Using Core Competencies to Develop a Bioinformatics Training Programme

Nicola Mulder
University of Cape Town
Outline

• Background – H3Africa and H3ABioNet
• Bioinformatics and related training:
  – Bioinformatics Masters degree
  – Introduction to Bioinformatics course
  – Genomic Medicine training
What is H3Africa?

“The Human Heredity and Health in Africa (H3Africa) Initiative aims to facilitate a contemporary research approach to the study of genomics and environmental determinants of common diseases with the goal of improving the health of African populations. To accomplish this, the H3Africa Initiative aims to contribute to the development of the necessary expertise among African scientists, and to establish networks of African investigators.”

www.h3africa.org
What is H3ABioNet?

• Pan-African bioinformatics network to develop bioinformatics capacity to enable genomic research in Africa.

• H3ABioNet has 32 institutions in 15 African countries, 1 in USA and 1 in UK

• www.h3abionet.org
Who do we need to train?

• H3Africa consortium
  – >$76 million
  – 25 projects, >500 investigators
  – 27 African countries
  – Nurses, study coordinators, geneticists, clinicians, data analysts

• H3ABioNet consortium
  – >$12 million
  – >120 people
  – Bioinformatics users, scientists, engineers
Who do we need to train?

- **H3Africa consortium**
  - $>76$ million
  - 25 projects, $>500$ investigators
  - 27 African countries
  - Nurses, study coordinators, geneticists, clinicians, data analysts

- **H3ABioNet consortium**
  - $>12$ million
  - $>120$ people
  - Bioinformatics users, scientists, engineers

Genomic Medicine

Intro to Bix

Bioinformatics MSc
Need for MScs in Bioinformatics

• Only a handful of MSc in Bix outside SA
• Many institutions wishing to establish programs
• Held Bioinformatics curriculum development workshop in Botswana
• Established African Bioinformatics Education Committee (ABEC)
ABEC

- [http://www.h3abionet.org/training-and-education/african-bioinformatics-education-committee](http://www.h3abionet.org/training-and-education/african-bioinformatics-education-committee)

- Curriculum development task force

- Set up website with guideline documents:
  - Considerations – key steps for starting a program
  - University processes for developing new programs
  - Existing programs and curricula
  - Curriculum development
H3ABioNet Bioinformatics curriculum

- Set of core and elective modules for a bioinformatics program using the ISCB guidelines have been defined
- Based on discussion, needs of individual institutions and existing curricula
- Trainers determined the content and contact hours for these modules
- Have included suggested lecturers from Africa
- [http://training.h3abionet.org/curriculum_development_wg/](http://training.h3abionet.org/curriculum_development_wg/)
H3ABioNet Bioinformatics curriculum

H3ABioNet Curriculum Development Taskforce

In the wake of the Gaborone Workshop (H3ABioNet / University of Botswana, March 11th-12th 2014), H3ABioNet decided to build a taskforce to develop a standard curriculum in bioinformatics, at the MSc level.

This site is the repository for the documents produced by this Curriculum Development Taskforce (CDTF), and primarily for the module outlines as proposed by the CDTF members.

Please find here the different modules proposed and the list of volunteers for these. The menu on top of this page provides links to the different outlines.

The meeting minutes are to be found on this website, here (tab “WG Meeting Minutes” on top of this page).
Module outline by the H3ABioNet Curriculum Development Taskforce

Biostatistics I
2014-03-06 07:03:32  Jean-Baka Domelevo Entfellner

Prepared by: Jean-Baka Domelevo Entfellner
Possible Lecturers: Jean-Baka Domelevo Entfellner, or any bioinformatician with a strong background in mathematics and statistics, ideally from his/her primary education.
Contact hours: For consistency reasons, each contact hour is fixed at 45min.
Theory (23), Practicals (30)

SPECIFIC OUTCOMES ADDRESSED
1. Generally speaking: develop an understanding of stochastic experiments
2. Understand and be able to build the framework of a statistical test

BACKGROUND KNOWLEDGE REQUIRED
Basic general-purpose scientific knowledge, basic arithmetic skills, and some familiarity with basic linear algebra.

BOOKS & OTHER SOURCES USED

COURSE CONTENT

(A) Theory lectures
I. Probability theory:
1. Atomic and complex events, probabilities as a measure on sets.
Module outline by the H3Africa Curriculum Development Taskforce

Biostatistics I
2014-03-06 07:03:32  Jean-Baka Domelevo Entfellner

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SPECIFIC OUTCOMES ADDRESSED
1. Generally speaking: develop an understanding of stochastic concepts.
2. Understand and be able to produce the framework of a statistical problem.

BACKGROUND KNOWLEDGE REQUIRED
Basic general-purpose scientific knowledge, basic arithmetic and familiarity with basic linear algebra.

BOOKS & OTHER SOURCES USED

COURSE CONTENT
(A) Theory lectures
1. Probability theory:
   1. Atomic and complex events, probabilities as a measure of chance

5. First continuous probability distributions: uniform, exponential
6. Central limit theorem and the normal distributions

7. Other continuous distributions: Student’s t and chi-square distributions.

II. Statistical hypothesis testing
III. Analysis of variance and regression models
IV. Multidimensional dataset analysis: Principal Component Analysis

(B) Practical component
We suggest the use of Rstudio throughout the course, as an integrated development environment to work with R. Being the fundamental statistical software in use across various research areas, it is essential that the students develop mastery over R during this course.
Alternatively, if computing resources are extremely scarce, use an interactive R interpreter to demonstrate the concepts, plus a simple text editor later on, once the students start writing functions.
This section “practical component” follows the same structure as the previous section “Theory lectures”: practicals just aim at having the students manipulate the concepts seen in the lectures, right after they were introduced to them.

ASSESSMENT ACTIVITIES AND THEIR WEIGHTS
We would suggest two written exams during the course of the module (total weight = \( \frac{3}{5} \)), and a final programming exam (weight = \( \frac{2}{5} \)). Of course, practicals can also be for marks all along the module, but our advice is not to make each and every practical for marks, not to put too much counterproductive stress on the students. Practicals are the privileged moments when students actually understand the concepts as they put them into play.
Core competencies

- For bioinformatics scientists and engineers we are mapping ISCB core competencies to curriculum

<table>
<thead>
<tr>
<th>Competency</th>
<th>Bioinformatics user</th>
<th>Bioinformatics scientist</th>
<th>Bioinformatics engineer</th>
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</thead>
<tbody>
<tr>
<td><strong>User competencies</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Apply knowledge of computing appropriate to the discipline</td>
<td>WK</td>
<td>WK to S</td>
<td>WK</td>
</tr>
<tr>
<td>Apply knowledge of biology appropriate to the discipline</td>
<td>S</td>
<td>WK</td>
<td></td>
</tr>
<tr>
<td>Ability to use current techniques, skills, and tools necessary for computational biology practice</td>
<td>WK</td>
<td></td>
<td>WK</td>
</tr>
<tr>
<td>Understanding of biological data generation technologies</td>
<td>WK</td>
<td>WK to S</td>
<td></td>
</tr>
<tr>
<td>Understand the limitations of bioinformatics tools</td>
<td>A</td>
<td></td>
<td>WK to S</td>
</tr>
<tr>
<td><strong>Scientist competencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a computer-based system, process, component, or program to meet needs</td>
<td></td>
<td>A to WK</td>
<td></td>
</tr>
<tr>
<td>Evaluate ability of a computer-based system, process, component, or program to meet needs</td>
<td>WK</td>
<td>WK to S</td>
<td>WK to S</td>
</tr>
<tr>
<td>Apply statistical research methods in the contexts of molecular biology, genomics, genetics research</td>
<td>WK</td>
<td></td>
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</tr>
<tr>
<td>Knowledge of general biology, in-depth knowledge of at least one area of biology</td>
<td>N/A to A</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Appreciation of algorithms to make informed decisions on their suitability to solve a research problem</td>
<td>S</td>
<td>A to WK</td>
<td></td>
</tr>
<tr>
<td><strong>Engineer competencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyze a problem, identify and define the computing requirements appropriate to its solution</td>
<td></td>
<td>N/A to A</td>
<td>WK</td>
</tr>
<tr>
<td>Design and implement a computer-based system, process, component, or program to meet needs</td>
<td>WK</td>
<td>WK</td>
<td>X</td>
</tr>
<tr>
<td>Apply mathematical foundations, algorithmic principles, and computer science theory in the modelling and design of computer-based systems</td>
<td>N/A to A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Apply design and development principles in construction of software systems of varying complexity</td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Generic competencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function effectively in teams to accomplish a common goal</td>
<td>S</td>
<td>A to WK</td>
<td>WK to S</td>
</tr>
<tr>
<td>Understand and uphold professional, ethical, legal, security, and social issues and responsibilities</td>
<td></td>
<td>A to WK</td>
<td></td>
</tr>
<tr>
<td>Communicate effectively with a range of audiences, including, other bioinformatics professionals</td>
<td>S</td>
<td>WK</td>
<td></td>
</tr>
<tr>
<td>Analyze impact of bioinformatics and genomics on individuals, organizations, and society</td>
<td>WK</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Engage in continuing professional development</td>
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<tr>
<td>Detailed understanding of the scientific discovery process and of the role of bioinformatics in it</td>
<td></td>
<td>WK</td>
<td></td>
</tr>
</tbody>
</table>

A: Awareness: the professional appreciates what is possible in this area and how the area impacts on their own work
WK: Working knowledge: the professional has a firm underpinning knowledgebase in this area and applies it effectively in his or her day-to-day work
S: Specialist knowledge: the professional actively contributes to advancement of the area, generating new understanding or new technology
Implementations

• First MSc in Bioinformatics program launched at the University of Bamako this year, lecturers local and distant
• New program in Malawi just been approved
• Other MSc in Bioinformatics programs such as in Kenya, Tunisia are being developed using the defined modules
• Using some as a base for Introduction to Bioinformatics course
Intro to Bioinformatics for Bix users

Aim
• Basic bioinformatics training for interested H3Africa members (bioinformatics users)
• bioinformatics tools, algorithms and resources and how to use them

Course logistics
• 6th July 2016: 3 months, 2 days contact time per week (3 hours per contact session)
• Distance learning model – physical classrooms connected to virtual classroom
• Mconf – video conferencing
• Vula – course management
Intro to Bioinformatics course

Curriculum modules

- Resources and databases
- Linux
- Sequence alignment theory & applications
- Multiple sequence alignment
- Molecular evolution and phylogenetics
- Genomics
- Protein Structural Bioinformatics

Lecturers & teaching assistants mostly from Africa
20 classrooms, 350/550 applicants

Each module is mapping core competencies to content
Genomic Medicine Curriculum

• Identified need for and interest in genomic medicine training
• Aim to establish a comprehensive, adaptable and coordinated Genomic Medicine Curriculum and Training plan for Africa
• Developing set of competencies for each target audience (nurse, clinician, scientist, lab technician, policy makers)
• Using Kern’s Six Step Approach in Curriculum Development
Kern’s Six Step Approach to Curriculum Development

- Step 1: Needs & Problem Identification
- Step 2: Targeted needs assessment
- Step 3: Goals & Objectives
- Step 4: Educational strategies
- Step 5: Implementation
- Step 6: Monitoring & Evaluation
Step 1. Problem identification

• Limited knowledge on how genetics and genomics contribute to disease in Africa.
• Limited learning opportunities which make use of African-specific case studies and diagnostics
• Limited curricula in Africa which sufficiently address genetics, genomics and emerging technologies
Step 2: Target Learners & Needs

- **Public Education**
- **Podcasts**
- **Online-based platforms**

- **Healthcare professionals & researchers**
  - MSc Courses
  - Undergraduate modules
  - Professional Development Course

- **High school learners, Patients and affected families & Journalists**

- **Pharmacists; Nurses; Medical Doctors; Laboratory technologists; Genetic Counsellors; Clinical trial & Study Coordinators; Pathologists; Ethics Committees; Community Health Care Workers**
Step 3: Goals & Timelines

- 2016
  - Professional Development Course
    - Curriculum Development
- 2017
  - MSc Courses
  - Online Course
- 2018
  - Undergraduate modules
    - Curriculum Adjustments
    - Implementation
- 2019
  - Curriculum Development
    - eGenomics Catalogue
    - Implementation
- 2020
  - Public Education
    - App Development and Maintenance
    - Podcasts
Step 4: Educational Strategies

• Case-based approach
• Blended learning – Professional Development Course
• Competency based learning
Step 5: Implementation

- African Genomic Medicine Curriculum Committee
- Small planning committee
- Independent review committee
## Step 6: Evaluations

<table>
<thead>
<tr>
<th>Factors</th>
<th>Evaluation question</th>
</tr>
</thead>
<tbody>
<tr>
<td>African Genomic Medicine Curriculum Committee</td>
<td>Change in knowledge, attitudes, practises in curriculum development</td>
</tr>
<tr>
<td>Professional Development Course</td>
<td>Impact of Genomic Medicine Professional Development Course</td>
</tr>
<tr>
<td>Healthcare professionals learners</td>
<td>Change in Knowledge, Attitudes and Practises in Genomic Medicine amongst Healthcare Professionals.</td>
</tr>
<tr>
<td>African Genomic Medicine Curriculum Committee &amp; Tertiary institutes</td>
<td>An inventory of Genetics &amp; Genomics training and curricula in institutes of higher learning in Africa.</td>
</tr>
<tr>
<td>Healthcare Facilities &amp; Laboratories</td>
<td>An inventory of Genetics &amp; Genomics resources and current practices in</td>
</tr>
<tr>
<td>Genetic/Genomics Diagnostic tests</td>
<td>Transferability of existing diagnostic platforms and tests to African populations</td>
</tr>
<tr>
<td>Public</td>
<td>Feasibility and acceptability of online educational strategies for high school learners</td>
</tr>
</tbody>
</table>
Template (Wordpress Site)

• Title:
  Prepared by:
  Possible Lecturer/s:
  Contact hours: For consistency reasons, each contact hour is fixed at 45min.
  Theory (XXhrs), Practicals (XXhrs)

• Aim
• Content Description
• Prerequisites
• Competencies & level of competencies aimed at
• Learning Outcomes
• Description of Case Study/ies
• Indicative Content & Activities/Practicals
• Assessments & Weights
• Additional Readings
• References
• Resources required
• Support required
Core competencies

• Some work done in this area already:

Framework for development of physician competencies in genomic medicine: report of the Competencies Working Group of the Inter-Society Coordinating Committee for Physician Education in Genomics

Bruce R. Korf, MD, PhD¹, Anna B. Berry, MD²,³, Melvin Limson, PhD⁴, Ali J. Marian, MD⁵, Michael F. Murray, MD⁶, P. Pearl O’Rourke, MD⁷, Eugene R. Passamani, MD⁸, Mary V. Relling, PharmD⁹, John Tooker, MD, MBA¹⁰, Gregory J. Tsongalis, PhD¹¹,¹² and Laura L. Rodriguez, PhD⁸

• Expanding on or adapting these where necessary for African setting
Competencies: EPAs (Entrustable Professional Activities)

• **A. Family History:** elicit, document, and act on relevant family history pertinent to the patient’s clinical status;
• **B. Genomic Testing:** use genomic testing to guide patient management;
• **C. Treatment Based on Genomic Results:** use genomic information to make treatment decisions;
• **D. Somatic Genomics:** use genomic information to guide the diagnosis and management of cancer and other disorders involving somatic genetic changes; and
• **E. Microbial Genomic Information:** use genomic tests that identify microbial contributors to human health and disease, as well as genomic tests that guide therapeutics in infectious diseases.
• **F. Research:** engage with communities in an ethical and culturally acceptable manner
# NHS competencies

<table>
<thead>
<tr>
<th>Role</th>
<th>Clinical bioinformatician</th>
<th>Other bioinformatician</th>
<th>Specialist clinician with genetics/genomics expertise</th>
<th>Other specialist clinician</th>
<th>Other clinician</th>
<th>Clinical genetic Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. responses</td>
<td>11</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example</th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White computer programmes and algorithms that can analyse data</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Analyse genomics data using pre-existing software, including linking genotype to phenotype/microbial strain comparisons</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge[2]</td>
<td>Awareness</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Employ good software development practice</td>
<td>Working knowledge</td>
<td>Specialiste knowledge</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Apply computer science theory to computer system design</td>
<td>Working knowledge</td>
<td>Working knowledge</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Manage and organise genomics data and results</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>Awareness[2]</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Apply statistical research methods to genomics, medical, and population genetics</td>
<td>Working knowledge</td>
<td>Specialist knowledge</td>
<td>Working knowledge</td>
<td>No knowledge required</td>
<td>No knowledge required</td>
</tr>
<tr>
<td></td>
<td>Use health informatics systems and understand their relevance to clinical genomics</td>
<td>Working knowledge</td>
<td>Awareness</td>
<td>Specialist knowledge</td>
<td>Awareness</td>
<td>Awareness</td>
</tr>
<tr>
<td></td>
<td>Principles of genetics, genomics and genome-sequencing technology</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>Awareness</td>
<td>Specialist knowledge</td>
</tr>
<tr>
<td></td>
<td>Principles of genetic disease</td>
<td>Working knowledge</td>
<td>Working knowledge</td>
<td>Specialist knowledge</td>
<td>Working knowledge</td>
<td>Specialist knowledge</td>
</tr>
<tr>
<td></td>
<td>Principles of systems biology</td>
<td>Working knowledge</td>
<td>Working knowledge</td>
<td>Awareness</td>
<td>No knowledge required</td>
<td>Awareness</td>
</tr>
<tr>
<td></td>
<td>Principles of next generation sequencing</td>
<td>Specialist knowledge</td>
<td>Specialist knowledge</td>
<td>Awareness</td>
<td>Awareness</td>
<td>Specialist knowledge</td>
</tr>
<tr>
<td></td>
<td>Ethical, legal and social implications of clinical use of genomic data (including issues surrounding identification of patients, clinical benefits and risks, patient consent, incidental findings and ethical implications of unexpected clinically actionable findings</td>
<td>Working knowledge</td>
<td>Working knowledge</td>
<td>Specialist knowledge</td>
<td>Working knowledge</td>
<td>Specialist knowledge</td>
</tr>
</tbody>
</table>

- NHS diagnostic clinical scientist, microbiologist, statistical/analytical epidemiologist
Summary & conclusions

• All learning a lot about educational practice!
• Experimenting with different learning strategies
• Targeting a wide range of audiences
• Very important to focus on who we want to teach and what we need them to know and be able to do after training