics people into modelling in SA is impossible, but without Biostatisticians on modelling teams, we are not going to be offered data."

Interviewees told me many stories of trouble getting access to data. "Getting that data out of the clinic was a struggle." One student is "battling to find genetic data". The "big problem" in another student's MSc was access to data. "I did lots of emailing, most didn't reply, some refused… HIV people are not nice to students!" Another student's research has been held up for six months by issues concerning ethics of data release, involving the Ethics Committee at UKZN.

Clearly there is conflict between ideals (*"I want to base my modelling on data I have participated in collecting"*) and realities (*"Big projects are highly risky, and exact a terrible toll"*). Having no first-hand experience, I can only tentatively suggest that there should be a four-pronged approach to accessing relevant data:

1. involving students in collection of their own data, in manageable small projects, or while on an internship at a hospital or clinic;
2. sourcing, storing and cataloguing as much available (public domain) on-line data as possible in a SACEMA data-base (see previous section);
3. high-level approaches to project-managers and data-bank managers with careful attention to protocol, tactful use of intermediaries, clear statement of credentials and realistic promise of student benefit, national interest and/or joint publication;
4. tactical use of insiders, and strategic networking.

"My position at the office means I have access to most of the data-sets most of the time. It also means I'm responsible for managing and cleaning them which is easier said than done. My main challenges are related to poor data-capturing, and missing data."

After a protracted struggle, one student finally acquired some data through a Dr V— at a big hospital, a contact of her supervisor, who took her to meet him.

It clearly helps to have an insider on-board – a clinician, a biologist, a medical researcher. SACEMA associates in influential positions, and senior people in modelling who have built bridges to the data-collectors, are extremely valuable here. CAPRISA works hand-in-glove

with SSAS in Durban. A number of students I interviewed had found data and help with biology when they were introduced to relevant people by a supervisor with wide networks. I personally met a Doctor at the TB hospital in Worcester who said there was lots of data stored there, and continually being (reasonably carefully) collected, that to her knowledge had not been used for modelling and analysis by researchers. A Data-manager at SACEMA might be tasked to investigate similar opportunities for both data access and internship.

Supervision

Some student views from the Clinic questionnaire are helpful in assessing the importance and necessary diversity of student-supervisor relationships:

The positive:
D. *".The role of mentors can never be over emphasised; they have been my source of inspiration and encouragement all through my career."*

The negative:
C. *"I still feel like I have been meandering through my academic career without anybody shoving me in the right direction."*

The ideal supervisor:
F. *"Mentors should identify potentials in their students, show belief in them, and make an effort to develop the identified potentials to the fullest extent. They should show concern for their student's welfare and academic progress, and give relevant support to ensure that the student achieves the set academic target. They should occasionally pay purposeful visits to their students – i.e. take the initiative."*

But opposite styles can suit different students:
C. *"I have had a lot of hands-off mentors and think this been bad for my academic development. I think closer interactions with my advisors would have helped me avoid mistakes in picking unrealistic projects and anticipating problems with them."*

G. *"My PhD advisor's mentoring/advising style really works well for me. In general it is almost completely hands off, he gives us the freedom to really explore our own ideas, but his door is always open for discussion and advice. I think if a student is already motivated this style works well."*

SACEMA students mostly put accessibility high on the list of criteria for a good supervisor, and most valued some kind of balance between discipline and flexibility. A number thought a good supervisor should be "inspirational", and even "someone you'd want to be like." It was notable how positive overall both students and supervisors were about their relationship and the way projects were going.

It is clear that selecting (and negotiating with) supervisors is a very important business, involving personalities, subtle inter-disciplinary issues, inter-institutional politics, and lots of time. This cannot safely be left to students, nor can the SACEMA Director carry the whole burden, which would best be undertaken by another senior SACEMA person with special responsibility for training.

In my extensive interviewing, I was struck by the fact that, far from perceiving me as a threatening inquisitor, supervisors and students appreciated being asked how it was going. They all agreed that such an evaluation needed to happen regularly, but differed on how often, some suggesting every 3 months, some every 6 months, some once a year.

Evaluation [such as I was doing] *"would be good every six months, when you have to account for yourself,"* and *"it might be an incentive to finish earlier."*

"They may think: 'This isn't where I want to be going.' But they shouldn't keep this to themselves; they should be encouraged to speak as early as possible, before too many years pass! There must be ways of encouraging them to speak in confidence, but this should be handled very carefully, or the student will be at the receiving end, and suffer pain."

A senior associate agrees that a 6-monthly review and evaluation of students' projects, interviewing both students and supervisors (as I was doing) would be good, presenting it simply as SACEMA policy, "good managerial practise", not to imply any distrust of supervisors.

A senior associate commented: *"The idea of short-term consultants, to evaluate student progress … and advise on coursework and other needs, is important. It is very easy for students to start to fall behind, be embarrassed about admitting it, falling even further behind and so on. By the time we pick it up it is often too late. I can't think of a good name but we could have [advisors/counsellors] who would be asked to make sure that once a month they took the student out to dinner. SACEMA could pay for the dinners!"*

There were differences on the advisability/practicability of co-supervision. More than one senior associate said SACEMA might make acceptance of co-supervisors (where perceived to be beneficial) a condition of the award. Others warned that it often caused problems. Co-supervision is sometimes used, or perceived, as a "political device", and, while it is welcome as a solution to staffing problems, some people much prefer to work as single supervisor.

In the experience of one doctoral student elsewhere: *"P is a senior person with good contacts and access to data, but has about 40 students (!), and not good for methodological problems, while S is a statistician who can give time and high quality input."* Co-supervision is a good thing – it *"increases richness and strength"* of mentoring, and *"having very different people makes it work."*

A. *"Mentors and role models have been extremely helpful. I have had a variety of mentors that have served different needs."*

Dr M— says his partnership with Dr Z— is an example of the way co-supervisors can be a benefit, e.g. bringing theoretical and practical together. It can also promote interaction between different departments and institutions.

Doctoral student: *"I am exceptionally lucky that I have two very different but equally fantastic supervisors."*[An oncologist and an epidemiologist].

A supervisor is positive about benefits of co-supervision: *"Can contribute particular skills while not responsible for the entire project."*

There may be delicate issues surrounding co-supervision, but the multi-disciplinary nature of epidemiological modelling demands that this (or even team supervision with a single responsible lead supervisor) be the norm rather than the exception, and this flexibility needs to be incorporated in the training model.

Some issues on which I think SACEMA may need to formulate a clearer strategy, and designate someone to be responsible for implementation: Who puts pressure on students to widen their academic scope when they start, and to begin some truly inter-disciplinary work? It

seems that when there is need for more/different (co)-supervision the Director spends a lot of time finding/approaching appropriate people. There is need for another senior staff member to take all this on board. What guidelines does SACEMA give supervisors? (e.g., facilitating access to mentors across disciplinary boundaries, suggesting co-supervisor(s), attendance at Research Days, regular reporting or acceptance of regular evaluation, recommendation of targeted coursework, etc.)

There is at present no regular evaluation of students' progress, or formalised accounting for time spent while funded. Should there be some measure of cost-effectiveness of a student's funding, e.g. publications (especially for doctoral students), seminar/conference presentations, etc? Does funding have an absolute deadline? What rules (formal or informal) should there be for completion of project (perhaps from afar) after funding ceases to be operative? What (necessarily flexible) guidelines should there be for taking part-time/full-time employment while funded, including criteria for the job to be beneficial to research? How are students and supervisors alerted to useful events and conferences, and encouraged to attend them? How are students and supervisors alerted to impending deadlines, and encouraged to meet them? Are all supervisors requested to attend and get involved, both in organisation and on-the-spot mentoring, at Research Day?

SACEMA needs more supervisors. Three students is, by the account of some, as much as a supervisor can adequately cope with, and give quality time. Several supervisors and senior people I interviewed expressed their willingness to take on more students. There are also some experienced external people (I met one or two) willing to act as (co-)supervisor, under certain conditions, including a minimal critical mass of direct contact time, and relevance to them of the project.

Coursework, research initiation and targeted courses

Recommendation 5 of the NRF Review was: "Targeted short courses should be given to provide broad background information on biology (e.g., immunology, epidemiology and parasitology) and mathematics (e.g., dynamical systems, advanced linear algebra, computational mathematics, statistical methods and optimization). This is necessary for a successful inter-disciplinary programme…."

There are SACEMA supervisors whose views, strongly expressed, epitomize opposite views (which could be caricatured as American vs. British styles of postgraduate training). But their students are extremely positive about their mentor's style, and the moral is: different students thrive on different supervision styles, and some find it easier to "work on their own" to "fill in the gaps" and "read up the necessary theory" than others.

Students are thus also aligned on opposite sides, but with the majority feeling they would like more coursework, and many stressing the strengths of multi-disciplinary training.

C. "*The strengths of my educational career are that I've had the opportunity to see disease ecology from multiple perspectives, e.g. from that of the field biologist, the mathematical modeller, the epidemiologist, and the biostatistician. I think this has given me the skills to take an integrated approach to problems and allowed me to converse with people from multiple fields as well as appreciate how all these fields complement each other.*"

D. "*The best way to produce effective mathematical modellers of biological data, is exposing people of strong mathematical background to biological modelling …, and those with strong biological background to mathematical modelling…*"

[South African student:] *"I would like a bridging course at the beginning, linking the biology and the modelling."*

C. *"In many ways mathematical modelling is the most coherent approach to problem solving. Several different aspects of a system can be incorporated into the same analysis and lead to insight about dynamics that could not otherwise be achieved. But because it is the most coherent and all-encompassing, modellers run the risk of not knowing enough about important components or processes within the system. On the other hand, a virologist can discover basic characteristics of a virus and still be doing great work even if s/he doesn't spend anytime thinking about population level processes. Mathematicians with insufficient biological training are especially likely to make fundamental mistakes (while biologists without mathematical training won't even be able to model so they can't get that far). For that reason, I think it is extremely important that modellers also be well-rounded biologists. I don't think they need to be experts in any one field, but a basic understanding of molecular biology, microbiology, immunology, ecology & evolution are important.*

I think three or four courses in the above topics would provide a strong background for a modeller. I similarly think training in classical epidemiology would be very useful for students who want their work to be useful to the rest of the field. To engage with data in a serious way, modellers need to be able to pick important questions. It is hard to know what is important without being in touch with the rest of the public health world. And to do this requires being able to converse in their language and understand how they design studies, gather data, and generally think about the world. One or two basic epidemiology schools would serve this purpose well".

F. *"I learnt a lot in my BSc degree [majoring in statistics] although I feel it would have helped if I had some skills courses in computing."*

B. *"I think one should build a solid background in both fields, mathematics and biology, in order to create simple and effective mathematical models for solving biological questions."*

[Ugandan student of his background, paraphrased:] The maths courses were all very theoretical, ODEs and PDEs had very little application and hardly any numerical solutions and computing, so AIMS came as a necessary shock! Did a biomaths course which provided (in retrospect) a "good background", with some applications, but still very theoretical – mostly deterministic models, a few of stochastic nature. A course in dynamical systems, including non-linearity and L Functions. Probability and measure were encountered, but has "not yet" been useful. Real analysis was not liked, and not much used; but he admits that some careful analysis is essential for a maths modeller solving differential equations. There were a number of statistics courses, and he is "still clinging" to the biomathematical and biostatistical background gained there.

[UKZN MSc student:] Some CW would be greatly beneficial to Masters students, to reinforce our undergraduate studies and *"tie up loose ends"* and, *"most importantly, to get used to [biological] terms in biomathematics."* The biological part is lacking in his training, but on the other hand the biologists *"seem to do only very simple things in statistics and mathematics."*

[Another UKZN student, in contrast:] *"if you have to do things by yourself, you learn best!"* Some students can often make up for poor background on their own: *"Because of the difficulties, I learnt that I had to do it by myself – and that I can do it – whatever I want to!"*

But it remains clear that most students will be disabled from achieving their potential in epidemiological modelling without a disciplined, relevant and well-structured programme of taught modules. However, we have to reckon with a daunting diversity of incoming students,

which is natural (because of the multi-disciplinary nature of epidemiology) and unavoidable (because of the variety of countries and backgrounds).

The AIMS background

At present, and perhaps for the foreseeable future, a substantial contingent of the student intake will have done the AIMS diploma course first, and these are in a different category with regard to coursework needs. It is useful to survey the AIMS experience briefly here, via student comments:

"AIMS helped me to learn to work on my own, to read books for myself."

"AIMS helped me to fill in the gaps, and understand more of my first degree".

"The first two months at AIMS were tough" [he had to get used to the enclosed environment, *with sometimes a whole week without going out: a severe lack of 'optical nutrition!'*] But the students were "fantastic" and the *"tutors were always there for you, willing to help at any time." "The lecturers were good, but there was a lot to digest in very short time-frames, so you couldn't comprehend things fully."* [But using the reading weeks well often brought that delayed comprehension, and in the end AIMS gave him great benefits.]

The computing skills course *"made a big, big contribution." "The biomathematics course was very practical"* and gave students a much-needed start in bioinformatics. *"To be realistic, if it had not been for AIMS, the [SACEMA] MSc would have been very hard for me, and I would not have finished in the time-frame. ... AIMS is doing a good job for African students."*

The first few weeks at AIMS were traumatic – *"I cried a lot."* Lecturers expected everything to be typed, and [although the support from the IT Dept was good] there was far too little time to master the necessary skills. In the end, the most valuable course (for present MSc purposes) was the skills course in Computing. The PDEs and finite elements course was not very relevant or applicable. Dynamical systems was useful, but there was far too little biomathematics in the programme.

The first few weeks were *"very difficult"* – facing many problems, including the weather and the intense pressures. But *"the students were friendly"* and the studies *"enjoyable"* – especially the availability of discussion times with tutors and lecturers. She especially appreciated the computing skills and problem-solving courses, also the more applied courses: biomathematics, data analysis, applied physics.

"At AIMS, the skills courses were invaluable"—especially the computing, and learning Python, which was *"hard but enjoyable."* She was so *"eager"* she would *"sometimes be at the computer all day."* The mathematics courses were well-taught – in particular *"the professors would listen, and allow questions,"* unlike those at her home University, although she had to pluck up her courage to take advantage of this unexpected openness. *"At AIMS, I had to change my habits, and learn to ask questions!"*

"At AIMS the ODE's built on previous courses I had done;" real and complex analysis were *"well-taught;"* fluids was *"enjoyable, but it was for physicists, and not important for biological modelling;"* probability and stochastic things are not felt to be relevant to her MSc work, *"but maybe will be for PhD."* No optimization was done at Dar or AIMS; she doesn't think she misses it.

The biomaths course was *"nicely taught"*, and *"confirmed my desire to do postgraduate work in modelling diseases."*

Student views on MSc foundational coursework

Given the diversity of incoming SACEMA students, the requisite content and timing of such courses must inevitably differ hugely, making planning a very complex business. It is again helpful to survey some responses of current SACEMA students to the proposal of some foundational coursework for MSc students:

"There are good and bad things about that." Her own experience of self-motivated learning-as-you-need-it in her MSc work [like the traditional British doctoral student] is positive – it's *"hard but nice, but sometimes it can take a long time to grasp small concepts"*. She learnt to be self-reliant at her home university – *"for others it might be harder."* In general, an introductory "crash-programme" would be good, a month or so, or even a series of one-day courses. This might include (her ideas) such courses as biomathematics in general, how to look at data, issues of deterministic versus stochastic models, and use of statistics and stochastic processes in general, PDEs – not theoretical, but how to apply them.

"I was thrown into the deep end somewhat, at the start of my MSc — told to download papers and read them; but I only floundered for a month or so."

"I would enjoy the discipline of coursework, and would feel less isolated." "Self-taught people can have persistent bad habits," and coursework helps to develop good habits.

"Non-AIMS students do need some help with presentation skills and research methods, as well as [depending on their background] computing, statistics and an introduction to modelling biological and medical stuff."

"Reading the clinical literature was tough." "But biology is too wide – we need a mini-curriculum on fundamentals for meaningful modelling."

"Courses I would have liked … introductions to both biomaths and biostats, and also computational skills."

His exposure to medical statistics [in part-time MSc before SACEMA funded his PhD] had been an *"eye-opener"*, taking him from purely quantitative stuff to applied biology, and turning him from a *"naïve to a useful statistician."* He suggested initiation courses on biomaths, biostatistics, clinical epidemiology, research methods (how to read and research literature, optimization, immunology, virology. After that he said it makes sense for supervisors to recommend courses as needed.

"I am a clinician by training (WITS Med School) and have an MSc (Med) in Epidemiology and Biostatistics. I'm studying towards a PhD at the WITS School of Public Health. I often find coming from a clinical background helpful in the health related questions and problems we tackle. I think there are some gaps in my stats and Epi training though."

"… what I'm actually looking for is a more practical version of "These are the stats available, this is when this model is useful/limited and here's how to apply it".

"… as I deal with large observational datasets I'd love some practical training on dealing with the issues that come with observational data. In particular, things like dealing with missing data (bane of my life). The Advanced Epi course [Advanced Epidemiology Methods course organized by Matthew Fox] is by far the most useful to date."

"We need to learn how to look at data both deterministically and statistically."

"There appears to be very little formal training on the PhD programme which I think is a major problem."

An MSc student suggests six months of (say) three courses from: population dynamics; PDEs applications to modelling real data; numerical analysis; DEs – stability analysis, Lyapunov functions, etc.; biostatistics (like the AIMS Clinic)

A PhD student says the MSc was *"not such a smooth start"*, with *"new exposure"* to the biology, and *"reading the clinical literature was quite tough."* The difficulties (accepted as inevitable and natural) lay in *"integrating the complex new biological concepts into a mathematical model."*

An MSc student suggests that MSc coursework introduction should *"be modelled on the MMBD Clinic."* It might include: *"looking at data; introduction to biomathematics, an introduction to the idea of [philosophy of] modelling – how mathematical models and data interact; dealing statistically with data; research methods – how to present work, how to write a thesis."*

An MSc student recognises a big gap in coursework (especially at Research Day), and feels that a bridging course between the modelling and the biology (tissues…genetics … natural history of disease) is needed at the beginning of MSc work. SACEMA winter-schools may be one way to do it.

A PhD student thinks the most important feature should be biological background: *"BIO-mathematics,"* for *"it is hard to develop a meaningful model if you don't understand the biology ... this is still a problem for me! You get outputs .. and you struggle to interpret them, for lack of understanding of e.g. [in his case] immunological concepts ... you have to dig deep... you need to know your epidemiology!"* Definitely need a course on research methods, and some guidelines on presenting one's work. Also (for some students) computing skills, optimization, numerical analysis (*"very important"*), dynamical systems (*"most things end up non-linear"*).

A PhD student with background in medicine: *"There is a serious need for SACEMA students to have an introduction to biological concepts." "For example, one person might want to understand what made the difference between latent and active TB; another might want to understand the difference between genotype and phenotype."* Some incoming MSc students *"really don't know what the differences are between molecular, cellular and organism levels."*

Courses generally agreed to be essential for initiation

Having surveyed at some length the variety of student views on the benefits and the content of coursework, it must be said that almost all the senior people I interviewed were very positive about the need for a solid coursework foundation:

"Coursework is very useful for forcing people to broaden their horizons." "It helps to bring epidemiology and modelling together, and to bring biomedicine and modelling together." "There is a general problem of narrowness, so coursework is essential." "We really do need initiation courses for MSc students, in research methods, concepts in biology, etc."

Some senior people feel that SACEMA should dictate – make attending certain modules a condition of the award. Others go for flexibility and balance: one says he acquired his training

through the "graduate seminar model," not the "solid, regular, cookbook" coursework model, but he respects the latter, and says students need both. A senior researcher believes that

"All students need a firm foundation in quantitative methods in statistics, mathematics and epidemiology; then biological questions might be dealt with in a series of appropriate talks… Econometrics is also valuable for all."

Another would single out DEs, PDEs, (including= nonlinear, analytical and numerical methods). Another says a key module should teach epidemiological and biomedical modelling together. And this should be complemented by a hands-on project which could provide raw material for the research methodology being taught.

The SACEMA Director says:

"It has become increasingly clear to us at SACEMA that we need to engage in increased training in statistical techniques for our modellers. While they often have good mathematical skills in such fields as differential equations and linear algebra they are sorely in need of the skills required to allow them to engage with data in a meaningful practical manner – and in a way that will improve their chances thereafter of constructing richer theoretical models."

I list below a rough consensus on the basic initiation courses that would be of substantial benefit to almost all incoming students. Of course, the content could be differently organized, some titles could be different, and certain courses could be taught in combination under an umbrella title. All courses should be aligned towards that fruitful interaction between theory and data that characterizes meaningful modelling and that was well exemplified by the MMBD Clinic in May 2009.

Research Methods: including how to find resources in library/internet; how to read a research paper; how to critique a paper using reviews and citations; how to present work; how to use on-line literature resources like "PUBMED", etc.

Computational skills: including introduction to programming and relevant software (there is a major disparity here between those who have/ have not been through AIMS).

Biomathematics: a bridging course introducing mathematics majors to those "complex new biological concepts," from molecules, cells and organs, etc., to population dynamics, thus also giving statistics and biology majors a refresher course in elementary differential equations, while providing an introduction to the philosophy of mathematical modelling for all.

Biostatistics: An introduction to the essential concepts of statistical analysis of data – with examples drawn from biology. Almost all the African students struggled with the statistics components of the AIMS Clinic in May, even those who had done (mostly very theoretical) statistics in undergraduate degrees, and those who been through AIMS.

Biomedical and Epidemiological modelling: This might include the natural history of diseases, and a broad introduction to immunology, epidemiology, parasitology, as well as the history of HIV-AIDS and milestones in its treatment and understanding. The mathematics might include introductions to both deterministic and stochastic models for the spread of infectious diseases in both discrete and continuous time.

Targeted courses as need arises

Below are listed some courses that seem most likely to be relevant and fruitful in epidemiological modelling. Where one student may have never done a particular course, another student will have done a similar course already in undergraduate training. Some research projects will merit a course that seems irrelevant for other projects. But the emphasis must be on timing and healthy motivation, rather than on a narrow specialism. A course may suggest directions for research as often as the research indicates the need for a course.

More than one researcher and a doctoral student made a plea for a return to stochastic models:

"Stochastic models were neglected earlier on, because the computers were not fast enough, and so deterministic models became standard and huge, and dominated in training. Now the computers are fast enough, people have forgotten about stochastic models, and need to go back and develop them to the same degree. There is the question of whether we have enough data to merit stochastic models – the answer may have been no 20 years ago, but things have evolved tremendously since then… The ODE models may suffice for some research questions, but for other questions ODEs should be abandoned."

Mathematics/statistics:

Advanced linear algebra.
Advanced DEs, and specifically biological applications of DEs (stability analysis, non-linear equations, stochastic equations, delay equations).
Dynamical systems (with lots of biological content), population dynamics.
Numerical analysis, numerical solutions of PDEs.
Optimization.
Control theory.
Analysis and probability.
Econometrics.
Statistics (regression analysis, time series modelling, Markov and stochastic processes, and multivariate stuff)

Biology:

Microbiology, immunology, epidemiology, parasitology, virology, evolutionary biology, genetics. (This is a very tentative list; naturally there are other possibilities that I would not know about.)

A comment from a senior associate and one of the architects of SACEMA:

"One of the [early] misconceptions [in planning SACEMA] was that the biology bit was pretty easy while the maths bit was rather hard. I fear that one of the consequences of this is that we have not understood how very weak many of the African students are in some of the most basic concepts in biology: mutation, selection, fitness, the basic ideas of genetics and even just evolution. What we have ended up with are students whose maths is much better than anticipated but whose biology is much weaker."

The University of Zimbabwe Mathematical Modelling Masters Programme

Initially highly successful then throttled by the worsening political and economic climate in Zimbabwe and consequent withdrawal of funding (Norwegian NUFU Programme), this programme ran for a decade, 1995—2005, taking in students from many countries and producing some excellent modellers now seasoning the region and beyond. In the scope and depth of its coursework content it has much to recommend it as a model to follow, even if it tended to be very theoretical and weak on dealing with real-world data. There may be useful lessons to be gained from an analysis of its strengths and weaknesses. See the coursework details in Appendix 5, with retrospective evaluations by a past student and a senior facilitator, from which the following is drawn:

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"The second strength of the programme was the inclusion as core courses of the four fundamental courses in Differential Equations, Numerical Methods, Optimization and Functional Analysis & Probability," – Prof. Alastair Stewart.

The logistics of mounting courses

The MSc initiation courses could be mounted at AIMS, for all beginning SACEMA students; alternatively, they could be hosted serially by the three hub universities, thus making maximum use of expertise available at or in the vicinity of those institutions.

The occasional targeted modules would have to be planned as the need arises, using recommendations from supervisors as to the particular needs of particular current students, and keeping close watch on all modules on offer in the various universities.

Some students suggest that common coursework modules would help to create cohesion, as well as productive interaction (between say biostatisticians and biomathematicians) with widely separated students based at different universities getting to know each other while working together. They could be brought together for a week-long course (perhaps at AIMS) every three months. Many of those who experienced the MMBD Clinic at AIMS in May 2009 believe it can stand as a model for this kind of regular training.

The major practical difficulty is of course finding people to design and give the courses. Sustained cooperation with international partners in capacity-building, like Rutgers/DIMACS, is a partial solution. The most effective (perhaps the only) short-term way to utilize local resources is to tap into existing programmes in mathematics, statistics, biology, medicine, biomathematics, biostatistics, clinical epidemiology, etc. The SACEMA Research Manager, Lynnemore Scheepers was positive about the idea of keeping SACEMA students and supervisors regularly informed about courses/seminars being run in the University of Stellenbosch, in consultation with Barry Green and Ingrid Rewitsky of the Department of Mathematical Sciences. The students would then be encouraged (perhaps required by supervisors?) to attend relevant courses, possibly on a non-assignment/exam basis. SACEMA could reciprocate by involving SACEMA students in tutoring/mentoring in the biomathematics programme at SU. Similar arrangements could be made at UKZN and WITS.

Brian Williams suggests: *"Perhaps we could invite biologists who are not themselves mathematically inclined but who appreciate the need for mathematical analysis to talk to the students. They may be able to engage more effectively since they are saying: 'Here I am, a successful scientist, but what I need is people like you who can help me with the maths and stats' "*

With the longer term in mind, the way forward for mounting adequate coursework is to combine, support and build upon the two timely and vital initiatives: biomathematics at Stellenbosch/AIMS, and biostatistics at UKZN, bringing to fruition the latter (currently frozen) initiative and the idea of a Stellenbosch School of Epidemiology. I cannot emphasise too strongly that, in my opinion, it is only thus that capacity building can really take off!

Internships

Recommendation 5 of the NRF Review included this: "SACEMA should encourage its students to spend time with practicing biologists in their labs to better equip them with the biological insight they need for effective modelling."

Some student responses are given below to the question of the relevance of fieldwork or internships in their training:

A. *"Courses can include a small amount of field work. However there is no replacement for immersion and students should take breaks in their academic training to do internships or go out into the real world to work for a few years (I took 7 years between my MA and PhD)."*

B. *"Hands on experience has been invaluable to me."*

C. *"It has helped me a lot to actually be in the field collecting data and seeing all the problems that one is faced with. It is easy to think of data as an abstract thing until you are actually there seeing the patient, clinic, hospital, or national park where it's being collected. Seeing the data in the real world has made thinking statistically and mathematically about these processes a lot easier."*

C. *"… it can be quite unproductive to send someone into the field if they don't have the training to organize what they learn. For instance, I would think that sending a mathematical modeller to a hospital to learn about malaria would be unproductive unless they had adequate biological training to understand the diagnostic tests & treatments, or at least to learn what they were."*

F. *"I think [that] Physical Science education, generally, in Africa has been more for theory rather than for practice. I believe that it should be more for practice than theory. Our education should reinforce understanding and practical application, while it should be tailored towards societal needs."*

One South African student described a very negative experience of "*being put in a corner to do some boring task just to keep you busy…You need to be fully integrated into project or work of clinic/lab if internship is to be of value to you."*

Another (American) student (not included in the written questionnaire responses), began with a mathematics degree, and then (quite accidentally) spent two and a half years with the New Zealand Ministry of Health doing hands-on work related to HIV. She describes this experience as the crucial inspiration for her later career as an epidemiologist (working for a PhD in malaria) within a US School of Public Health. She also emphasizes that integration into the internship project is crucial. One of the AIMS/SU Biomaths Honours students received his initial inspiration and motivation to go for biomathematics from a project in a safari park. A Nigerian PhD student was inspired by a project in his final year, applying mathematics and statistics to study cocoa production data and pricing changes, 1967 - 1994, which developed both the interest and the courage "to aim to apply mathematics: Maths is not just for teaching!"

A PhD student describes her (ideal) situation : *"I work in the haematology/oncology clinic once a week so I still get to do some clinical work, and it's nicely focused in my area of interest."*

A senior researcher and supervisor commented thus (paraphrased):

Multi-disciplinary work is extremely challenging; it needs perpetual learning, with lots of humility and courage. When mathematics students are thrust into the "real world" of labs/clinics/communities there can be "spectacular embarrassment!" But students should be obliged to spend time in Medical Schools, clinics, etc. We have to learn to engage with the narrative of Public Health people – to know how to approach them for cooperation. We should compile a list of "basic questions" to use in such approach. There is always politics in the background, and mutual respect has to earned. The ideal is to jointly own the data – which means getting in at the developmental stage.

Other senior people agreed that: *"A hands-on project or internship can provide material for applying the research methodology being taught."*

There is no disagreement or doubt about the importance of internships or hands-on experience with biological, medical and human community realities. The difficulty is finding appropriate placements at appropriate times in each student's career, which will inevitably involve a great deal of exploration of possibilities, negotiating and planning. This cannot easily be done within current staffing constraints at SACEMA. Possible major centres for internships that came to my attention are CAPRISA in Durban, and Africa Centre, but there may be many opportunities for short-term internships in university laboratories and public health clinics and hospitals. The potential for enriching SACEMA training with internships, and the capacity of clinical experience and expertise for implementing it, will naturally be greatly improved with the establishment of the envisioned SU Graduate School of Epidemiology.

Solving the staffing/senior mentors problem

The biggest problem for SACEMA, because it is key to solving most of the other problems, is the staffing – in particular, the missing middle-age senior cadre. Why is it so hard to recruit good, experienced people? Margaret Ward asserts:

"there are hardly any qualified and experienced people to draw on locally. The only option is to draw on international skills and create some kind of efficient transfer mechanism to contribute to building up reasonable capacity in mathematical epidemiology in this country. The DIMACS interaction is one such successful way of doing this, but perhaps more is needed … There is a lot of work to be done in sustaining that transfer of skills and translating it into a critical mass of local skills …"

I propose some ways of implementing this agenda below, all of which I think may be worth the investment of some energy, although it should be recorded that some senior associates remain sceptical about efforts to attract international mentors to spend time in South Africa, suggesting that some hard players in the [northern hemisphere] career-game will dismiss it as time wasted "flirting with light-weights". It may be hard to persuade them to "take us seriously". There are also problems caused by local politics and policies on employment and work-permits. These negative perceptions are useful as guidelines on designing realistic solutions, and are not put forward as arguments against making the attempt.

1. Actively sell Sabbaticals to targeted institutions and individuals in Europe and America. SACEMA is a very congenial centre in a very attractive setting, associated with a number of prestigious universities, with connections to a number of important and ground-breaking projects. Ms Lynnemore Scheepers, the Research Manager, has expressed willingness to prepare profiles of what is wanted, and target people.

2. Target freshly retired people especially – big names who are still active, but no longer on the career treadmill. Commission influential associates of SACEMA to assist with this through their networks. Look for people who are eager to interact with bright young students who will be influential scientific leaders all over Africa, and willing to use their experience help solve big problems of the world.

3. Seek co-supervisors and mentors abroad, using high-quality students as irresistible bait, to mutual benefit. This can lead to fruitful student exchanges and institutional cooperation.

4. Actively seek to forge links with European and American groupings, on a reciprocal basis, including student/researcher exchange. The Director of AIMS, Fritz Hahne, has relevant ideas and experience, and would be a useful resource here.

5. The most important strategy for the immediate future is to sustain and build upon the highly successful joint action that has already been initiated with partners in capacity building, such as AIMS and DIMACS. Also to extend this to partnerships with a resuscitated UKZN Biostatistics Centre initiative, and with the well-launched SU Biomathematics initiative, and ultimately with the highly desirable full-flowering of this SU initiative into a SU Graduate School of Epidemiology. These partnerships, existing and potential, are so important they merit a section each below.

6. There may be other unexplored possibilities for partnerships with institutions and people elsewhere in Africa. There are now many alumni of AIMS, in Africa and elsewhere, who will be of strategic value in building such networks. One SACEMA MSc student dreams of a group of connected researchers in Tanzania, perhaps coordinated from the Institute with which she was associated. It is suggested (by SACEMA students) that there is a developing cooperation plan between a number of African countries to launch a centre for biomathematics or infectious disease modelling; cooperation with SACEMA would obvious be of mutual benefit. There is an annual 2-week programme "modelling, simulation and optimization" held at Cape Coast in Ghana, with which at least one SACEMA student has been involved. There are known biomathematicians at Makerere, and perhaps elsewhere, who have been external examiners for SACEMA. Strengthening and widening such links is desirable.

Sustained cooperation with Rutgers/DIMACS and AIMS

The NRF Review stated: "The shortage of core qualified researchers to handle the training program necessitated that SACEMA increase its efforts to foster linkages with reputable international and national institutions notably DIMACS (USA), and the African Institute of Mathematical Sciences (AIMS) at Muizenberg outside Cape Town. These collaborations have significantly helped SACEMA increase its student population base, in addition to enhancing its international profile."

Part 1 of this report, focusing on the training value of the MMBD Clinic of May 2009, concluded that this Clinic can stand as a model for the kind of training that will make all the difference to currently perceived deficiencies in modelling training. The association with

DIMACS and AIMS has been of immense value for training and must be sustained, cultivated and emulated in other such associations..

This cultivation will include holding regular clinics/workshops after the highly successful MMBD model, bringing together a diversity of students and inspirational mentors from North America and Africa, taking account of the critique, suggestions and student incorporated in Part 1 and Appendices.

The AIMS-SACEMA association is a close and fruitful one, partly because of the close working relationship between the Directors, and partly because they share a similar vision: to nurture young African talent, building up intellectual and scientific capacity in Africa with the purpose of seeking solutions to the problems of society and providing relevant answers to Governments, agencies and companies. The present Director of AIMS stresses the commonalities, and insists there is no competition – in particular with the biomathematics initiative, and the research and modelling of disease that may develop in the AIMS research Centre. AIMS is not only a place that can host SACEMA events, but is a resource for SACEMA, increasingly so as the Research Centre develops its full capacity (of perhaps thirty resident researchers at any one time). Both Directors have expressed their intention of standing down in 2010, so the relationship between AIMS and SACEMA may be threatened unless the informal flow of information is sustained as well as the formal cooperation.

Joint capacity building with UKZN in biostatistics and with SU in biomathematics

A very timely and strategically crucial proposal (first round 2006, second round 2007) was made by UKZN and the South African Medical Research Council (MRC) for an NRF Chair in Biostatistics, located at UKZN, associated with a Biostatistics Centre to be established within SSAS. This would offer an MSc in Biostatistics, enriched by exchange of students (as interns) and researchers from the University of Washington, Seattle, where the identified incumbent of the new Chair, Mary Lou Thompson, is currently based. The proposal cited the "wide and growing range of medical research activities, the majority of which have a biostatistical component", and "the major shortage of qualified mid- and senior-level research biostatisticians in South Africa."

Unfortunately the proposal seems to have fallen foul of political and personnel changes at the NRF, and funds for the initiative were frozen after initial verbal information was received by UKZN in May and August 2008, from the then CEO of NRF, that the Chair had been awarded. If this proposal, or something similar, is not fought for and redeemed, a unique opportunity for capacity-building in biostatistics will be lost, the discipline will remain critically under-developed, and vacancies are likely to remain unfilled for years at many institutions, including the Biostatistics Unit of MRC, SACEMA, and CAPRISA. It is felt by the planners of this initiative as intolerable that, at this point in South Africa's history, there are no Masters or Doctoral programmes in the country in Biostatistics. (At best, single modules may be offered at Honours or MSc level.)

With regard to the collapse of the Biostatistics Centre initiative, the Director of CAPRISA, Professor Slim Karim, affirms that he supported it strongly, and agrees it "would be wonderful for capacity-building." UKZN/CAPRISA on their own could not raise sufficient funds for Director's salary, student funding, and development of a library. No-one seems to have thought of involving SACEMA. CAPRISA also struggles to hire biostatisticians. "There is a general problem to find Fellows with interests in biostatistics, and to keep them." Professor Karim says he would hire tomorrow five biostatisticians at Masters level; and ideally would like to see between five and ten students every year, of which three could be sponsored.

Professor Jimmy Volmink, Deputy Dean (Research) in the Faculty of Health Sciences at Stellenbosch University, responds similarly in a message to the SACEMA Director, referring to the "desperate need for capacity-building in biostatistics in South Africa," and expressing "deep disappointment" in learning of the withdrawal of NRF approval. "I very much hope that biostatistics initiative at UKZN will be successful and that the benefits will soon spread to other institutions in the country and the rest of SSA."

The identified incumbent of the proposed new Chair at UKZN, Mary Lou Thompson, has communicated (in a letter addressed to Dr. Carl Lombard and copied to Prof. Delia North, who copied it to me) the welcome news that, in spite of the collapse of the Biostatistics intiative, "Bruce Weir, my head of department here at the UW, would still be prepared to bring some of the short courses from the UW's Summer Institute in Statistical Genetics (http://sisg.biostat.washington.edu/index.php?menu=schedule&location=seattle) to South Africa at some point if there were sufficient interest." Perhaps this could be followed up and developed into a sustained co-operation along the lines of that with Rutgers/DIMACS.

Biomathematics at SU begins in the second year, and this year there are five students in the final Honours year, taught partly at AIMS. Barry Green and Ingrid Rewitsky of the Department of Mathematical Sciences have worked together, and cooperated closely with AIMS, on the biomathematics initiative, and have developed a very useful network of colleagues, in Oxford, and at SU, in various departments (like biology, medicine, clinical epidemiology, etc) and so students can do projects with people on the biological side.

I did not find out how the SU and AIMS components were designed, and assume that the AIMS courses will follow the AIMS pattern of bringing in excellent lecturers, and giving substantial freedom to them. The course titles (given in Appendix 8, with my notes on interview with the five students) are perhaps inevitably vague, and the AIMS website seemed to have no details of content. The students feel that the AIMS section of the course has been rather unstructured, and would benefit from more liaison and better organization. But it has been "exciting and stimulating," and the five students say they have worked well together, so the diverse backgrounds have not mattered (SU, Northern Cape, UKZN, Venda). One researcher commented that the Biomathematics course was very general, and that it might be hard for students to move on to any of the Biomaths nodes in RSA (more technical backgrounds needed for e.g. invasion biology) or into MSc work. SACEMA is perhaps the likeliest place for them to be absorbed. It is indeed hoped that some of the Biomaths Honours students can be taken on at SACEMA. But, in this matter as in so much else, there will be enormous gains when the goal of the next section is achieved.

Pursuing the goal of a Stellenbosch Graduate School of Epidemiology

The SACEMA Management Response to the firm recommendations on training of DST/NRF Review stated bluntly that "the provision of a wide variety of focussed short courses in biology and mathematics is not feasible with current staff and funding. What is required is much broader-based teaching support from an established institute of higher learning."

Many of the most important recommendations of this present report also impinge on staffing and funding. Recommendations on three major areas: mounting multi-disciplinary coursework, integrating internships and clinical experience into training, and solving the staffing/senior mentors problem, each led inexorably to a reiteration of the strategic importance of establishing a truly multi-disciplinary Graduate School of Epidemiology (or Epidemiological Modelling) at the University of Stellenbosch.

Indeed, the University of Stellenbosch has already recognised the need to provide sound, multi-disciplinary epidemiological training that will impact on South Africa as a whole. The Vice Rector for Research and the Dean of Sciences both lent their weight to the idea of establishing such a Graduate School at the University when the report of the DST/NRF Review came out, and reiterated their support at a lunch with the SACEMA Director at which I was present. Many indicators: national interest, desperately-needed capacity building in a range of crucial disciplines, Stellenbosch University's own strategic development towards effective multi-disciplinary studies and training that will genuinely impinge on society, and the threat to sustained success of SACEMA, all combine to urge that this idea must now be pursued vigorously and put into real effect.

The (frozen) biostatistics initiative at UKZN and the (thus far highly successful) biomathematics initiative at SU/AIMS have much in common, yet it appeared to me that the two groups knew little or nothing of each other's activities. There is also much common purpose with the new and vital initiative to establish a Graduate School of Epidemiology at SU, and all three initiatives are bound up with SACEMA capacity-building. There seems to me to be great merit and strategic value, for epidemiological (and wider) capacity-building in South Africa, in bringing together the following people:

Professor Delia North of SSAS at UKZN, Dr Carl Lombard head of Biostatistics Unit of the MRC, Professor Mary Lou Thompson of the Dept of Biostatistics, University of Washington, Professors Arnold van Zyl, Eugene Cloete, Barry Green, Ingrid Rewitsky, Jimmy Volmink, and the Heads of other relevant departments at SU, and Professor Fritz Hahne of AIMS, as well as other interested parties and stakeholders (international as well as local), perhaps facilitated by the Director of SACEMA.

Outreach

The report of the NRF Review recognised the "inherent difficulty in attracting qualified South African students into mathematics" and praised the outreach initiatives already undertaken, co-sponsored or supported by SACEMA. The report urged SACEMA to "continue with its spirited efforts to attract more South African students into mathematical modelling of diseases. It should devise an effective outreach strategy, particularly targeting black students."

The current outreach initiatives are:

- an introductory course (known colloquially as the "Epi-Intro Course" among senior people, and the July "Winter School" among students), in collaboration with AIMS and CARe, for final year undergraduate and honours students;
- the AIMS/SU biomathematics degree programmes at undergraduate and graduate levels.

The Epi-Intro Course has attracted a number of good students into SACEMA. Here are some of their comments:

"The Winter School in July was inspiring"; [it was] "very mathematical, but applying ideas to the real world – nice!" Another student who went in his final year said his reaction was: *"Wow! Really nice!" "It was a good introduction, I thoroughly enjoyed it, but there was a lot packed into each day. I would have liked more tutorial time; Python was a big problem! The group assignments and case studies were good for networking."*

This outreach must clearly be continued and perhaps expanded in various ways. It is hard to meet the NRF demands on minimum student capacity and maintain the quality. It is therefore essential to attract highly talented young South Africans, widening the scope of the outreach,

targeting schools, and using the media. There is much to learn from others here (see the examples below).

Invitations to the Epi-Intro week should target schools and universities more widely and pro-actively. Offering internships to high school and under-graduate students to work on projects with SACEMA students was a recommendation from the NRF report, which is clearly a good idea. A similar idea came from a SACEMA student, here paraphrased:

"We could be involved in mentoring undergraduates at their universities – it must not be too demanding, but it would be to our own benefit to have to do some teaching, and it would inspire students to get into mathematical modelling and epidemiology."

Another SACEMA student suggests that students could go and do presentations in schools for one hour per week, to mutual benefit. Perhaps SACEMA could collaborate with the SU/AIMS Biomathematics programme in doing something similar to the SAWomEng (Woman Engineers) mentoring initiative, where they pair third-year UCT female engineering students with interested high school students.

Linke Keller (AIMS/SU Biomathematics Hons student) is eager to be involved in outreach to schools – even would like to make a career of it. Linke's vision is set out in Appendix 8. It is about encouraging students to work on projects (with wider scope than maths, but including biomathematics) with a strong emphasis on community outreach and real life problems to be solved, to enable students to grow in their social responsibility.

Ingrid Rewitsky has (in collaboration with others at SU) produced some wonderfully attractive leaflets and large posters, as well as placing advertisements in media (Die Burger, The Sarie, Mark Shuttleworth Foundation, etc.), designed to bring students into the SU/AIMS Biomathematics Honours programme. Career possibilities are listed as: "Biotechnology, pharmaceutical companies, academic and research institutions," with work involving "fundamental scientific research and/or diverse applications including: drug design, immunology and medical applications, forensics, and molecular evolution and population biology." The projects "will be supervised [jointly, as I understand it] by a researcher in biomathematics or bioinformatics and a researcher in biological or medical sciences." The course will assume "a strong foundation in mathematics and an introduction to mathematical modelling using differential equations" [presumably taught from second year at SU] and will include (amongst others) modules on: "computational and discrete methods in Biomathematics, non-linear dynamical systems in Biomathematics."

CAM at WITS has an annual lunch for 3rd year students at WITS selling its Honours programmes. And David Sherwell is very positive about the idea of mounting a "Biology and Mathematics Research Day" [his title], for 3rd year and Honours students, and "make it sound exciting."

If/when SACEMA (Mini) Research Days are held at the three hub universities, all or parts of the programme could be opened to interested undergraduates from all universities within range. An MSc student thinks we *"need both informal and formal approaches"*, and *"it's good to target third year undergrads"*. Lots of statistics students are drawn towards Financial Maths and Actuarial Science at Honours level, so we need to trumpet rival attractions.

At UKZN, one MSc student is eager to be involved in outreach. She is willing to travel to schools with Professor Delia North, who does a great deal of work with schools in connection with the national statistics initiative. The same student thinks an Information Day for undergraduates and high school students would be fruitful, with postgraduates presenting their work in statistics, maths, biology and medicine "to show how modelling brings them all together."

The Schools Enrichment Centre at AIMS (instigated by Toni Beardon) seems to be developing well now, with the appointment of a full-time ex-teacher, Barry Barnard, with a PhD in mathematics education, and positive communications with the Dept of Education. Ideally, local tutors will be used, mixed with external visitors. It seems important to link SACEMA's outreach strategy with this and with Ingrid Rewitsky's inspired publicity campaign for biomathematics, and to involve Linke Keller, with her vision and energy.

Major recommendations

1. Bring together the admirable and promising capacity-building ideas and initiatives at Stellenbosch (biomathematics) and at UKZN (biostatistics), making maximum use of established expertise and existing strengths. Prepare a joint proposal for adequate funding, emphasizing the strategic importance of a truly interdisciplinary epidemiology (and ecology) at this point in South Africa's history.

2. Simultaneously, pursue vigorously the timely vision of an integrated Graduate School of Epidemiology at Stellenbosch University, which can work with SACEMA to bring the clinical and the mathematical into sustained healthy engagement, thus providing the much-needed focus for crucial, country-wide, inter-disciplinary training needs. Funding proposals may profit by combining these first two recommendations. I suggest that a wider-based, joint proposal with multi-disciplinary coherence and hence with appeal to a variety of potential funding bodies, has the promise of enriching and combining the parallel initiatives, restoring hope for South African epidemiological capacity-building, and, in particular, resurrecting the biostatistics initiative at UKZN.

3. Appoint a Deputy Director (Training) at SACEMA, who should (ideally) be an inspirational teacher and researcher with administrative skills, tasked with over-seeing training and capacity building. Such a person would monitor and evaluate student progress and supervision, design initiation and occasional coursework modules and workshops, and coordinate the development of a body of good teaching material, including such inter-active data-fitting worksheets as were such a success at the MMBD Clinic, as well as the resources listed under the section on: "Library, data-base, literature pool, model templates." At the very least, appoint short-term consultants to evaluate student progress (perhaps every 6 months), give early-warning of problems, assist with appropriate networking, and advise on coursework and other needs.

4. Cultivate the fruitful and highly-valued association with Rutgers/DIMACS, holding regular one- to two-week workshops after the highly successful MMBD pattern, bringing together a diversity of students and inspirational mentors from Africa, North America and elsewhere, taking account of the critique and suggestions in Part 1 of this report.

5. Expand the leadership team to explicitly include PhD students. Encourage all incoming students to see, and be involved in, a strategic agenda for SACEMA: What are the targeted questions? What are the model frameworks? Which people are working on what? Who are the group leaders? With a clearer vision on its short/mid-term/long-term goals in research output, the students could be drawn into this vision and this would naturally encourage them to expand their own base and engage in a more inter-disciplinary way with the crucial questions. "It would be nice to see SACEMA as a whole, and share a common mission and vision."

6. Encourage interaction between isolated students, and more opportunities to talk about their work and critique/support each other, and widen their perspectives, by holding "Mini Research Days" in UKZN and WITS, in addition to a slightly extended annual event "Research Days" at Stellenbosch. Student-run "Journal Clubs" must also be encouraged, especially in UKZN and WITS. More CAM Colloquia and UKZN Stats Dept Seminars, relevant to and involving SACEMA students, would be of great value.

7. Offer initiation courses for MSc students, in research methods, computing skills, biomathematics, biostatistics, and biomedical and epidemiological modelling, emphasizing the biological concepts and the interactive engagement between theory and data that characterizes meaningful modelling. In cooperation with all involved universities, invite SACEMA students to attend regular modules of relevance, as advised by supervisors. Mount special intensive short courses to meet needs and encourage meaningful modelling, after the style of the MMBD Clinic.

8. Expand and build on the success of the "Epi-Intro Week" and the SU biomathematics publicity campaign in attracting good students, widening the scope of the outreach and using the media more imaginatively. Target schools with leaflets; arrange visits to schools by SACEMA students/staff; offer internships to high school and under-graduate students to work on projects; involve SACEMA students in mentoring undergraduates at their Universities.

APPENDIX 1: Retrospective oral comments on the Clinic

[in interviews with some SACEMA students]

[Geomira Sanga, Tanzanian, ex-AIMS, MSc from 2008: TB dynamics, modelling detection and delayed treatment.] The MMBD Clinic was a great experience, taught her to "think in a new way," and was "the first time to look at data in that way". Also the first time to use Excel or R [she would be familiar with Python]. The Clinic helped her to feel that the mathematics and the data were more "connected," and she hopes to develop along those lines when she does her PhD, hoping to look especially at malaria, which is a major problem in Tanzania.

[Doreen Mbabazi, Ugandan, ex-AIMS, MSc from 2008: HIV & TB.] She feels that an MSc coursework introduction could well be modelled on the MMBD Clinic. Thus it might include: looking at data; introduction to biomathematics, an introduction to the idea of (I suggested words: philosophy of) modelling – how mathematical models and data interact; dealing statistically with data; research methods (how to present work verbally, how to write a thesis).

[Joseph Ssebuliba, Ugandan, ex-AIMS, MSc at SACEMA from 2007, "Intracellular modelling and control of HIV-1 kinetics, T-lymphocyte decline and Immunosenescence;" PhD from 2009, modelling cancer host dynamics, at cellular level.] The MMBD Clinic was at first "strange for me", … "integrating an entire simple model into cells, and seeing the model pop out ... I am used to using Python and MATLAB – it took me hours to learn what was going on ... I didn't know what Excel could do ... I used R at the previous DIMACS workshop, and I still use R occasionally, but mostly Python." The Clinic helped him to recognise the need to diversify, and use more statistical tools. The theoretical content of the statistical presentations were not new to him, but these had not previously been applied, and he appreciates the need for a more statistical approach to working with data. "The first DIMACS workshop was too demanding – it was more relaxed for me this second time." And it was particularly interesting this time, with "the emphasis on data ... the feeling of understanding how modelling can capture realistic situations."

APPENDIX 2: Written responses on the Clinic, questions 1—3

Although I talked with most people at the Clinic, and tried to incorporate the overall perceptions in my report, I later sent a questionnaire to all student participants, in the belief that different and useful perceptions can be elicited by (a) informal, spontaneous, immediate, oral communication, and (b) formal, considered, retrospective, written communication. Although some felt they had nothing to add to their oral discussion with me, nearly half the students responded in writing. Below are their written responses to Question 3 of the questionnaire, and its preamble; following that, to help interpret their answers in context, are their responses to Questions 1, 2 of the questionnaire, giving their backgrounds and goals. The respondents are colour-coded to facilitate identification.

To student participants in the DIMACS/AIMS/SACEMA clinic on Meaningful Modelling of Biological Data:

I enjoyed talking with you at AIMS, and hope you have been continuing to ponder some of the questions I was asking. I would greatly appreciate your thoughtful, perhaps more detailed and more leisurely responses to the following. We need your help in planning better training programmes and mentoring styles for the future, especially for SACEMA.

Question 3. Your retrospective evaluation of the MMBD Clinic, May 2009, in the context of your professional-personal development.

(a) Overall style and emphasis

A. "I found the style excellent."

B. "It was excellent."

C. "I think that the emphasis was pretty much right on. After attending the last two AIMS/DIMACS mathematical modeling workshops in 2007 & 2008, I thought that there was a lack of connection with the data, which John spelled out pretty well during the first day of the MMBD. The only worrisome part to me was the disconnection from classical epidemiology. I think that mathematical modeling has a specific functional role in infectious disease epidemiology but it is not a catch-all for how to analyze data. I wish there had been some more of an emphasis on how simpler epidemiological analyses can be used to understand what data are saying. As for style, I think it was a little haphazard and necessarily flexible since we didn't have it planned to the T."

D. "The style was good and professional, however it was a bit technical for highest number of the African students present in the clinic."

E. "I am really positive about the AIMS clinic in general and I feel that those who are going to do an MSc in Epidemiology have to have some general and basic background to the discipline, like general epidemiology, statistics, research methods, and computational aspects for those who need."

F. "The AIMS-MMBD clinic 2009 was very good in all areas of the criteria listed in the question except that the mentoring aspect was not really emphasized during the clinic. I think it will be good, if the mentors could follow up the progress of the participants in the their various study/research and give guidance cum assistance where needed … The MBBD 2009 is another of the memorable workshops which have immensely facilitated my PhD research degree programme."

G. “This was pretty good... however the course was probably too ambitious given the variance in the ability of students.... The emphasis was on learning to meaningfully model biological data... but I felt that a number of people focused on just learning the software program R towards the end.”

H. “In my opinion, I think the MMBD clinic workshop was great. So far it is the best workshop or conference I have ever attended to, although I have only attended a few. I learnt so much from there. It changed the way I looked at epidemiology, it inspired me and it also me an idea on what I would like to do for my PhD and I can not wait to start working on that. The overall style was nice and friendly.”

I. “Well-planned, informative.”

J. “(a)-(h) of the criteria were all fine to me. For a junior student it was really an experience to be thrown in the deep end like that. It was enriching to be exposed to so many things at once.”

(b) Timetabling and organization

A. “Well done, it was nice to have the schedule for each day”

B. “They were both perfect.”

C. “See above for organization. I think we could have done a better job but were not sure what we were really doing. I think next year we will be able to organize it much better. The order of the lectures & group work didn't make perfect sense easier but again I think this will be easy to improve after doing it once.”

D. “Timetabling was loaded too much for the short period of the program.”

E. “If a two weeks program is wide specially for Mentors (because on our discussion at AIMS students have of course much more time) then the first one week program can be run with one or two mentors to guide students and introduce the basic tools of the Clinic like programming, data, basic statistics. So the second week can be lots of discussion and presentations where all the Mentors will join us. PS: every year different group of people may join so it will be a good idea for not to organise the same agenda for those who were present last time.”

G. “Organization was very good in my opinion. The timetable was very packed... I think in the future, as the lectures become more streamlined there could be more room in the timetable for just group work. Julie was amazing and I was very impressed by how easily she adjusted to continually changing conditions.”

I. “As much as most of us like working in a schedule, I liked the idea of having a variable timetable to accommodate both what has been covered, and also any situation that may arise.”

(c) Presentations

A. “Most were excellent. I especially enjoyed John Hargrove’s.”

B. “Excellent but that would be good if we could have some few lectures on the biology of the HIV disease.”

C. I take it this means lectures from the mentors? If so, I think John did a great job introducing the purpose of the workshop as well as the HIV data. I think Brian's talk on trends of various

infectious diseases was excellent and could have been given the first day (though of course he wasn't there). I think the stats lectures (including my own) could have been better planned out, but we wrote them during the workshop which is obviously not the best way to go.

D. "The presentations were fine, but with too much assumption that everybody present had enough background in statistics or non-parametric test."

G. "In general, excellent. I think Brian's and John Hargrove's presentations were enlightening and in some ways moving. All the presenters did a great job. Some of the material was a bit rough, but I thought pretty well done for the first time. It would be great to see the instructors in some way stay with the existing theme of the workshop and work to refine and clarify their existing presentations [for a future workshop]."

H. "The atmosphere there was accommodating. There was a good interaction during the presentation."

I. Were pretty good and informative although I got lost at times, I guess it was because of my level of study.

(d) Data-modelling assignments

A. "These were very good, though in the beginning it seemed some students got stuck on the basics while others took the assignments further."

B. "Great. However, it would be more interesting if students could write their own codes to fit the existing data instead of just using the one written by the mentors. I really enjoyed the use of Excel for fitting Clinical Data. That was something totally new for me. I can therefore use the same techniques to analyze other clinical data for other infectious diseases such as malaria, tuberculosis, etc…"

C. "I liked the Excel format a lot. It gave people the ability to jump right into modelling the data. The downside was the ad hoc nature of it, but as Brian showed you could publish that way. While I personally think there are much better ways to do this in R, it became pretty clear that very few people could jump right into R, even with canned code, and do something productive without running into heaps of bugs."

D. "Yes, the assignment periods were very good."

G. "I think the first assignments on using the likelihood methods was well done, as the workshop progressed however I felt the assignments were a bit vague, in fact I'm not sure we had any assignments really in the later half other than work on what we felt was interesting... In general I liked this approach, and it allowed me to get excited and explore some of my own ideas. However, some more directed assignments on the Bayesian methods and using profile likelihood would have helped me understand these ideas a bit better."

H. "The only problem is that we did not have enough time to do group work and practical work on the computer. Maybe at the next workshop we could be [shown] how they calculated the parameters used in the models, I think it is important."

I. "Very good – hands-on stuff is what I really needed. It was also good that everyone was given some kind of introduction beforehand, so everyone was at approximately the same place."

(e) Group work

A. "Same as above?" [Good, though in the beginning it seemed some students got stuck on the basics while others took the assignments further]

B. "Excellent."

C. "I think we should have done more group work. When we had small groups at the end it was very useful. It would be good to have small mentor-led groups, and cycle around, and just discuss research ideas a bit more. I also think that picking the groups ahead of time would be better than letting participants self-organize. That will make it a little more formal and also force people to interact more."

D. "It actually helped, especially when paired with somebody who had idea of what the assignment was all about."

G. "I had mixed feelings about this. In general I think it's an excellent idea, and I enjoyed my group work a lot. I learned a lot from hearing the other people's perspectives in my groups. However, I felt a bit unclear as to what my role in some of the groups was as an American student, having had experience with the programming language and some of the concepts beforehand... I was not sure how much I should be serving as a mentor in my group and helping the other African students learn the material... or how much I should just be leading the group. Again, I think in the future this can be remedied by working harder to make sure more of the students are on the same page in terms of programming experience."

I. "Mingling with everyone from everywhere with different backgrounds and fields of study was very good."

(f) Mentoring

A. "I didn't feel I received mentoring except when I sought it out, which was fine for me but maybe not for others. I thought maybe a discussion of career options would have been helpful to me and to others."

B. "Excellent."

C. "I think mentoring was a bit sub-par at this workshop partially because we spent a lot of the time planning the next day instead of talking with the students. I think it will be nicer next year when we have lectures & code pre-made."

D. "I will advise that the organizers in the future assign students to specific mentors during the workshop, whose responsibility should include guidance and mentoring the student right from the workshop till the end of his/her postgraduate studies."

F. "The mentoring aspect was not really emphasized during the clinic."

G. "I think because this was the first time this type of material was presented at the workshop, the faculty were almost always busy reorganizing and retooling presentations and lectures. Although the faculty made themselves available to any students during the group time... this is different from the faculty actively interacting with the students during the group project time. I think the faculty should always make an effort to work in the same room as the students are in during the group time... and ideally just be floating around and actively interact with each group."

I. “Good, helpful.”

(g) Communal interaction

A. “Early icebreakers would have helped me to get to know more of the students, along with names, pictures, and brief bios distributed early. Group activities were very nice and helped build relationships, including the first dinner, the drumming, and the games night “

B. “It was good but it could be much better if people were seriously introduced [to each other] at the beginning of the Clinic.”

C. “This was also sub-par as discussed at the feedback session. Integration of the American & African students didn't happen throughout the workshop partially because of the free-for-all nature of group work and partially because of a lack of ice-breakers at the beginning.”

D. “Fine.”

G. “If anything, I think there should be a bit more social activities. I made a lot of friends at this workshop, but I feel a bit pessimistic about whether any of them on the African side will actually become colleagues. I think as an American, I will probably continue to work with the other N. American students and faculty, which by itself is tremendously valuable. However, I really don't feel optimistic that I will have working collaborations with the African students... I was really hoping for this, but naturally it’s difficult.”

I. “Good everytime.”

(h) Other

A. “I appreciated that there was a mix of mathematicians, ecologists, statisticians, and epidemiologists. Perhaps a discussion of that outright and how we all fit together might have been very interesting.”

G. “I got a lot out of this workshop, I am still thinking about the concepts that were presented there and have used the workshop as a springboard to go a bit deeper on my own with certain things. In particularly the concepts about using Bayesian methods that were not that well fleshed out. In general I would hope to be able to attend this workshop again, even if it was almost the same, because I think there were some difficult concepts that I would probably be able to understand on a repeated exposure. Also, seeing many of the people again really allows you to start to cement some friendships, and make it more likely that true collaborations are formed out of this meeting.

I'm not sure what was done in earlier workshops ... but I liked the theme of this workshop and think it’s important that it continues and the lectures are refined. I think also that if this workshop continues, then more would be gained by trying to have a mix of people that are returning along with some new people, rather than all new people. I was hoping that I would be able to form more collaborative projects with some African students through this workshop. I think that a number of the faculty really deserve mention, Juliet Pulliam, Steve Bellan, and Jonathan Dushoff were outstanding. As were Brian Williams and John Hargrove on the days they were present.”

H. “My general thought is for SACEMA, AIMS, DIMACS to organize more workshops and conference like the MMBD clinic. Also it will be nice for students to go out there to know how

these data we use are collected, because it will help you to know what you want to do and how you want to do it, and even how to make your own assumption with the understanding of the data."

I. "I liked the idea of us having Juliet before the clinic to 'fill us in'." [Juliet Pulliam taught the biomathematics courses at AIMS for the five Honours students, who would have been the youngest and least experienced participants in the Clinic.]

Backgrounds and goals of respondents

Question 1: Your goals, professionally and personally – integrated (ideally).

Question 2: Your training background over your educational career to date: its strengths and weaknesses as you see them, and its highs and lows.

A. Judith Hahn. US researcher and mature student. Studying potential impact of vaccine on HCV epidemic in IDU.

1. "My professional goal is to be an epidemiologist conducting studies of infectious disease transmission and patterns that will have an impact on health outcomes. My personal/professional goal is to accomplish the former while retaining a work/life balance and enjoying the work."

2. "I have a MA in biostatistics from 1989 and a PhD in epidemiology received in 2001. It is a weakness that I did not do post-doctoral training. However I have had plenty of hands-on experience, and I am currently funded by an NIH career development award (a K01) to increase my skills in infectious disease epidemiology, with a focus on mathematical modeling. As a faculty member of University of California at San Francisco, I am required to bring in my entire salary through grants, and have succeeded in doing so for 4 years, which I consider an accomplishment."

B. Bassidy Dembele. African from Mali studying and teaching in USA. (University of Virginia?)

2. "My mathematical background was ok [for the purposes of the MMBD Clinic] but my biological background on HIV disease was not really strong."

C. Steve Bellan, US ecologist-turning-epidemiologist, mentor and PhD student working in Namibia.

1. "My goal is to work in international infectious disease epidemiology with a focus on integrating field epidemiological (randomized control trials, observational studies, cohort studies) projects with mathematical modeling. I'd like to leave academia for a few years after I finish my PhD and work in the field and on the computer for WHO, CDC, or another applied epidemiology organization. I also have a strong interest in teaching, especially internationally. I expect to teach at the university level in conjunction with research at some point in my career."
2. "I did my Bachelors degree in Ecology & Evolutionary Biology with a focus on animal behaviour but became interested in infectious disease ecology towards the end of the degree and consequently entered a PhD program in Environmental Science, Policy & Management. My dissertation research is on anthrax & scavenger ecology in Namibia with a focus on

estimating anthrax incidence from opportunistic observation of carcasses. As my interest in infectious disease epidemiology grew I concurrently completed an MPH in Epidemiology last year. The strengths of my educational career are that I've had the opportunity to see disease ecology from multiple perspectives, e.g. from that of the field biologist, the mathematical modeler, the epidemiologist, and the biostatistician. I think this has given me the skills to take an integrated approach to problems and allowed me to converse with people from multiple fields as well as appreciate how all these fields complement each other. I think the weaknesses of my training are that I have not settled in on any one major field for a long enough time to complete projects to the point of publication (though I'm working on it now). I also think that I would have benefited from seeking & receiving more extensive advice from more senior people in the fields I work in. While I am doing my dissertation research in a wildlife system now, I expect to work with humans when I finish my PhD and this discord bothers me somewhat. I enjoy the work I do now but sometimes wonder at its utility both in terms of helping society and furthering my career."

D. Kazeem Okusun, Nigerian, PhD student at SACEMA from 2009.

1. "My goals are to be relevant and contribute to knowledge in my chosen field."
2. "My high school background in the sciences has a lot of strengths in my academic pursuit afterwards. Those days many of our science teachers were Indians and Ghanians, I think this were the reasons for our strong background in sciences. (As at that time Nigeria had very few science teachers)"

E. Bewketu Teshale Bekele, Ethiopia, ex-AIMS, SACEMA MSc student from 2008.
1. Goals include working in a Research Institute on community-based projects promising to achieve positive changes to the community, and especially the communities of his homeland of Ethiopia.
2. University degree (at institute in Ethiopia) was B Ed over four years, with first year in general science, subsequent years in maths, physics and pedagogy, majoring in maths. Did not encounter PDEs, optimization, numerical analysis/computational methods, or non-linear DEs, until he got to AIMS, but did a fair amount of statistics, and did fluids in third year.

F. Tajudeen Tunde Yusuf, Nigerian.

1. "I would like to acquire as much knowledge as possible in Mathematical Biology coupled with their application to solving real life problem. In addition, I would like to contribute my quota towards the upliftment of Mathematics education as well as its understanding with a view of making it more applicable to real life endeavours and making it look more abstract in nature."
2. "My training has been very good, though with mild deficiencies in the some areas of real-life applications of some of the abstract Mathematics courses during my undergraduate classes. My two masters' degree programmes (one in Information science and the other Mathematical modelling) has made up greatly for the deficiencies in my undergraduates class while the series of workshops I have attended, where MBBD 2009 is another memorable one, have immensely facilitated my PhD research degree programme."

G. Vijay Panjeti, US student.

1. To collaborate successfully with other students as well as mentors.
2. I did my undergraduate in Physics and Mathematics and am finishing my PhD in Ecology and Evolution of infectious diseases. The strengths are that I feel very comfortable with Math, and have a lot of experience modeling dynamical systems... however I have not integrated modeling with data, or used real data much.

H. Bilkisu Abdulra'uf Bello, Nigerian, ex-AIMS, SACEMA MSc student from 2008. BSc

1. "To me a goal is the same as travelling, you know where you are going, you know when and the time you want to go and you know your destination. But setting the goal is not as important as accomplishing that goal. I don't make a life-time goal because I don't know what life has in store for me. When I make a decision on what I want to do, then I set a goal. Like I made a decision to do MSc and finish this year and I am working towards that. Now I have made a decision to do a PhD and I am going to, but the "where and when" I still need to know. My professional and personal goals are inter-woven and reaching just one will not make me happy. However, spending a year at AIMS has helped me to make one decision, and that is to contribute to my country and to Africa, to give back the gift I have been given, to teach them and make them realise that they can do more with their lives and also accomplish more." Her long-term goal, as stated in interview, is be involved with Public Health, in both a teaching and a research capacity, and to be applying mathematics to data collected from her homeland, especially grappling with diseases like polio and leprosy, important in N. Nigeria.

2. Mathematics degree at Bayero University, Kano, with some physics and statistics in the first year. Did a serious analysis course (didn't like it!) and in final year did discrete mathematics and a course in dynamical systems. Also did some probability theory (pure approach). "I have had a very good and solid background in mathematics in my undergraduate years. I did some wonderful courses and it has really helped me to get to where I am today. However, we were taught mostly in order to pass. We where not given enough practical work, so we could be able to think. But so far it [training experience] has been great."

I. Hloniphile Sithole, South African student, ex-UKZN, with a strong statistics background, doing AIMS/ Stellenbosch Honours Biomathematics course.

1. "I am currently doing my Honours and would like to finish it and pass it well. I'm really working hard and it is far from being easy, but I enjoy it a lot. We have the best lectures but a lot of work has to be covered alone and there is approximately no time. I would like to continue with my MSc and PhD at some point, but back at UKZN."
2. "I have nothing more than a BSc degree with statistics background, but I am very happy to see that it can also be applied in biomathematics. I learnt a lot in my BSc degree although I feel it would have helped if I had some skills courses in computing."

J. Dieter Winkler, South African student (Stellenbosch University) doing AIMS/ Stellenbosch Honours Biomathematics course.

1. "I would like to be specialising in either Bioinformatics or Epidemiology. I would like to do my MSc and PhD in one of these fields.

APPENDIX 3: Written responses on training, questions 4 – 7

[COLOUR-CODE relates to respondents given in Appendix 2]

Question 4. Specific other courses/training-events/field-experiences/projects that have been significant in your training.

A. "Hands on experience has been invaluable to me."

C. "It has helped me a lot to actually be in the field collecting data and seeing all the problems that one is faced with. It is easy to think of data as an abstract thing until you are actually there seeing the patient, clinic, hospital, or national park where it's being collected. Seeing the data in the real world has made thinking statistically and mathematically about these processes a lot easier."

D. Optimisation and Operation research, Statistical Inference, Biometry, Abstract Algebra, Linear Algebra, my undergraduate project (Mathematics in Agriculture: Cocoa producer price forecasting in Ondo State Nigeria), Six months Industrial Training, Mathematical Modelling Computational Technique."

F. "My two masters' degree programmes (one in Information science and the other in mathematical modelling) made up greatly for the deficiencies in my undergraduates class while the series of workshops I have attended, where MBBD 2009 is another memorable one, have immensely facilitated my PhD research degree programme."

G. ".I've attended a workshop on disease modeling in the states... I thought there was something they did in this workshop that was very good. They had a lot of group work, but the faculty were present during all of the group work, just wandering around, actively interacting with each group."

H. "The courses I took at in my undergraduate degree programme have been helpful to me so far namely: general topology, dynamical system, calculus, real analysis, differential equation, functional analysis, mathematical methods,statistics and so on. The courses I took at AIMS were wonderful. Especially the computer skills courses and problem solving in mathematics. My Essay project was also very helpful to me, because it gave me a glimpse of Biomathematics."

Question 5. Your experiences and ideas, based upon all phases of your own learning about the roles of mentors, (co-) supervisors, and role models.

A. "Mentors and role models have been extremely helpful. I have had a variety of mentors that have served different needs."

C. "I have had a lot of hands-off mentors and think this been bad for my academic development. I think closer interactions with my advisors would have helped me avoid mistakes in picking unrealistic projects and anticipating problems with them. The more senior PhD students in my lab have been very good about giving me advice and discussing projects but I still feel like I have been meandering through my academic career without anybody shoving me in the right direction."

D. ".The role of mentors can never be over emphasised; they have been my source of inspiration and encouragement all through my career."

F. "Mentors should identify potentials in the mentees and show belief in the mentees potentials.

Mentors should make effort to develop the identified potentials to the fullest extent.
Mentors should show concern about mentees welfare and academic progress and give relevant support to ensure that the mentees achieve set academic target.
Mentors should occasionally pay purposeful visits to their mentees."

G. "Outside of lots of experience teaching students in labs and discussions. I've not really mentored students directly. However, my PhD advisor's mentoring/advising style really works well for me. In general it is almost completely hands off, he gives us the freedom to really explore our own ideas, but his door is always open for discussion and advice. I think if a student is already motivated this style works well.."

H. ".I have had good and bad experiences with supervisors. But it has been good so far in my current work. However, it would be nice if student and co- (supervisor) interact and work together more, because if they work together they will be able to accomplish more."

Question 6. Your views on problem-based learning, project-focussed training, and how best to integrate coursework with field-work and research.

A. "I think problem-based learning is very valuable, and courses can include a small amount of field work. However there is no replacement for immersion and students should take breaks in their academic training to do internships or go out into the real world to work for a few years (I took 7 years between my MA and PhD)."

C. "I think it is rather hard to address this in a few sentences. But generally I would say that I think problem-based learning is only useful when there is a backdrop of fundamental theory over which is built. For instance, if we had tried to work with the HIV data in the Excel spreadsheets with people who didn't have a strong biomathematics (or at least modeling) background, I think that the problem at hand could have been solved without any real understanding of what was going on in the model & the fitting. I don't think I'm extremely clear on the distinction between problem-based learning & project-focused learning. I think field work is a valuable experience for anyone who works with real data or tries to model real socio-ecological systems. But at the same time it is difficult to expect mathematical modelers to spend a whole semester doing so. At the same time it can be quite unproductive to send someone into the field if they don't have the training to organize what they learn. For instance, I would think that sending a mathematical modeler to a hospital to learn about malaria would be unproductive unless they had adequate biological training to understand the diagnostic tests & treatments, or at least to learn what they were. Again hope these specific examples are clarifying what I'm saying but I think this topic could warrant several long conversations..."

D. "There is nothing wrong except where the background of the student is weak as regards the chosen field of training. Project-focussed training should be complemented with workshops/summer schools and training."

F. "I think [that] Physical Science education, generally, in Africa has been more for theory rather than for practice. I believe that it should be more for practice than theory. Our education should reinforce understanding and practical application, while it should be tailored towards societal needs."

G. “This workshop in my opinion did it the right way... theory and formal lectures on how to do certain things, followed with hands on practice. I don't think you can really learn something unless you do it for yourself.”

H. “From my point of view I think the present program run by SACEMA is quite good. However, if the student they are taking do not have good backgrounds in Biomaths or Biostats courses then it will be advisable for them to take some courses. Also it will be nice if they are given group or individual projects to work on before engaging in their own personal research.”

I. “Field-work is important and if it is implemented at a very early stage of undergraduate work it will be good.”

Question 7. Your thoughts and feelings about training in general, in biomathematics, biostatistics, epidemiology, etc., and especially how best to incorporate serious engagement with the biological side, in order to produce effective mathematical modellers of biological data.

A. “As an epidemiologist/biostatistician I appreciate the value of the field, and I am interested in the application of biomathematics to public health data. However there is a gap between the mathematicians and the applied researchers that may still need to be filled. So far in my experience a team approach, including both mathematicians and epidemiologists has been the most productive.”

B. “I think one should build a solid background in both fields, mathematics and biology, in order to create simple and effective mathematical models for solving biological questions. In fact, a better understanding of the biology can allow one to simplify as much as possible the models in keeping the biological keys. At the same time, one cannot limit himself or herself on just the numerical results obtained from the model. Some mathematical proofs are also needed.”

C. “In many ways mathematical modeling is the most coherent approach to problem solving. Several different aspects of a system can be incorporated into the same analysis and lead to insight about dynamics that could not otherwise be achieved. But because it is the most coherent and all-encompassing, modelers run the risk of not knowing enough about important components or processes within the system. On the other hand, a virologist can discover basic characteristics of a virus and still be doing great work even if s/he doesn't spend anytime thinking about population level processes. Mathematicians with insufficient biological training are especially likely to make fundamental mistakes (while biologists without mathematical training won't even be able to model so they can't get that far). For that reason, I think it is extremely important that modelers also be well-rounded biologists. I don't think they need to be experts in any one field, but a basic understanding of molecular biology, microbiology, immunology, ecology & evolution are important.

I think three or four courses in the above topics would provide a strong background for a modeler. I similarly think training in classical epidemiology would be very useful for students who want their work to be useful to the rest of the field. To engage with data in a serious way, modelers need to be able to pick important questions. It is hard to know what is important without being in touch with the rest of the public health world. And to do this requires being able to converse in their language and understand how they design studies, gather data, and generally think about the world. One or two basic epidemiology schools would serve this purpose well.”

D. “I feel training is aimed at equipping, developing and improving individuals. The best way to produce effective mathematical modellers of biological data, is exposing people of strong

mathematical background to biological modelling workshops/training/conferences, and those with strong biological background to mathematical modelling workshops/training/conferences."

F. "The training should be introduced [as early as possible] at undergraduate levels, so that students already have some background in the area. This would enhance the quality of research at postgraduate levels."

G. "I think modellers have to start to work with people that are doing empirical studies or collecting data in populations. In this sense having Brian and John Hargrove come for a few days was important to me, because it helped me stop looking at the data sets as abstract quantities that we were just working with, and start to appreciate were they came from and what it really represented and the difficulties associated with getting the data."

H. "My general thought is for SACEMA, AIMS, DIMACS to organize more workshop and conference like the MMBD clinic. Also it will nice for students to go out there to know how these data we use are collected, because this will help you to know what you want to do and how you want to do it, and even how to make your own assumptions based upon the understanding of the data."

I. "The training [in modelling] is attractive because of the variety of fields involved. I liked the way they all come together. No-one is left out as long as they are passionate about working with biological data."

APPENDIX 4: List of people interviewed

SACEMA MSc students

Mr Bewketu Bekele (Ethiopian, SU, 2008)
Ms Bilkisu Abdulra'uf Bello (Nigerian, SU, 2008)
Ms Geomira Sanga (Tanzanian, Stellenbosch University (SU), 2008)
Ms Doreen Mbabazi (Ugandan, SU, 2008)
Mr Richard Kuo (South African, UKZN, 2008)
Ms Tarylee Reddy (South African, UKZN, 2009)
Mr Jordache Ramjith (South African, UKZN, 2008)
Ms Ronel Sewpaul (South African, UKZN, 2008)
Ms Someya Essop (South African, UKZN, 2009)
Ms Reshma Kassanjee (South African, WITS, 2008)

SACEMA PhD students

Mr Carel Pretorius (South African, SU, 2007)
Mr Wim Delva (Belgian, UGhent, 2008)
Mr Joseph Ssebuliba (Ugandan, SU, 2009)
Mr Kazeem Okosun (Nigerian, University of the Western Cape, 2009)
Ms Theresia Marijani (Tanzanian, SU, 2009)
Mr Matadi Maba (DRC, UKZN, 2007)
Ms Kerry Cawse (South African, Wits, 2009)
Mr Edmore Marinda (Zimbabwean, Wits, 2007)
Ms Mhairi Maskew (South African, Wits, 2008)

SACEMA post-docs

Dr Farai Nyabadza, Postdoctoral Fellow, Supervisor (Zimbabwean, SU, 2007)
Dr Simon Childs, Postdoctoral Fellow (South African, SU, 2008)

SACEMA supervisors

Professor Glenda Matthews, Statistics and Actuarial Science, UKZN
Dr Henry Mwambi, Supervisor, UKZN (Pietermaritzburg)
Professor Peter Leach, Maths, UKZN, SACEMA Scientific Advisory Comm.
Professor David Sherwell, Computational and Applied Mathematics, WITS

SACEMA team members / staff

Professor John Hargrove, Director, supervisor
Ms Lynnemore Scheepers, Research Manager
Dr Rachid Ouifki , Research Fellow, supervisor
Dr Alex Welte, Research Fellow, CAM, supervisor, Lead consultant: CIDA project
Ms Nelly Biondi, Researcher: Health Economist

[continued]

SACEMA associates / external stakeholders

Dr Brian Williams, SACEMA consultant, WHO
Ms Margaret Ward, ex-Research Manager
Professor Fritz Hahne, Director: AIMS
Dr Jeremy Lauer, WHO, Consultant: CIDA project
Professor Salim Abdool Karim, Pro-VC Research, UKZN, Director: CAPRISA
Professor Ingrid Rewitzky, Head of Division: Mathematics, SU
Professor Delia North, Head, Statistics and Actuarial Science, UKZN
Dr Alan Matthews, Physics, UKZN
Dr Michael Murray, Statistics and Actuarial Science, UKZN

APPENDIX 5: A case study

The UZ Mathematical Modelling Masters Programme 1995—2007

This Programme was funded by NUFU (Norway), and produced 60+ graduates from many countries, who are seeded throughout the region. Part 1 was coursework, over a year, but (because many lecturers came from afar and gave short intensive courses) was flexible in time-scale. Part 2 was the dissertation.

MTS 508 Differential Equations
MTS 510 Analysis & Probability
MTS 514 Optimization
MTS 515 Numerical Methods
MTS 516 Stochastic Differential Equations
MTS 517 Control Theory
MTS 518 Theory of Differential Equations
MTS 519 Mathematics of Finance
MTS 521 Numerical Methods for PDEs
MTS 522 Climate Modelling
MTS 523 Engineering Design Modelling
MTS 524 Population Dynamics

Overview of epidemiological modelling techniques focusing on aspects of importance to public health in the region. Deterministic and stochastic models for the spread of infectious diseases in both discrete and continuous time. Epidemics and endemic diseases. Models for specific diseases. Parameter estimation. Use of modelling for policy development (prevention, immunization, etc.). Case studies: the dynamics of schistosomiasis; HIV infection and its effects on population structure.

MTS 525 Mathematics of Insurance
MTS 531 Further Topic in Pure Mathematics
Under this course, the following option may be offered
Option 1: Graphs and Networks
MTS 532 Further Topic in Applied Mathematics
A number of options may be offered under this general course.
Option 1: Dynamical Systems
Option 2: Environmental Modelling
Option 3: Fluid Mechanics
MTS 533 Further Topic in Mathematical Statistics
A number of options may be offered under this general course.
Option 1: Statistical Inference
Option 2: Time Series
Option 3: Mathematics of Economics
MTS 534 & MTS 535 General Graph Theory 1 & 2
MTS 536 & MTS 540 Algebraic Graph Theory
MTS 537 & MTS 541 Matroid Theory with Applications

Suggested modifications to MSc Modelling Program after 2007 review

The review subcommittee was composed partly of young, idealist post-docs (having done their BSc Hons and Masters at UZ followed by PhDs in US), who tended to ignore the worsening realities of the UZ situation. The subcommittee proposed that Part I be run over three sessions, of four months, designed in such a way that courses in subsequent sessions normally have pre-

requisites in prior sessions, with exams for each session sat before the end of the session and results made available before the start of the following session. The programme died in 2007, due to Zimbabwe's general collapse, so none of this was implemented.

1. Change Control Theory (MTS 517) to "Calculus of Variations & Control Theory," in order to meet the standard requirements of other courses on the program especially those that are based on or utilise advanced numerical techniques of PDE's (say, Numerical Solutions of PDE's, SDE's, CFD etc.)
2. MTS 508 & MTS 518, previously taught mostly as techniques of ODE's, should be changed to: MTS 508, PDE's (needed for courses like 521, 516 CFD), and MTS 518, Theory of Differential Equations, to include non-linear ODE's, delay DE's etc. to serve Epidemiology.
3. Numerical Analysis should replace Numerical Methods, as a more rigorous course in advanced numerical computation, since most mathematical modelling problems are intractable analytically.

Session 1

MTS 510, Analysis & Probability
MTS 517, Calculus of Variations & Control Theory
MTS 515, Numerical Analysis
MTS 508, Partial Differential Equations

Session 2

MTS 521, Numerical Solutions of PDE's (Pre-requisites: 517, 515, 508)
MTS 514, Optimization (Prerequisites: 517)
MTS 516, Stochastic Differential Equations (Pre-requisites: 510, 517, 508)
MTS 518, Theory of Differential Equations (Pre-requisites: 510)

Session 3

MTS 532, Computational Fluid Dynamics (under Further Topics) (Prerequisites: 510, 521)
MTS 519, Mathematics of Finance (Pre-requisites: 516)
MTS 524, Population Dynamics (Pre-requisites: 518, 516, 521)

Perceptions of a Postdoc at SACEMA who did the UZ MSc in Modelling

He recalls his courses during the MSc as:

- Functional analysis and probability (Dzino and Chareka), which was perhaps the toughest – only Farai, Dorothy (now at NUST) and Sure Mataumvura (now at UKZN) passed!

- Qualitative theory of DE's (Mark Roberts)

- Stochastic DE's (Jan Ubo, Norway), a course which helped with part of PhD thesis later.

- Dynamic programming

- Game theory -- never explicitly used since, but encountered in reading the literature, so not wasted.

- Graph theory (Herbert Fleischner) – apparently not especially relevant, but later it enabled him to write a joint paper with Simon Mukwembi (Durban).

- Optimization (Misha Petrov)

- Mathematical epidemiology (Edward Lungu) – the course that decided his future interests.

The main gain of the MSc period was the fruitful regional networking that grew out of it, with students from about nine countries, now spread all over the region. It was a reasonably cohesive, happy postgraduate community, with minor divisions and frictions over financial issues, arising from decisions made in Norway about levels of funding of extra-nationals on the course. (The non-Zimbabweans were paid a stipend which eventually was far greater than a UZ lecturer's salary, let alone that of a Teaching Assistant! This issue grew in magnitude in later years.)
Perceived weaknesses in the programme (probably inevitable in view of UZ staffing problems and the difficulty and expense of bringing in many lecturers from afar):

- Imbalances and holes in the structure: too much graph theory while missed advanced linear algebra and matrix theory, dynamical systems, control theory.

- Too broad, needed more focus, little chance to specialise.

- Background weakness (in undergraduate courses) was the lack of useful introduction to mathematical modelling, either as explicit course or implicitly in the applied maths options.

- The approach was purely academic, with little integration of biological, statistical and real-life aspects, and no engagement with actual data-collecting.

Reflections of one of the main facilitators of the UZ MSc in Modelling

[What I would regard as] one of the strong points of the programme is regarded by others as one of its weakest points. It is a two year programme with the first half being taught courses (called coursework at UZ) while the second year is a research project. This allowed students to have a good grounding in the theory to apply to their research and as a result our earlier graduates did very well when they went out into employment or further studies. This period is regarded as too long for students to be out of full-time employment (since it is a full-time study programme so they should not be employed outside of their studies.) Some students treated their research project as very much a part-time exercise to be completed after hours while employed full-time, usually with disastrous effects.

The second strength of the programme was the inclusion as core courses of the fundamental courses in Differential Equations, Numerical Methods, Optimization and Functional Analysis and Probability. This was watered down in later years by the removal of the core (i.e. has to be taken and PASSED) from these courses mainly because students failed some of them, especially the last one. Students had to take ten courses, the four core courses and six optional courses and to pass eight of them. I think it would have been better to have increased the core courses to five by adding either control theory including stochastic control or a further course in the statistics applicable to the later courses, and to have increased the minimum number of courses to be passed to ten.

The third strength was the "excellence" of the teaching staff and the fact that there was a good mix of local and imported lecturers. This ensured a good standard of final product but unfortunately the excellence was eroded by the deteriorating situation in Zimbabwe which resulted in so many of the good locals leaving and restricted the number of ex-patriot lecturers

who were prepared to come. This also affected the standard of the supervision available for projects. Initially most projects had a local supervisor and an ex-pat. co-supervisor which helped both the local staff and the students to achieve more. Eventually nearly every student had only foreign supervisors and this required resources to allow them to visit their external supervisors which severely impacted on the finances of the programme.

The fourth strength was the provision of scholarships for the students which allowed them to concentrate on their studies. The altered funding of some (or all in the end) of the students, by making them Graduate Teaching Assistant's (GTA's), was not as successful, as the GTA's found it very difficult to balance their studies with their teaching duties, especially if they were the weaker ones and especially if the lecturers came from outside Zimbabwe and gave their courses at the rate of five or more hours a day and asked the students to write their examinations immediately after the course.

The greater reliance on external supervisors led to less communications between students and local staff at the research level which lost one of the really important aspects of the programme. It also led to a decrease in the supervision of the students and of their approach to the organization and structuring of their studies.

One of the major objectives of the original project was to "home-grow" graduates who would move into positions in their home country, which I think was a great idea. I feel however that our students need to have some time abroad to find how the other much-more -than-half live and work. [And I feel] that students should continue beyond masters level to PhD level before embarking on their careers. This is of course becoming increasingly difficult to achieve and there is pressure from Government to get them into Universities with minimum delay since the staffing situation, especially in Zimbabwe, is so bad.

[In contrast, another UZ programme on Women and Law] tries to meet the financial needs of the students so they can concentrate on their studies [but] without necessarily giving them enough to meet family and developmental commitments. However [their] students' research projects are related to their employment and take place at their home station with lecturers from the centre visiting their students at their work place and the students are brought back for a "write-up" period at the end.

[Professor Alastair G R Stewart, July 2009]