Global activities in bioinformatics training and education

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Outline

- Challenges in bioinformatics education & training
- Addressing challenges -Education summits
- H3ABioNet & NGS Academy -running a diverse bioinformatics training program
- Other applications of trainer resources

General challenges in training

- **Qualified trainers** who are knowledgeable in the topic and are good trainers
- Developing and updating **training materials** –lectures, tools and practice datasets
- Teaching a **mixed audience**
- Keeping the **audience engaged**
- **Assessing competency** and skills gain
- **Going virtual**

Challenges in bioinformatics training

- There is a **huge demand** for more people with bioinformatics skills
- Bioinformatics **topics are vast,** in flux and change rapidly
- **Audiences are broad** and need different levels of competency
- Competencies often require **additional foundational skills** (statistics, programming)
- Training requires **theory and hands-on practice**
- Few trainees have a standard bioinformatics education

Global efforts to address challenges

Challenges:

- Audiences are broad and need different levels of competency
- Assessing competency and skills gain
- High demand, not enough trainers
- Qualified trainers who are knowledgeable in the topic and are good trainers
- Teaching to a mixed audience, keeping the audience engaged
- Developing and updating training materials
- Bioinformatics topics are vast and in flux

Solutions:

Develop and use competencies

Use different training modalities

Train the Trainer

Develop Trainer portal

Education summits

AIM: Bring together Bioinformatics trainers and educators to drive the development of standards and guidelines for Bioinformatics training and education globally

- Summit I: 14-17th May 2019, Cape Town hosted by H3ABioNet
- Summit II: May 2020 virtual hosted by EBI
- Summit III: May 2021 virtual hosted by CABANA
- Summit IV: May 2022 virtual hosted by APBioNet

Format:

- Minimal presentations
- Breakout working sessions
- Discussions

H3ABioNet

iSCB INTERNATIONAL SOCIETY FOR COMPUTATIONAL BIOLOGY

elixir

APBioNET

CABANA Capacity building for bioinformatics in Latin America

Break out groups

Education summit projects

- Competencies
- Course endorsement
- Trainer resources
- Train-the-trainer
- Going virtual
- Training in LMICs

Competencies: what are they?

- https://www.td.org/insights/what-is-a-competency
- something you need to be able to do a specific job
- to demonstrate competence, workers must be able to perform certain tasks or skills with a required level of proficiency
- A competency is broken down into specific skills or tasks
- To achieve competence in a particular job, a person should be able to perform various tasks or skills at a target proficiency level

Knowledge

Skills

Attitudes

Developing competencies

Define audience/persona

Bioinformatics User

- Physician
- Lab technician
- Ethicist
- Biocurator

Bioinformatics Scientist

- Academic life science researcher
- Molecular life science educator
- Academic bioinformatics researcher
- Core facility scientist

Bioinformatics Engineer

- Bioinformatician in academic or research infrastructure support role
- Bioinformatics software developer/ software engineer

Developing competencies

Define audience/persona

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Determine competencies required

Relationship	#	Competency
Bioscience	A3	*Work at depth in at least one technical area aligned with the life sciences*
	B3	*Prepare life science data for computational analysis*
	C3	*Have a positive impact on scientific discovery through bioinformatics*
Data Science	D3	*Use data science methods suitable for the size and complexity of the data*
	E3	*Manage own and others' data according to community standards and principles*
	F3	*Make appropriate use of bioinformatics tools and resources*
Computer Science	G3	*Contribute effectively to the design and development of user-centric bioinformatics tools and resources*
	H3	*Make appropriate and efficient use of scripting and programming languages*
	I3	*Construct, manage and maintain bioinformatics computing infrastructure of varying complexity*
Professional Conduct	J3	*Comply with professional, ethical, legal and social standards and codes of conduct relevant to computational biology*
	K3	*Communicate meaningfully with a range of audiences - within and beyond your profession*
	L3	*Work effectively in teams to accomplish a common goal*
	M3	*Engage in continuing professional development in bioinformatics*

Developing competencies

Define audience/persona

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Determine competencies required

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Define knowledge skills & attitudes

E3 - Manage own and others' data according to community standards and principles (UKNOS: COGBIO1; COGBIO2)

What do you need to know to exhibit competency in this area?	What skills do you need to exhibit competency in this area?
KE3-1 (UA K15). Database design and management, including information security considerations, big-data technologies, and database languages and systems. KE3-2 (UA K6). Current approaches for modelling and warehousing of life science data. KE3-3 (UA K20). The role of governance, curation and information architecture in data management. KE3-4 (EA3.4c). Common document identification, tracking and control procedures. KE3-5. Broader implications of using/storing sensitive data. KE3-6 (UA K8). Knowledge representation including file formats, ontologies and other controlled vocabularies. KE3-7 (UA K10). Data storage and format requirements of downstream techniques to integrate, interpret, analyse and visualise biological data sets.	SE3-1 (UA S27). Designs and implements appropriate data storage formats and associated database structure. SE3-2 (UA S28). Chooses appropriate computational infrastructure and database solutions - including internal or external/cloud resources. SE3-3 (UA S29). Stores and analyses data in accordance with ethical, legal and commercial standards, including checking who has access. SE3-4 (UA S30). Curates biological data using suitable metadata, ontologies and/or controlled vocabularies. SE3-5 (UA S31). Makes use of suitable programming languages and/or workflow tools to automate data handling and curation tasks. SE3-6. Drafts and files an appropriate Data Management Plan. SE3-7 (UA S33). Prepares data for submission to appropriate public data repositories as required, being aware of ethical and legal considerations.
How does a person with this competence behave?	**How does a person with this competence avoid behaving?**
AE3-1 (UA A51). Acts with awareness of the wider context in which scientific research operates, recognising the implications for professional practice.	NE3-1. Uses proprietary systems for data management. NE3-2. Publishes scientific results without making adequate data available for reproducibility. NE3-3. Uses third-party data without appropriate legal or ethical approval and/or without citation or acknowledgement appropriate to the discipline.

48	D3: Use data science methods suitable for the size and complexity of the data		
49	D3: Use data science methods suitable for the s	KD3-1: Appropriate statistics in the context of bioinformatics and life science data analysis	Knowledgeledge
50	D3: Use data science methods suitable for the s	KD3-2: Statistical and mathematical modelling methods, and key scientific and statistical ana	Knowledgeledge
51	D3: Use data science methods suitable for the s	KD3-3: General data science approaches to life science problems	Knowledgeledge
52	D3: Use data science methods suitable for the s	KD3-4: Experimental design to ensure the statistical validity of high-throughput experiments	Knowledgeledge
53	D3: Use data science methods suitable for the s	KD3-5: Comprehensions the importance of statistics in experimental design, data analysis an	Knowledgeledge
54	D3: Use data science methods suitable for the s	SD3-1: Determines the best methods for data analysis, including the selection of statistical te	Skill
55	D3: Use data science methods suitable for the s	SD3-2: Identifies and defines appropriate computing infrastructure requirements for the analysi	Skill
56	D3: Use data science methods suitable for the s	SD3-3: Applies statistical methodologies appropriate to the analysis of data in the context of t	Skill
57	D3: Use data science methods suitable for the s	SD4-4: Can process data into formats suitable for analysis, whilst maintaining integrity of the	Skill
58	D3: Use data science methods suitable for the s	AD3-1: Approaches problems with a systems-based, data-driven approach to scientific discov	Effective attitudes
59	D3: Use data science methods suitable for the s	AD3-2: Recognises own limitations and consults experts when required	Effective attitudes
60	D3: Use data science methods suitable for the s	AD3-3: Is conscious of the risks of overfitting and of appropriate methods for validation and cor	Effective attitudes
61	D3: Use data science methods suitable for the s	AD3-4: Critically reviews results before interpretation and communication	Effective attitudes
62	D3: Use data science methods suitable for the s	AD3-5: Reports on statistical methods applied in a project, the rationale, limitations and result	Effective attitudes
63	D3: Use data science methods suitable for the s	ND3-1: Does not engage with statistical components of project	Ineffective attitudes

Developing competencies

Define audience/persona

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Determine competencies required

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Define knowledge skills & attitudes

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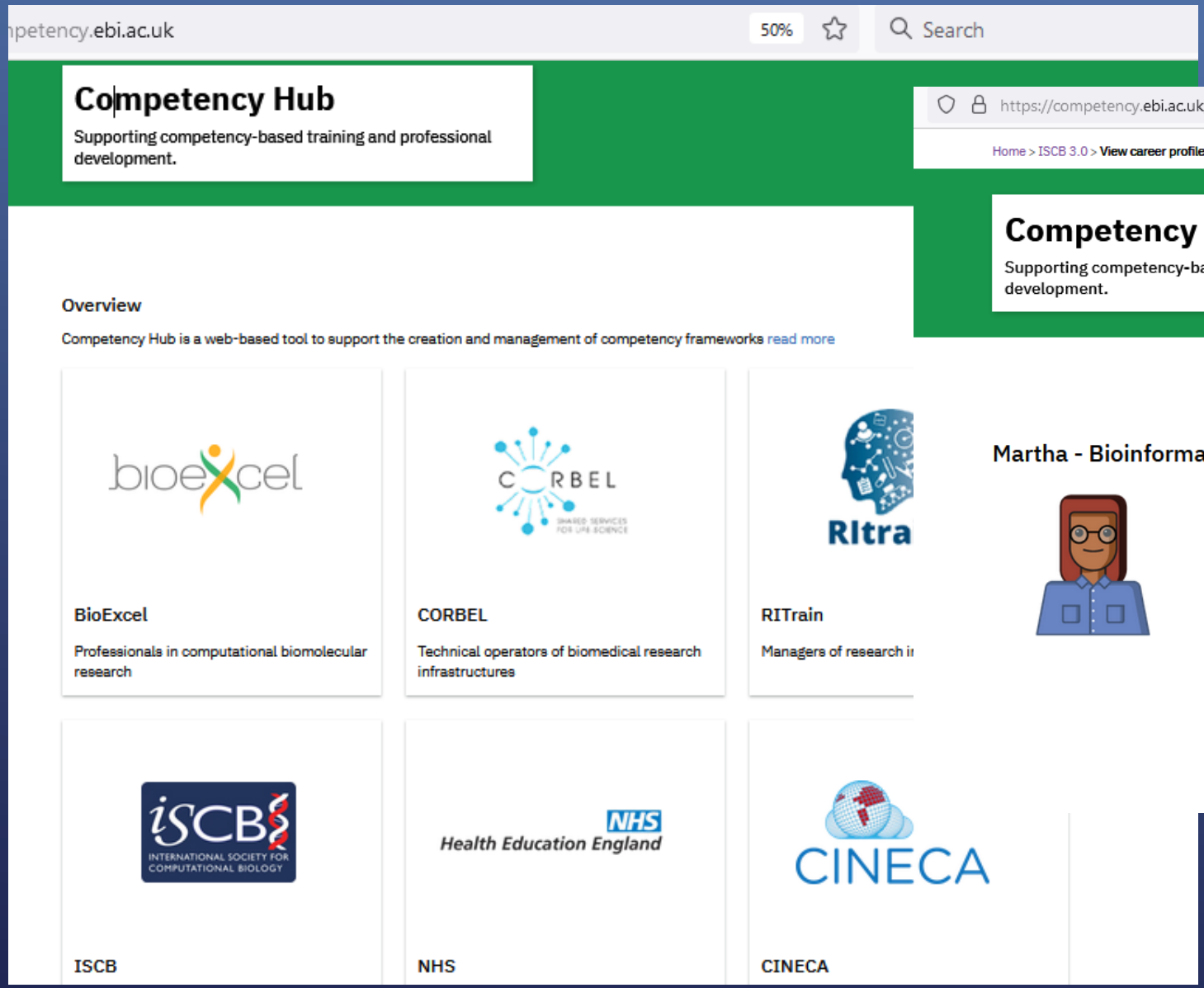
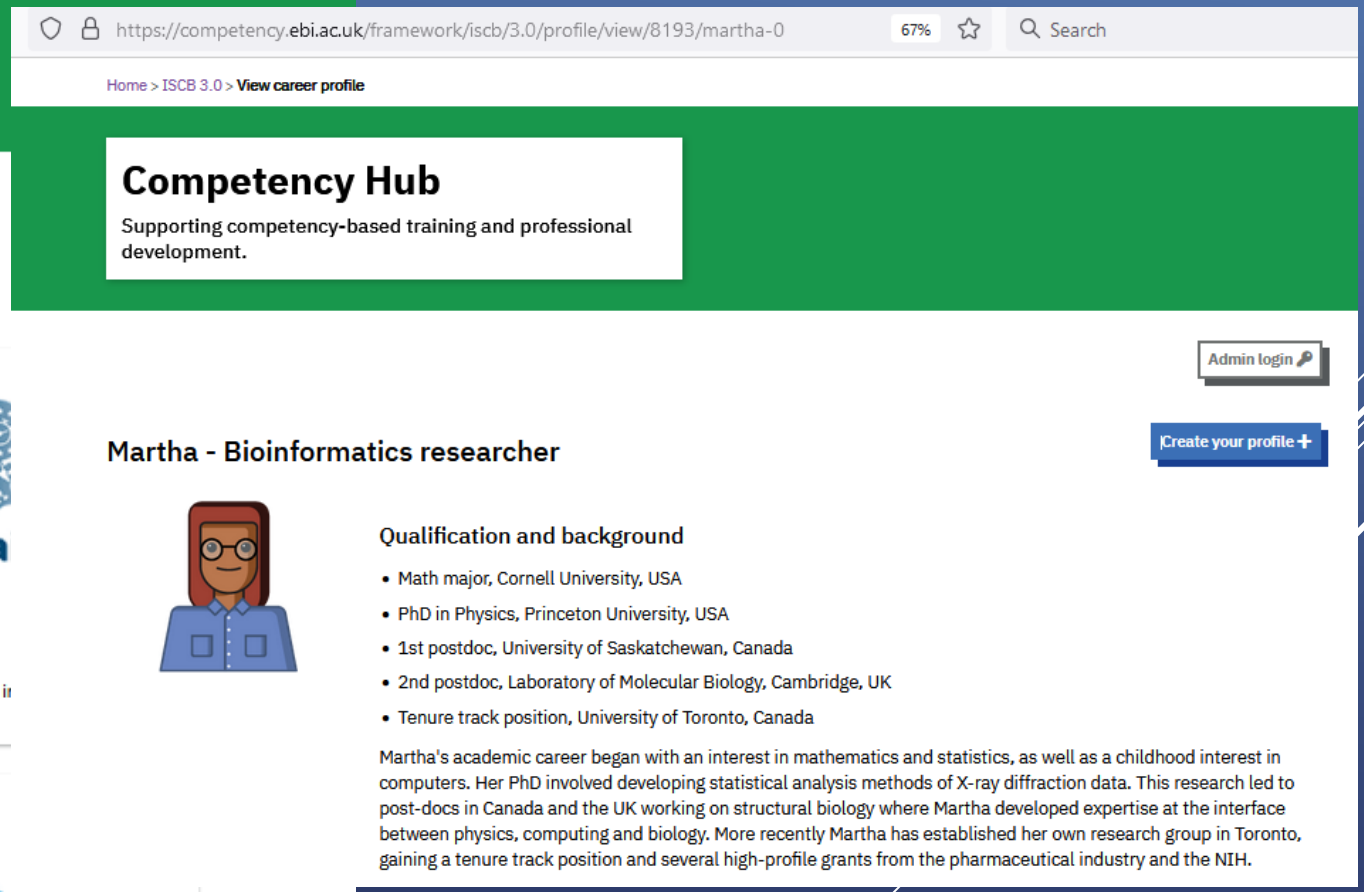
Determine level required for persona

		Scientist roles				Engineer roles		
	Competency	Discovery biologist (e.g. pharma or agri-food industry); Academic molecular life science researcher;	Molecular life science educator	Academic bioinformatics researcher	Core facility scientist	Bioinformatician supporting an academic lab or department	Bioinformatician in a research infrastructure setting	Software developer/ software engineer in a bioinformatics role
A	General biology	evaluation	comprehension	synthesis	knowledge	application	application	application
B	Depth in at least one area of biology (e.g., evolutionary biology, genetics, molecular biology, biochemistry, anatomy, physiology)	create	analyze	create	evaluate	comprehension	comprehension	comprehension
C	Biological data generation technologies.	evaluation	understand	evaluation	evaluation	comprehension	comprehension	comprehension
D	Details of the scientific discovery process and of the role of bioinformatics in it.	application	evaluation	synthesize to create	application	application	application	application
E	Statistical (research) methods in the context of molecular biology, genomics, medical, and population genetics research.	application	evaluation	synthesize to create	application	application	application	synthesis to application

Competency hub example





How do we use the competencies?

Designing a new course

Define course objectives and learning outcomes → Identify competencies needed → Decide on Blooms level required for each competency → Add proposed content to address competency (knowledge)

Core competency	Desired target level (Bloom's)	Starting student level (Bloom's)	Proposed courses/modules/activities
(a) General biology			
(b) Depth in at least one area of biology (e.g., evolutionary biology, genetics, molecular biology, biochemistry, anatomy, physiology).			
(c) Biological data generation technologies.			
(d) Details of the scientific discovery process and of the role of bioinformatics in it.			
(e Statistical research methods in the context of molecular biology, genomics, medical, and population genetics research.			
(f) Bioinformatics tools and their usage.			

Add proposed content to address competency (knowledge) → Look for overlaps in content between modules → Flesh out curriculum and depth of content (consider KSAs) → Determine assessment methods that assess skills

Mapping competencies to a course

Get curriculum content & competencies

Score competencies for each module

Sum up scores and look for gaps

Fill gaps with additional content or modules

DEGREES

COURSES

Decide on Blooms level targeted for each competency

Map to specific KSAs?

Identify and fill gaps in content

Core competency	Intro to biology	Biostatistics	Programming
(a) General biology	2		
(b) Depth in at least one area of biology (e.g., evolutionary biology, genetics, molecular biology, biochemistry, anatomy, physiology).	2		
(c) Biological data generation technologies.	1		
(d) Details of the scientific discovery process and of the role of bioinformatics in it.	1		
(e Statistical research methods in the context of molecular biology, genomics, medical, and population genetics research.	0		
(f) Bioinformatics tools and their usage.	0		

Core competency	Bloom	Knowledge	Skills	Attitude
(a) General biology				
(b) Depth in at least one area of biology (e.g., evolutionary biology, genetics, molecular biology, biochemistry, anatomy, physiology).				
(c) Biological data generation technologies.				
(d) Details of the scientific discovery process and of the role of bioinformatics in it.				
(e Statistical research methods in the context of molecular biology, genomics, medical, and population genetics research.				
(f) Bioinformatics tools and their usage.				

Guidelines document

How we have applied these

- H3ABioNet → Pan African bioinformatics network for H3Africa – building bioinformatics capacity
  - Mapping existing courses
  - Used to design new courses
- NGS Academy
  - Development of a recommended curriculum for pathogen surveillance

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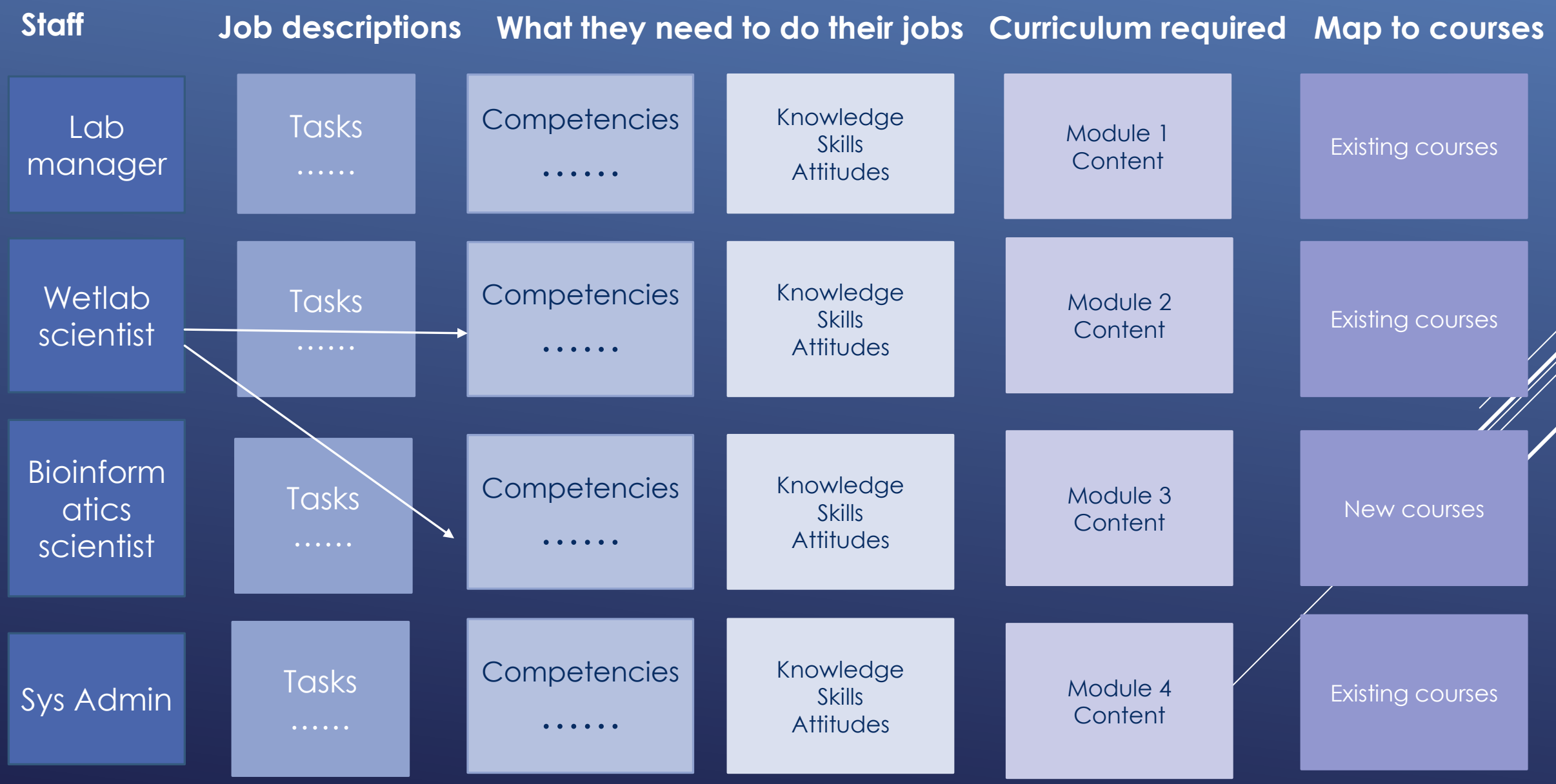
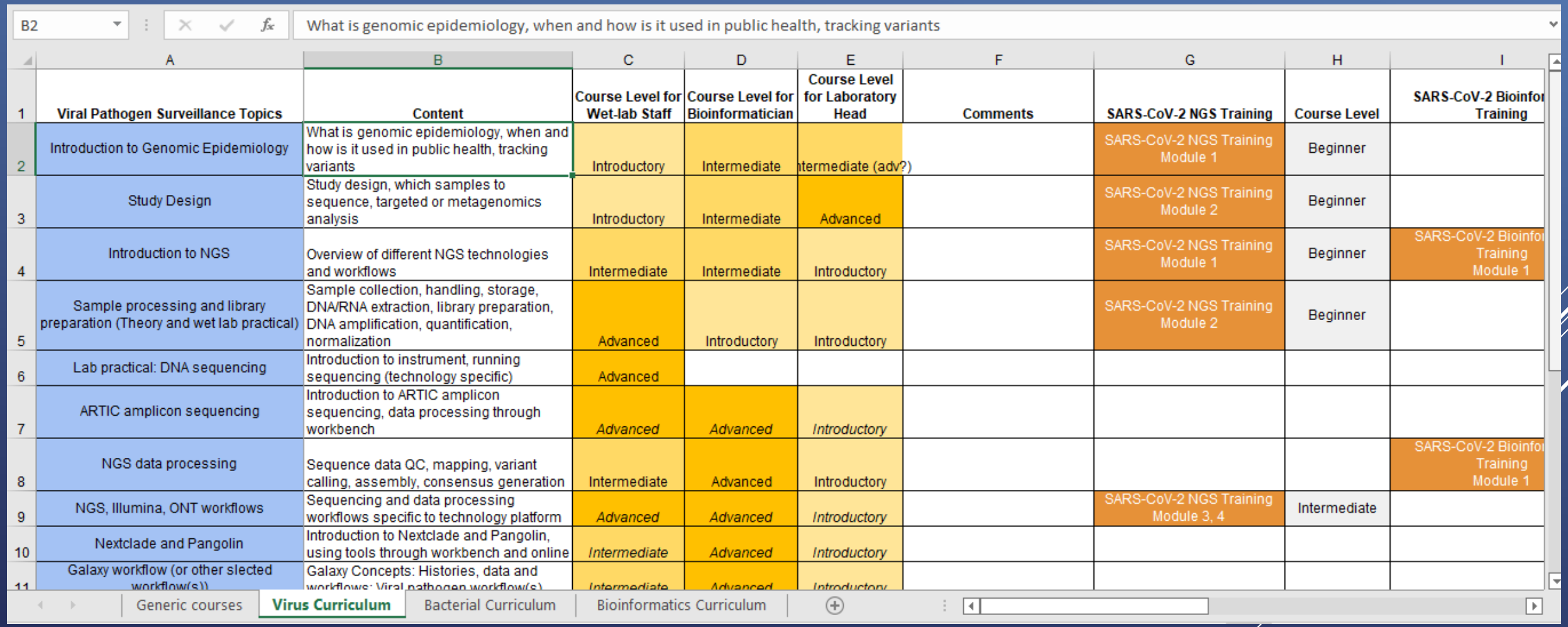
NGS for pathogen surveillance Training program for the Africa CDC Pathogen Genomics Initiative

NGS academy curriculum development



Example of the curriculum



B2: What is genomic epidemiology, when and how is it used in public health, tracking variants

	A	B	C	D	E	F	G	H	I
1	Viral Pathogen Surveillance Topics	Content	Course Level for Wet-lab Staff	Course Level for Bioinformatician	Course Level for Laboratory Head	Comments	SARS-CoV-2 NGS Training	Course Level	SARS-CoV-2 Bioinfor Training
2	Introduction to Genomic Epidemiology	What is genomic epidemiology, when and how is it used in public health, tracking variants	Introductory	Intermediate	ntermediate (adv?)		SARS-CoV-2 NGS Training Module 1	Beginner	
3	Study Design	Study design, which samples to sequence, targeted or metagenomics analysis	Introductory	Intermediate	Advanced		SARS-CoV-2 NGS Training Module 2	Beginner	
4	Introduction to NGS	Overview of different NGS technologies and workflows	Intermediate	Intermediate	Introductory		SARS-CoV-2 NGS Training Module 1	Beginner	SARS-CoV-2 Bioinfor Training Module 1
5	Sample processing and library preparation (Theory and wet lab practical)	Sample collection, handling, storage, DNA/RNA extraction, library preparation, DNA amplification, quantification, normalization	Advanced	Introductory	Introductory		SARS-CoV-2 NGS Training Module 2	Beginner	
6	Lab practical: DNA sequencing	Introduction to instrument, running sequencing (technology specific)	Advanced						
7	ARTIC amplicon sequencing	Introduction to ARTIC amplicon sequencing, data processing through workbench	*Advanced*	*Advanced*	*Introductory*				
8	NGS data processing	Sequence data QC, mapping, variant calling, assembly, consensus generation	Intermediate	Advanced	Introductory				SARS-CoV-2 Bioinfor Training Module 1
9	NGS, Illumina, ONT workflows	Sequencing and data processing workflows specific to technology platform	*Advanced*	*Advanced*	*Introductory*		SARS-CoV-2 NGS Training Module 3, 4	Intermediate	
10	Nextclade and Pangolin	Introduction to Nextclade and Pangolin, using tools through workbench and online	*Intermediate*	*Advanced*	*Introductory*				
11	Galaxy workflow (or other slected workflow(s))	Galaxy Concepts: Histories, data and workflows: Viral pathogen workflow(s)	*Intermediate*	*Advanced*	*Introductory*				

Generic courses | **Virus Curriculum** | Bacterial Curriculum | Bioinformatics Curriculum

Mapping to competencies developed from: job descriptions, existing competency frameworks

Using the curriculum

Lab manager

Wetlab scientist

Bioinformatics scientist

Sys Admin

Foundational skills

Health & Safety

Ethics & policy

Intro to Genetic Epi

Unix, scripting

Programming

Bioinformatics

Workflows, HPC

Applied skills

Introduction to NGS, Study design

SARS-CoV-2

Viral pathogens	Bacterial pathogens
Sample preparation	Sample preparation
Sequencing	Sequencing
Data QC processing	Data QC processing
Analysis workflow	Analysis workflow
Phylogenetics, Bioinformatics	Phylogenetics, Bioinformatics
Data curation & submission	Data curation & submission

Presenting data for policy/action

Tuberculosis

Using the curriculum

Lab manager

Wetlab scientist

Bioinformatics scientist

Sys Admin

Foundational skills

Health & Safety

Ethics & policy

Intro to Genetic Epi

Unix, scripting

Programming

Bioinformatics

Workflows, HPC

Applied skills

Introduction to NGS, Study design

SARS-CoV-2

Viral pathogens	Bacterial pathogens
Sample preparation	Sample preparation
Sequencing	Sequencing
Data QC processing	Data QC processing
Analysis workflow	Analysis workflow
Phylogenetics, Bioinformatics	Phylogenetics, Bioinformatics
Data curation & submission	Data curation & submission

Presenting data for policy/action

Tuberculosis

Education summit projects

- Competencies
- Course endorsement
- Trainer resources
- Train-the-trainer
- Going virtual
- Training in LMICs

Development of process for endorsement of courses & degrees by ISCB

Education summit projects

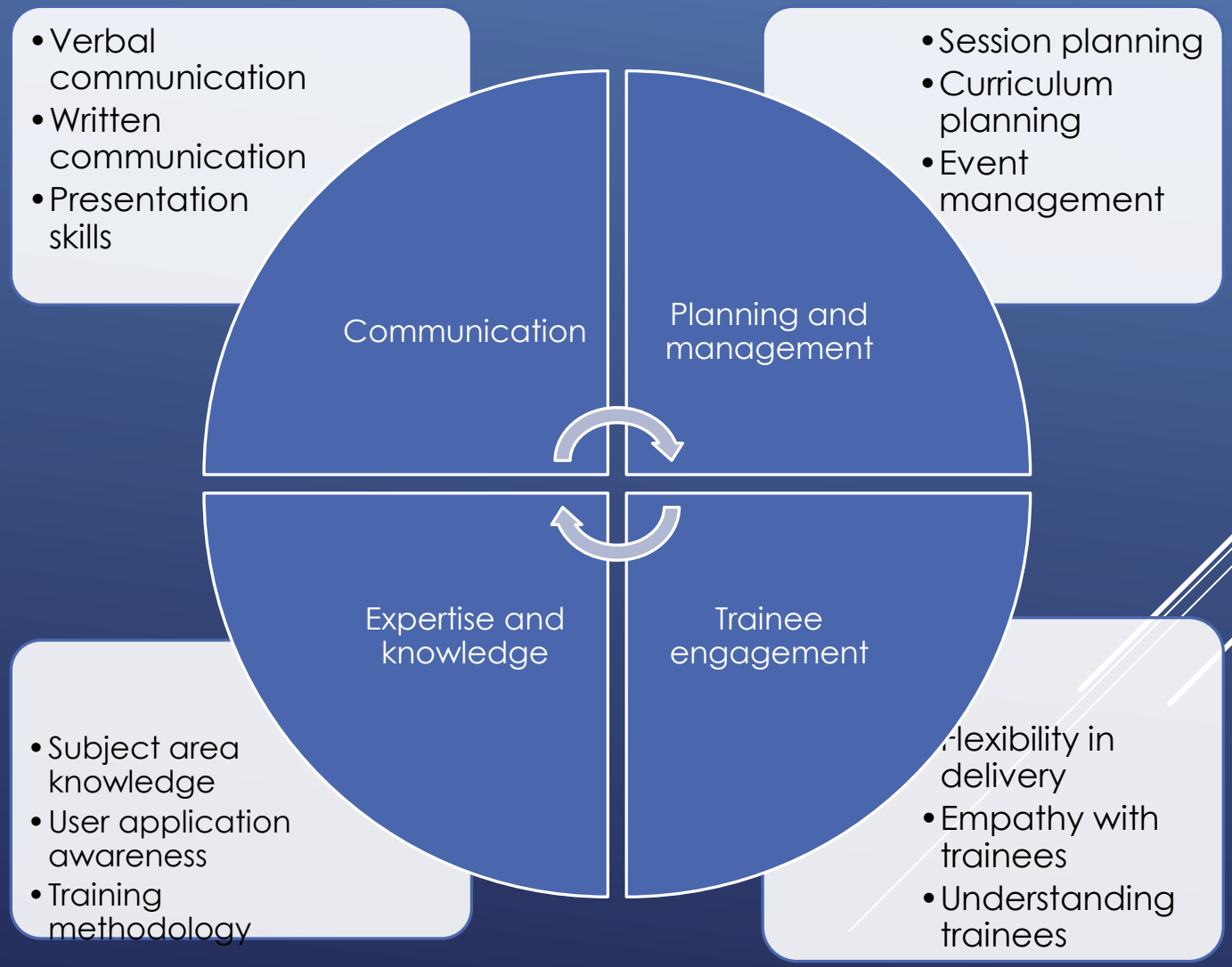
- Competencies
- Course endorsement
- Trainer resources
- Train-the-trainer
- Going virtual
- Training in LMICs

Training trainers in developing & delivering training

Online T-t-T course

- Developing along with EBI, Wellcome Connecting Science
- Building TtT curriculum to be run using remote classroom model

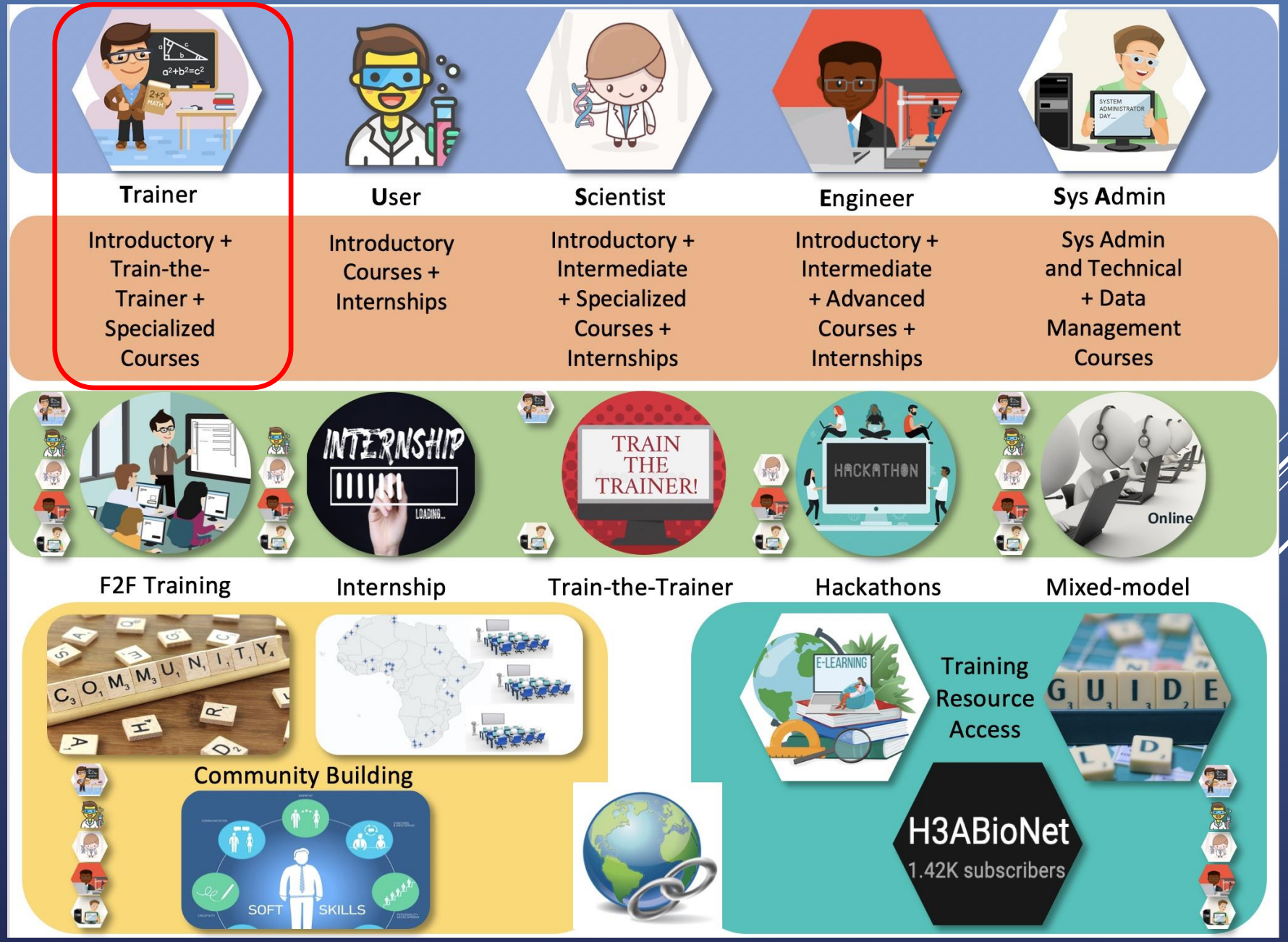
First course will run in November 2022



Course outline

- Week 1: Training theory and practical aspects
  - Theoretical aspects
  - Course design elements and factors
- Week 2: Training design elements
  - Course design Part 1
  - Course design Part 2
- Week 3: Training evaluation
  - Assessment and evaluation
  - Review and feedback of course designs

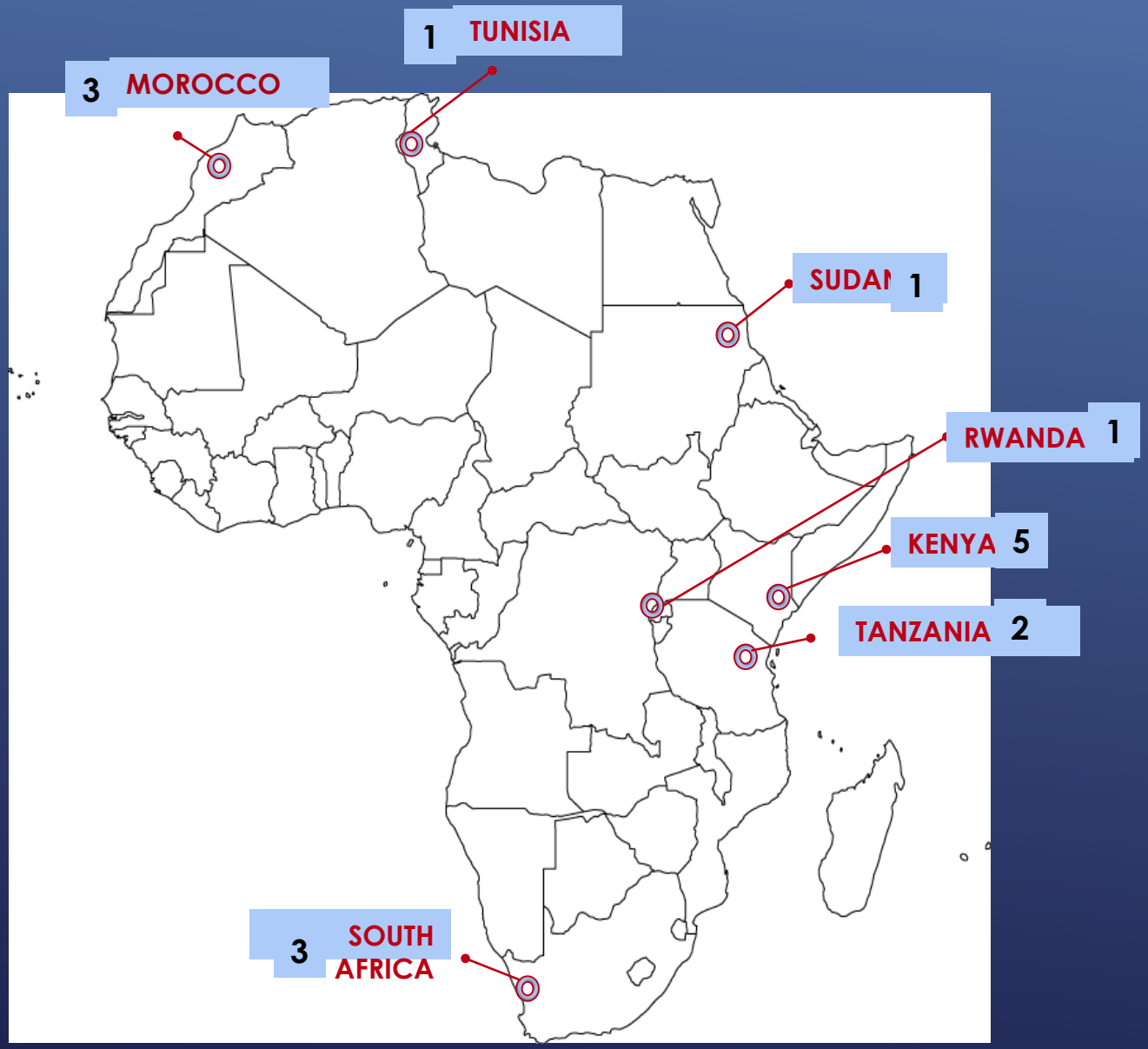
H3ABioNet Train-the-trainer



H3ABioNet train-the-trainer activities

- **Focused on developing local trainers throughout by:**
  - Dedicated T-t-T courses and events
  - Building faculty from trainees to TAs to trainers
  - Train-the-trainer web resources
- **Software & Data Carpentries**
  - Software (Command Line, Python, Git), Data (R, Spreadsheets) & Library Carpentries
  - Build up and foster a community of certified Carpentries instructors within H3ABioNet
  - Teach foundational coding and data analysis skills at local and regional institutions

Carpentries Instructors



KENYA
International Centre of Insect Physiology and Ecology (ICIPE)

MOROCCO
University Mohamed First (MFU)
Institut Pasteur du Maroc (IPM)

SOUTH AFRICA
University of Cape Town (CBIO)

TANZANIA
Muhimbili University of Health and Allied Sciences (MUHAS)

TUNISIA
Institut Pasteur de Tunis (IPT)

SUDAN
University of Khartoum (UofK)

RWANDA
Carnegie Mellon University Africa

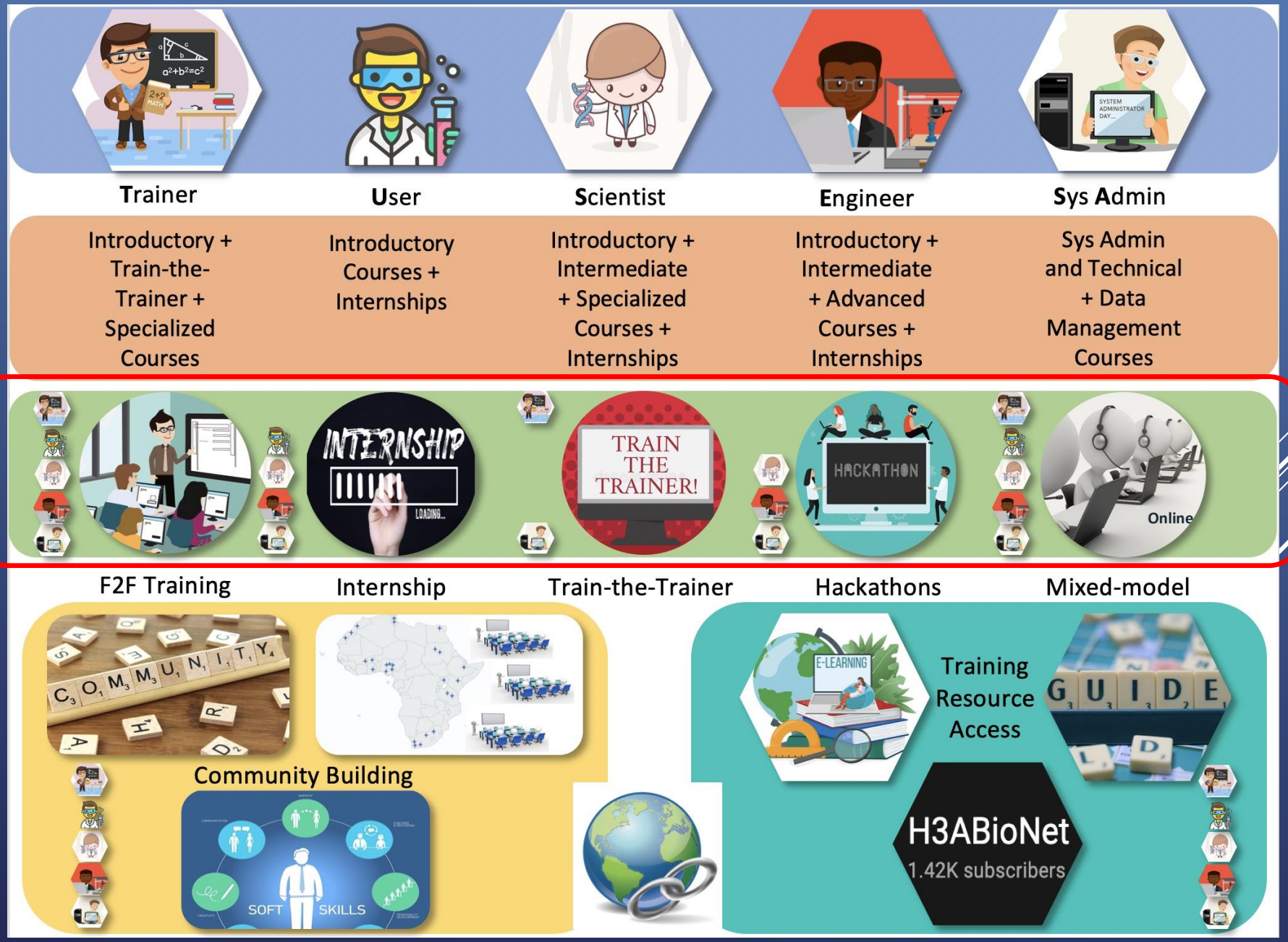
Education summit projects

Tools for delivery; challenges, assessing learning, FAIR

Guidelines; building infrastructure; language barriers, EDI

H3ABioNet Training Environment

Going virtual

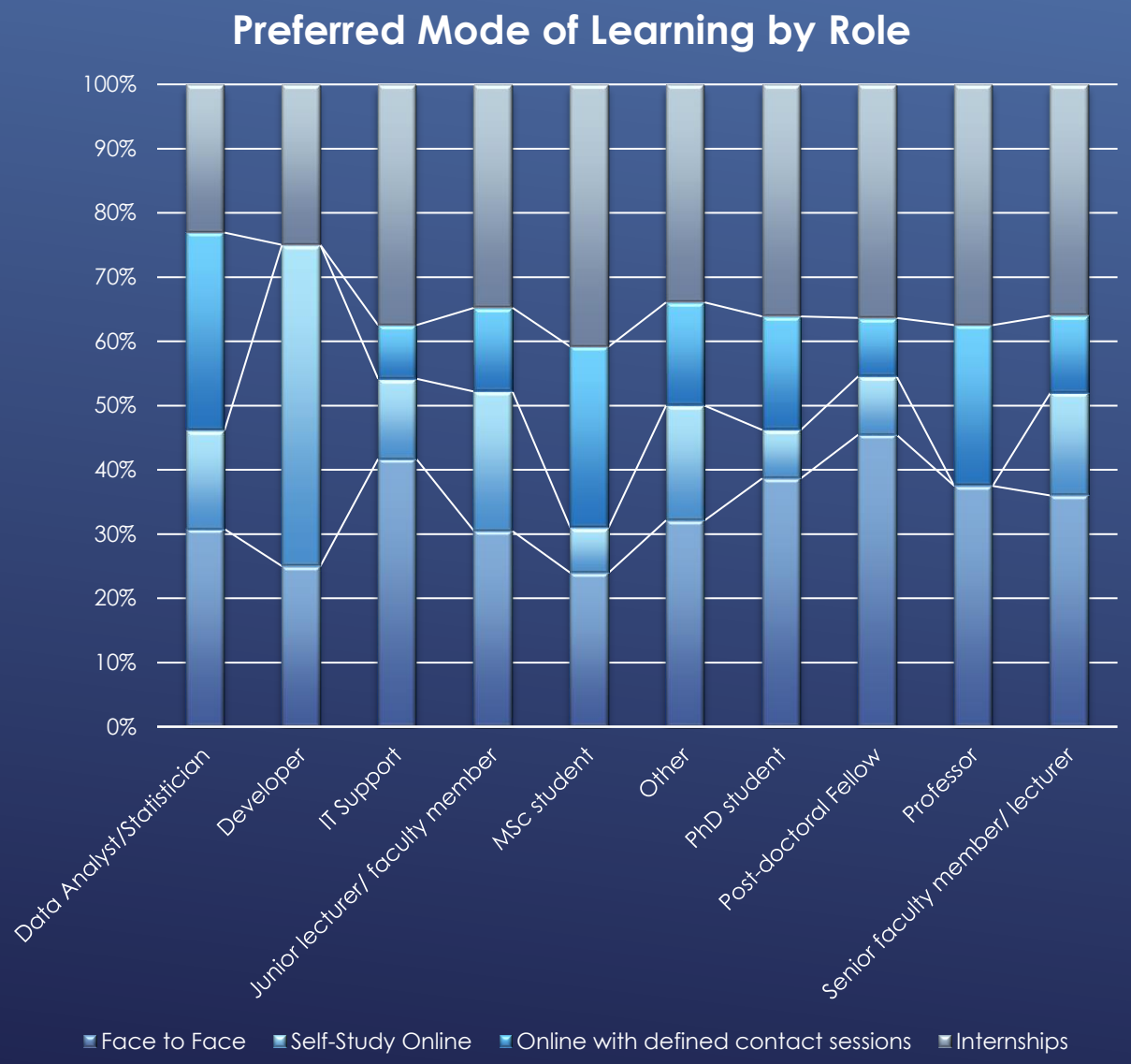


Slides: Shaun Aron

Training mode challenges

Online Training	
Pros	**Cons**
Cost efficient	Challenge to foster sense of community
Reach a large audience	Challenge to form collaborations
Easy to share material	
Live Workshops/Internships	
Pros	**Cons**
Dedicated time	Costly/unpredictable logistics
Close interaction	Limited audience reached
Hackathons	
Pros	**Cons**
Defined aims and output	Selection of participants crucial
Develop practical skills	Base knowledge level required
Cross-disciplinary	Limited audience

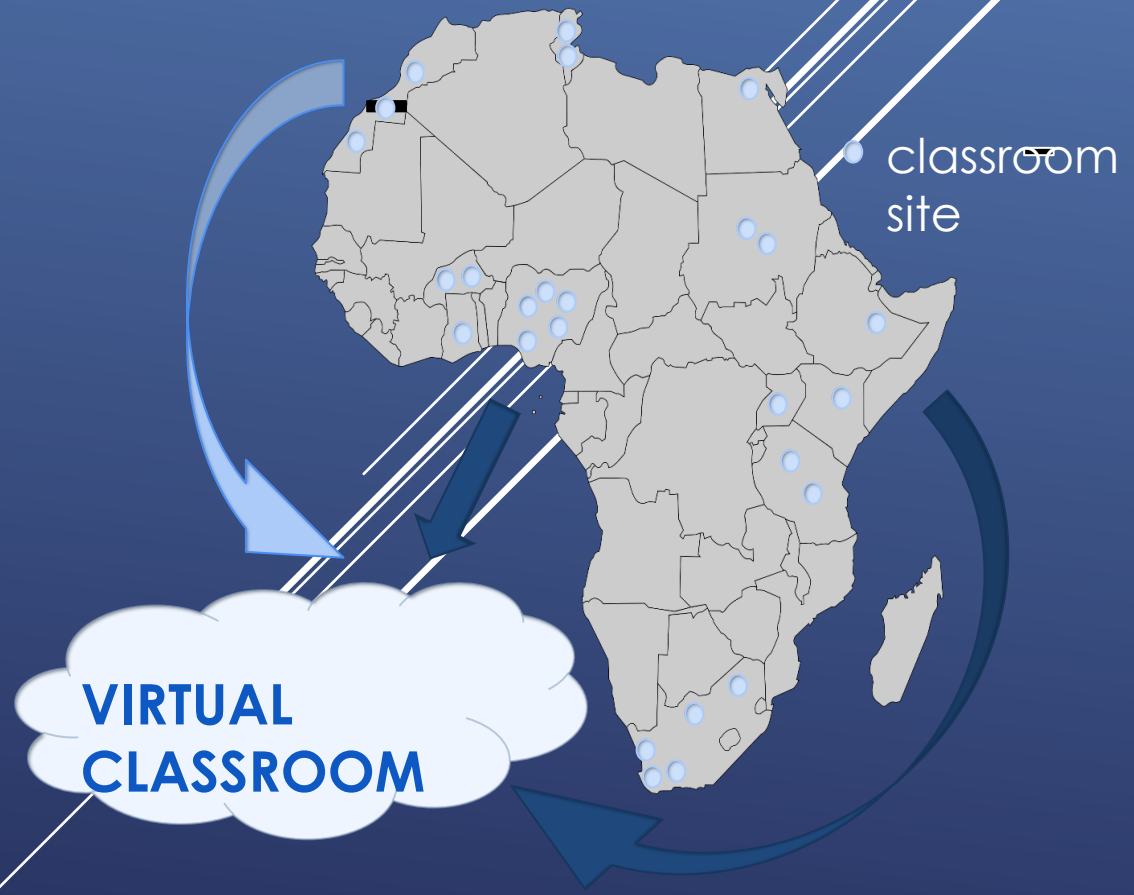
Training mode requests



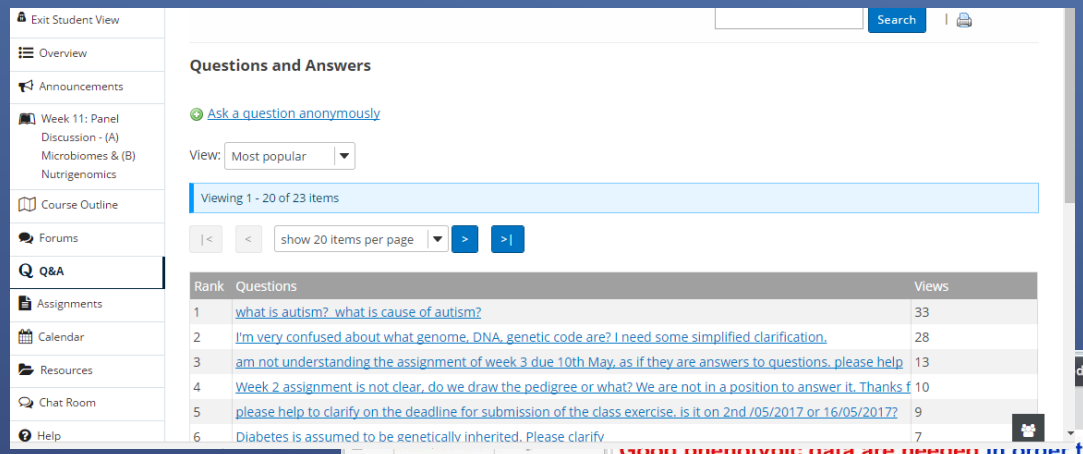
- No optimal mode suitable for all training
- Learning styles differ between individuals from different backgrounds
- Live training events are still the preferred option
- Live online training has proven successful

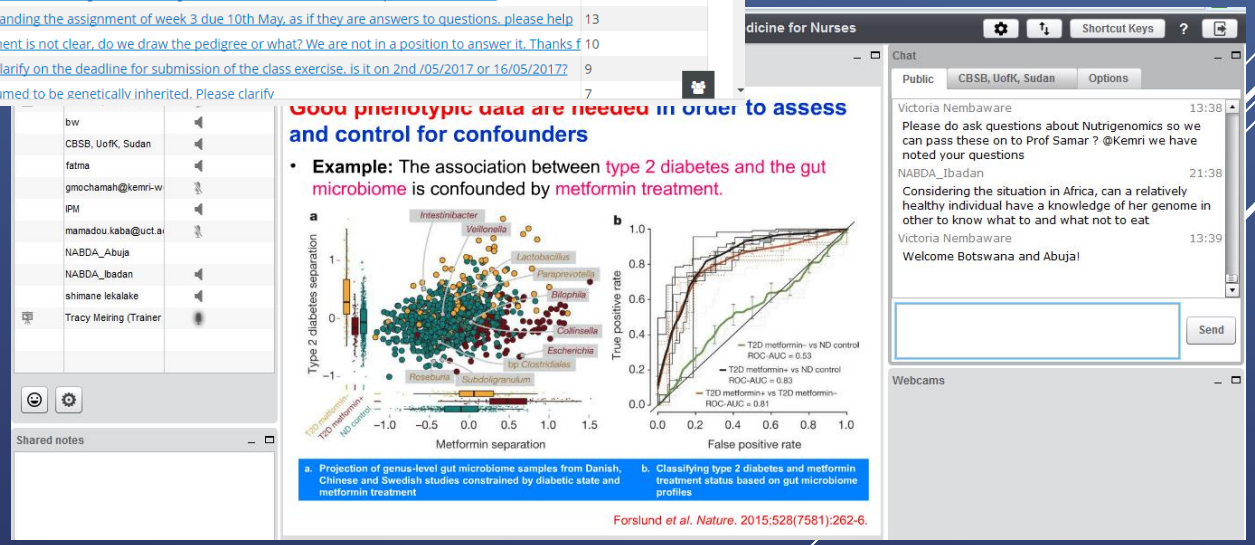
Distributed classroom model

- Run on specific days over 1-2 months,
- set contact time per week (3 hours per contact session)
- Distance learning model – physical classrooms connected to virtual classrooms
- Use video conferencing facility
- Course management system, e.g. Sakai



Remote classroom training





Run successfully for:

- Introduction to Bioinformatics (>1000 participants)
- Intermediate Bioinformatics (~300-400 participants)
- Genomic Medicine

AGMT
AFRICAN GENOMIC MEDICINE TRAINING INITIATIVE

Increasing impact -making training materials FAIR

Use BioSchemas for training courses and materials

Make training accessible to wide audience

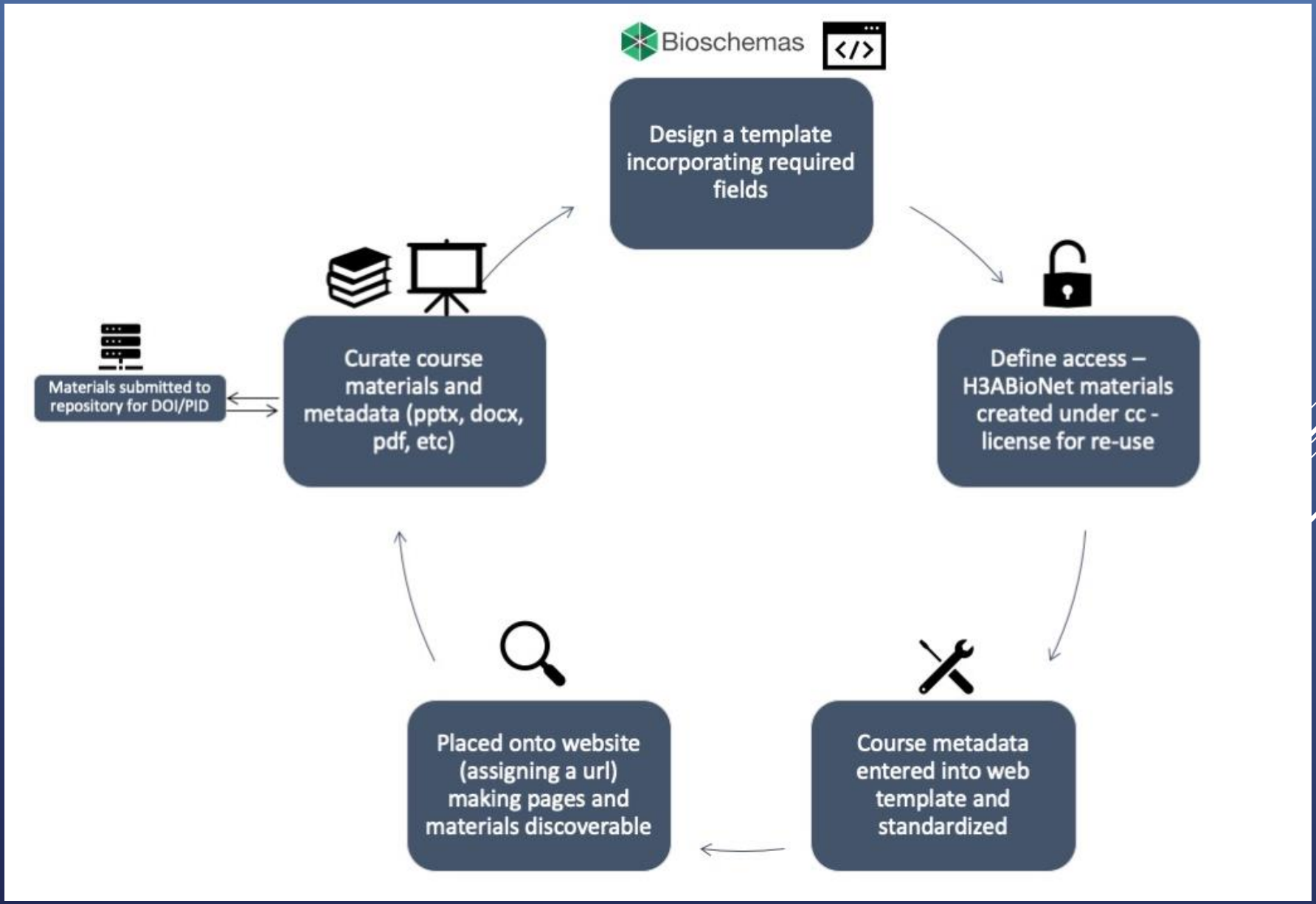
Map training materials to EDAM Ontology

Make training materials findable with license info and available: YouTube, TESS, GitHub etc

Slides: Verena Ras

Curating training materials

Need to curate materials and make them accessible for wider reach



Slides: Verena Ras

Bioschemas example

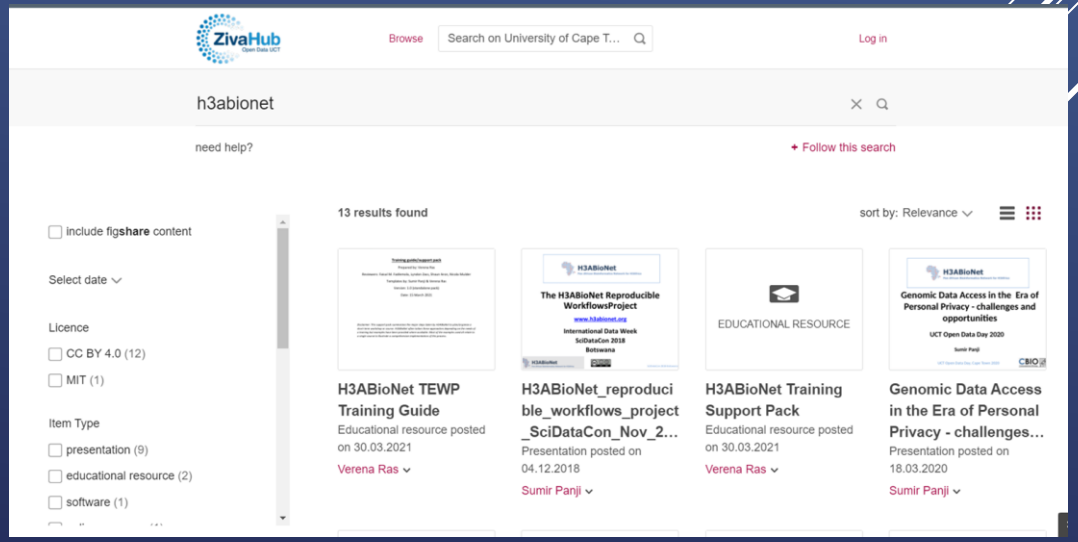
- Making materials/content searchable online
- A lightweight way of structuring data online
- Created by a consortium of search engines to improve experience and search efficacy
- Training:
  - **Course Instance**
  - **Course**
  - **Training Material**

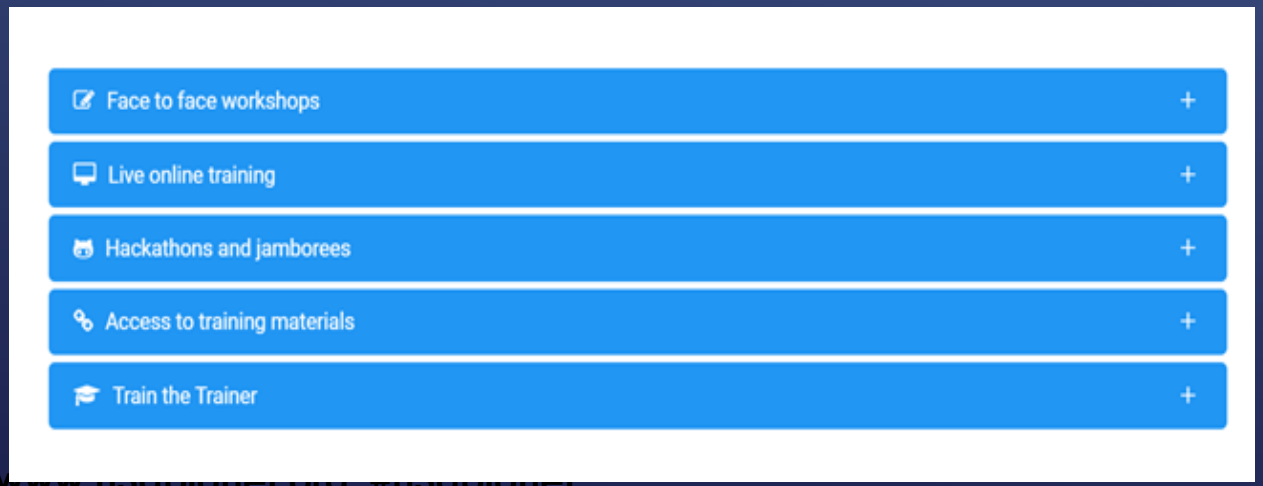
Home | Getting Started | Specifications | Deploy & Develop | Community | About

Property	Expected Type	Description	CD	Controlled Vocabulary	Example
Marginality: Minimum.					
courseMode	Text URL	**Schema:** The medium or means of delivery of the course instance or the mode of study, either as a text label (e.g. "online", "onsite" or "blended"; "synchronous" or "asynchronous"; "full-time" or "part-time") or as a URL reference to a term from a controlled vocabulary (e.g. https://ceds.ed.gov/element/001311#Asynchronous).	MANY	• "online", "onsite" or "blend of online and onsite" • "synchronous" or "asynchronous" • "full-time" or "part-time"	
location	Place PostalAddress Text	**Schema:** The location of for example where the event is happening, an organization is located, or where an action takes place. **Bioschemas:** Location of the Course Instance. If the Course Instance is online, add the connection details as text	ONE		
Marginality: Recommended.					
endDate	Date DateTime	**Schema:** The end date and time of the item (in ISO 8601 date format).	ONE	ISO 8601	

Training Material Curation

- H3ABioNet delivers a range of training courses
- Courses result in a range of training materials that could be beneficial to the community
- Materials currently only located on website, not easy to find or know when to re-use
- Aim to curate training materials and making them more accessible





NGS academy course pages

SARS-CoV-2 Bioinformatics Training

Home
About
Courses
Resources
Contact

Click here for the training survey

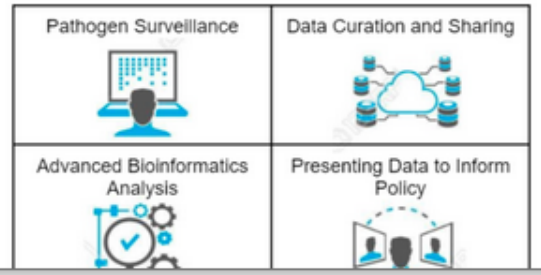
The NGS Academy forms part of the Africa CDC Pathogen Genomics Initiative (PGI). This initiative is funded by the Bill & Melinda Gates Foundation. Our training initiatives are carried out in partnership with the African Society for Laboratory Medicine (ASLM).

Course overview:

The SARS-CoV-2 Bioinformatics Training was a follow-up to our SARS-CoV-2 NGS t the modules was more advanced bioinformatics analysis, data curation and dissemi from SARS-CoV-2 NGS data.

Intended audience:

Personnel of national public health institutions on the African continent, carrying out analyses, and individuals involved in SARS-CoV-2 research.



A pre-course workshop was October 2021. A number of t course were introduced, inclu

1. Unix, command line
2. Git, version control
3. High perfomance computir

1 item se

Course curriculum:

Module 1 Workflows for SARS-CoV-2 analysis
Module 2 Data curation and sharing
Module 3 Advanced bioinformatics analysis
Module 4 Presenting data to inform policy
Recommended materials: Model bioinformatics analysis

Course schedule:

Pre-course workshop | Module 1 | Module 2 | Preparatory sessions | Module 3 | Module 4

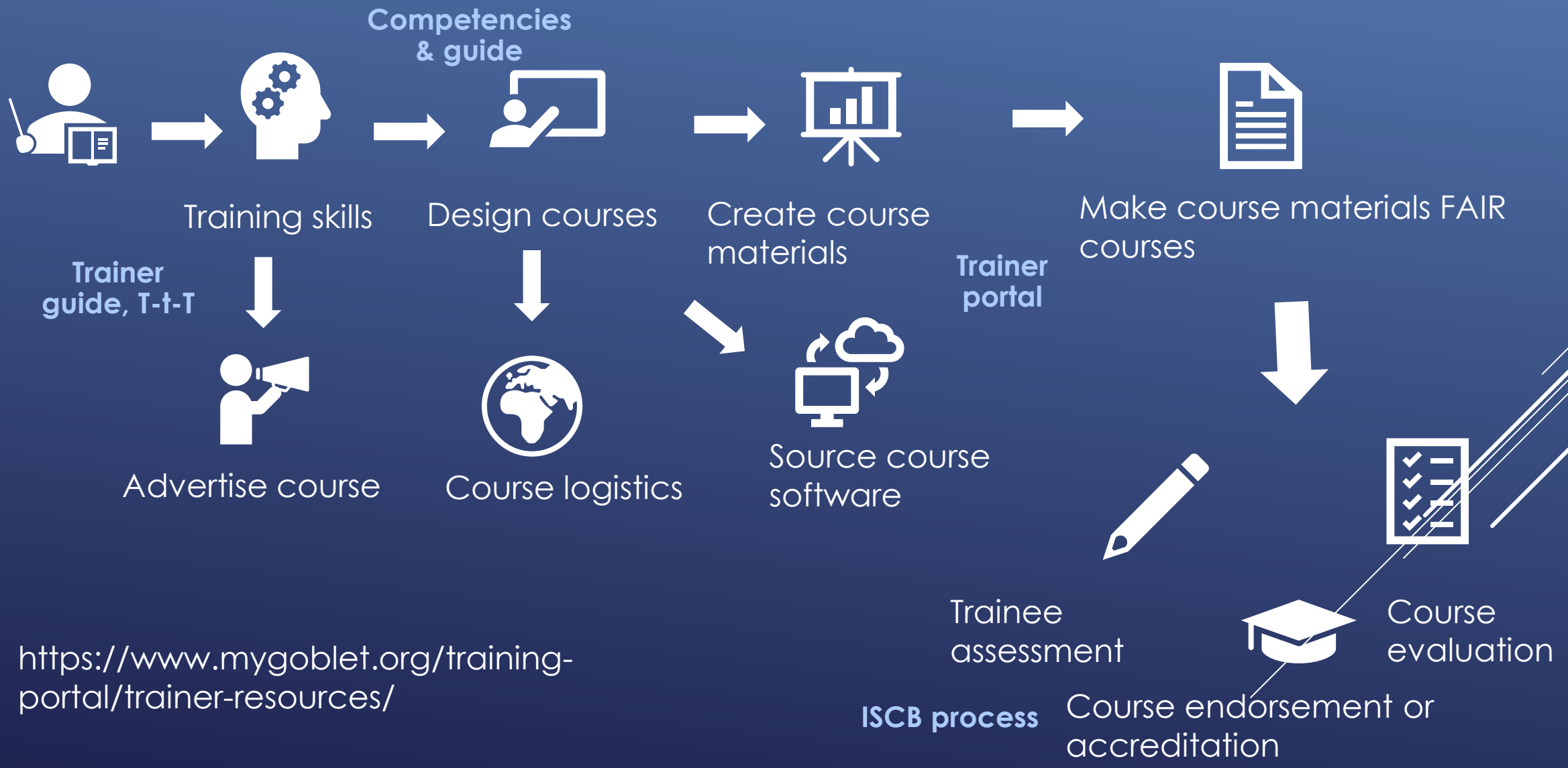
Date	Course materials	Training partner	Interactive Sessions with Instructor/s
5-7 Oct 2021	Unix, command line, git and version control. Introduction to HPC, software containerization, workflow tools	H3ABioNet/The Carpentries	Trainers: Gerrit Botha, Kauthar Omar, Lyndon Zass, Ruth Nanjala, Verena Ras, Ziyaad Parker Helpers: Chaimae Samtal, Nihad Alsayed

Education summit projects

- Competencies
- Course endorsement
- Trainer resources
- Train-the-trainer
- Going virtual
- Training in LMICs

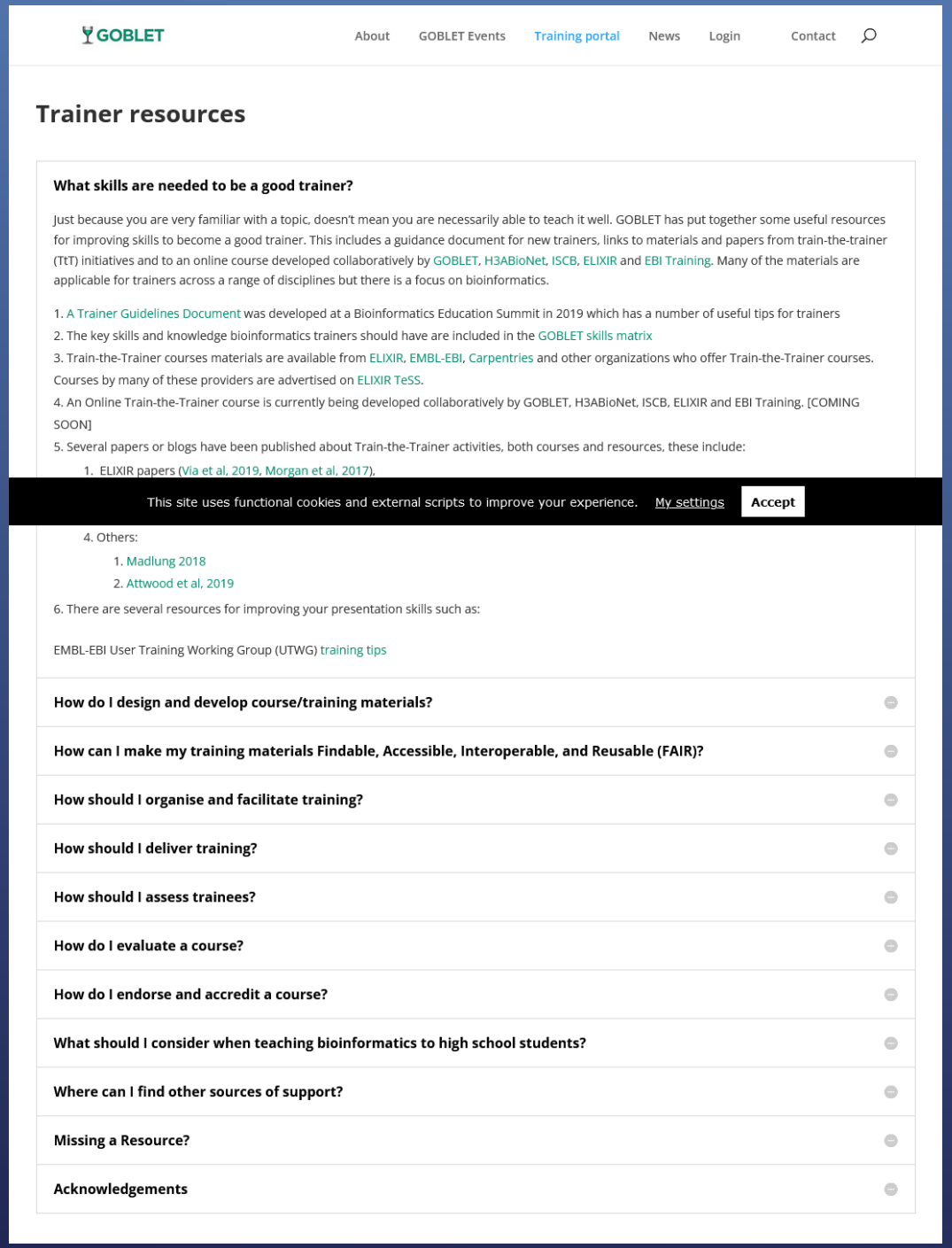
Development of resources to support trainers

Trainer portal



https://www.mygoblet.org/training-portal/trainer-resources/

Trainer portal



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Trainer resources

What skills are needed to be a good trainer?

Just because you are very familiar with a topic, doesn't mean you are necessarily able to teach it well. GOBLET has put together some useful resources for improving skills to become a good trainer. This includes a guidance document for new trainers, links to materials and papers from train-the-trainer (TtT) initiatives and to an online course developed collaboratively by GOBLET, H3ABioNet, ISCB, ELIXIR and EBI Training. Many of the materials are applicable for trainers across a range of disciplines but there is a focus on bioinformatics.

1. A Trainer Guidelines Document was developed at a Bioinformatics Education Summit in 2019 which has a number of useful tips for trainers
2. The key skills and knowledge bioinformatics trainers should have are included in the GOBLET skills matrix
3. Train-the-Trainer courses materials are available from ELIXIR, EMBL-EBI, Carpentries and other organizations who offer Train-the-Trainer courses. Courses by many of these providers are advertised on ELIXIR TeSS.
4. An Online Train-the-Trainer course is currently being developed collaboratively by GOBLET, H3ABioNet, ISCB, ELIXIR and EBI Training. [COMING SOON]
5. Several papers or blogs have been published about Train-the-Trainer activities, both courses and resources, these include:
    1. ELIXIR papers (Via et al, 2019, Morgan et al, 2017),

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    4. Others:
        1. Madlung 2018
        2. Attwood et al, 2019
6. There are several resources for improving your presentation skills such as:

EMBL-EBI User Training Working Group (UTWG) training tips

How do I design and develop course/training materials?

How can I make my training materials Findable, Accessible, Interoperable, and Reusable (FAIR)?

How should I organise and facilitate training?

How should I deliver training?

How should I assess trainees?

How do I evaluate a course?

How do I endorse and accredit a course?

What should I consider when teaching bioinformatics to high school students?

Where can I find other sources of support?

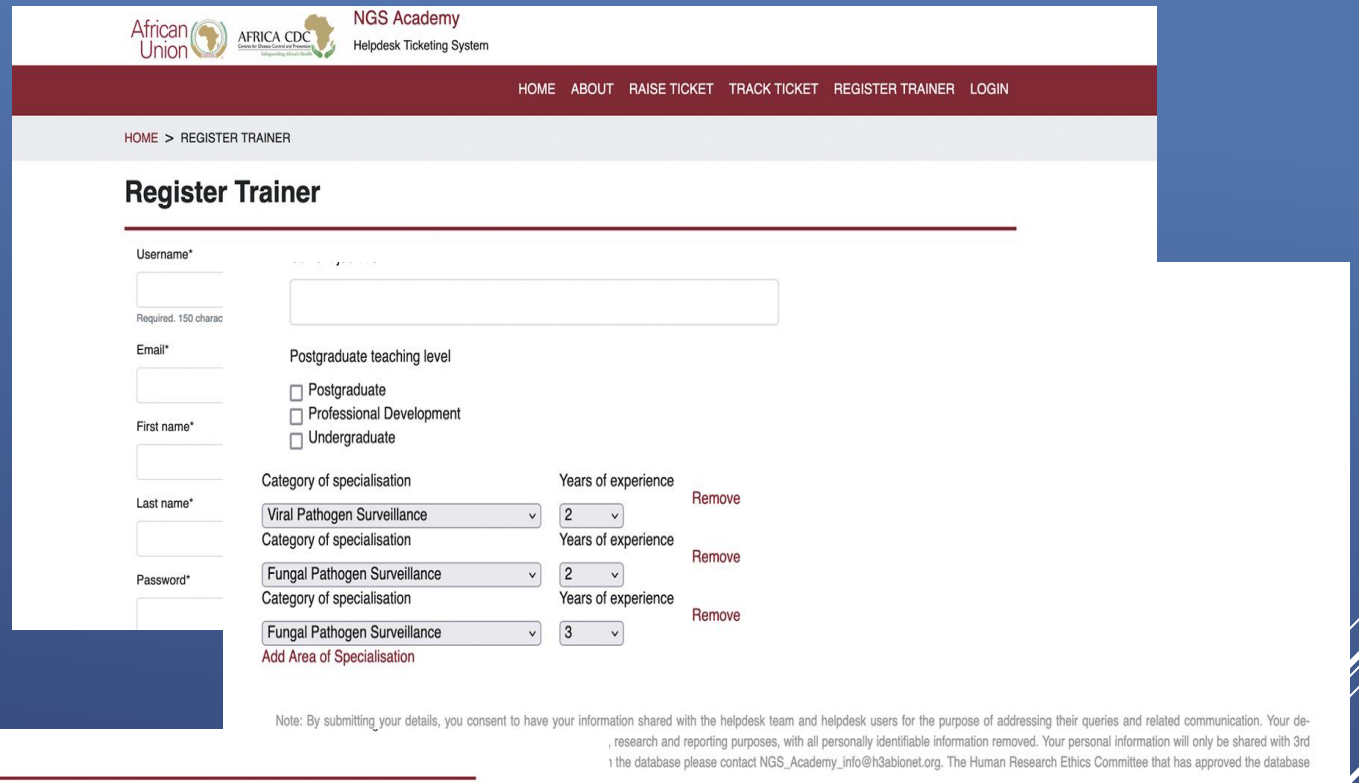
Missing a Resource?

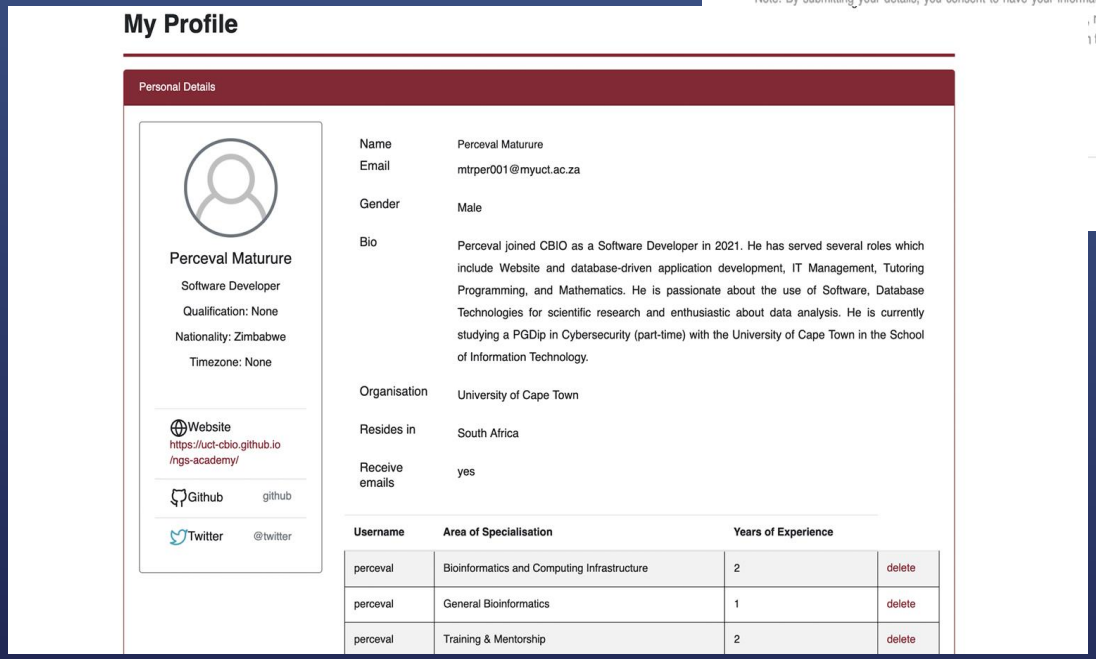
Acknowledgements

Additional resources

- Need to identify suitable trainers
- Requests for longer term support
- Requests for mentorship

- Trainer Database





Additional resources

- Need to identify suitable trainers
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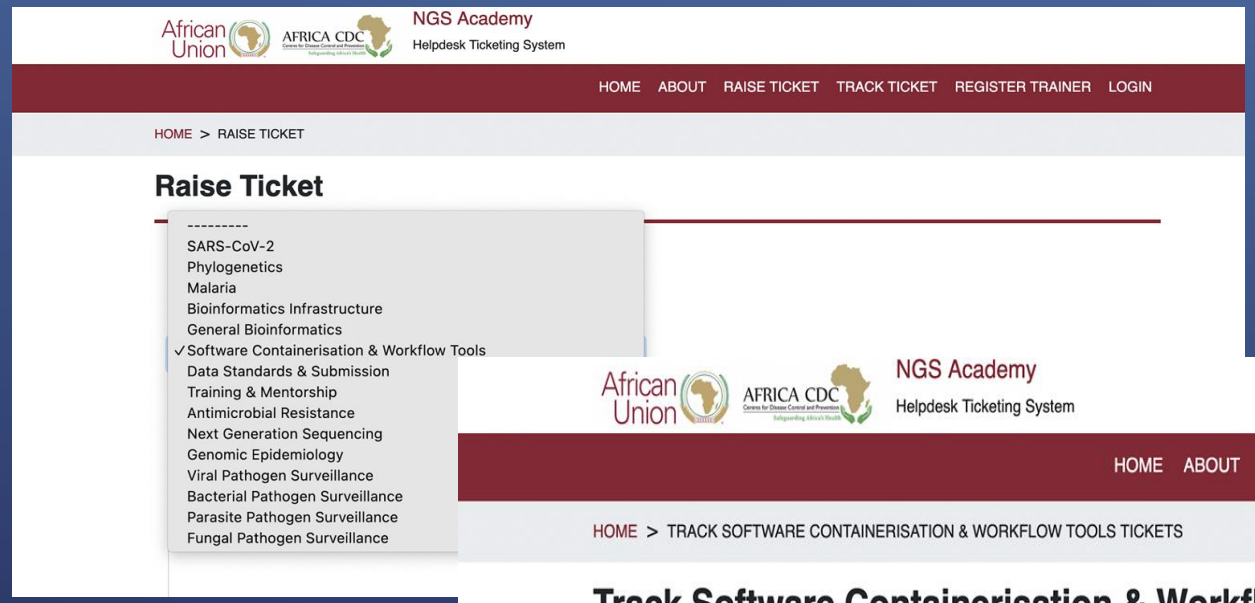
- Requests for mentorship

- Trainer Database

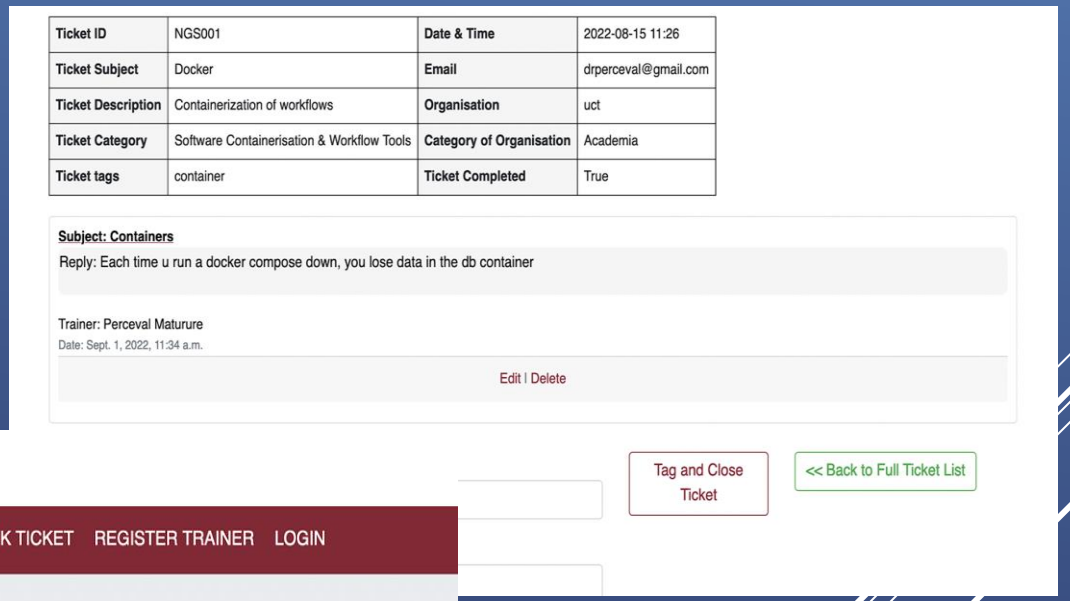
- Trainee Helpdesk

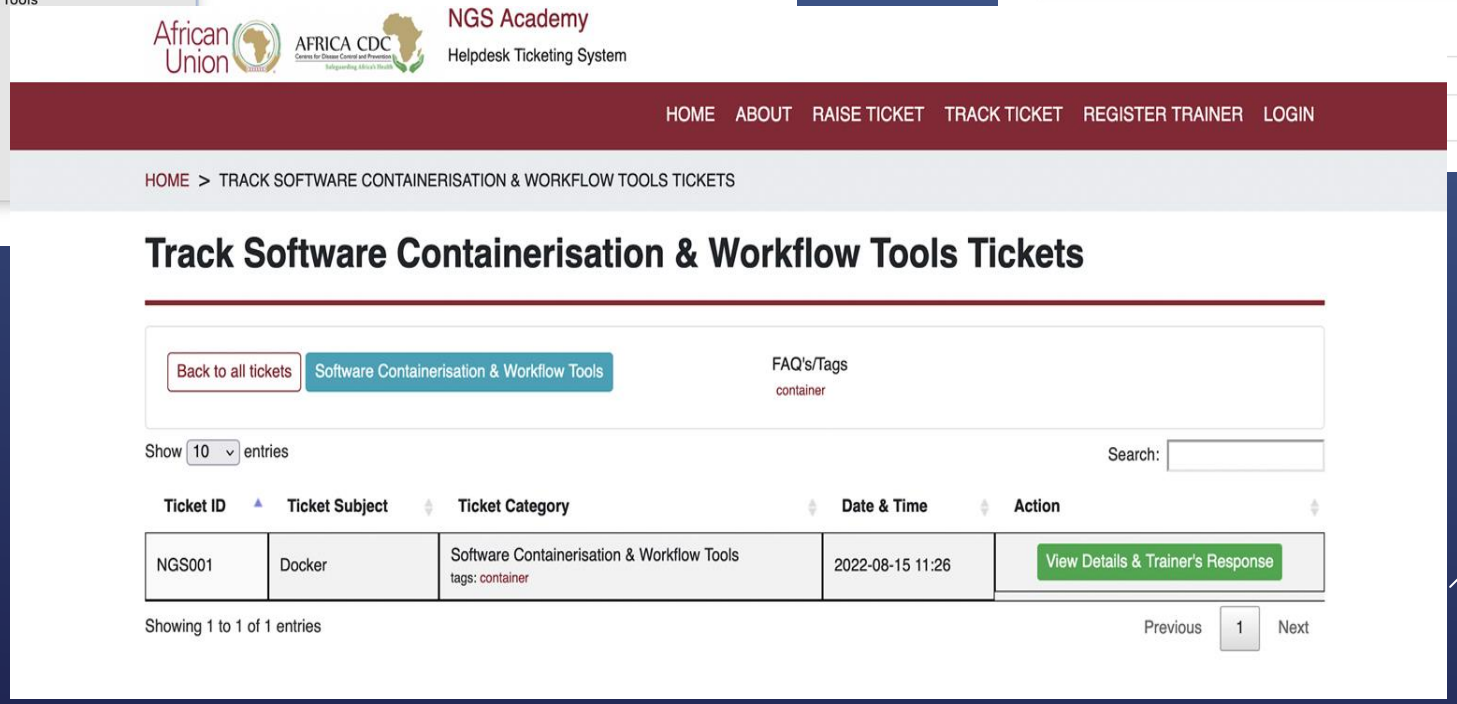
Helpdesk/Trainer database

Submitting a helpdesk ticket



Trainer responses & the knowledgebase





Other useful resources

- Training guide & support pack

H3ABioNet TEWP Training Guide

Cite | Download (1.58 MB) | Share | Embed | + Collect

Version 1 (old) Educational Resource posted on 30.03.2021, 09:20 by Verena Ras , Sumir Panji, Faisal M. Fadlemolma, Shaun Aron, Lyndon Zass, Nicola Mulder

H3ABioNet Training Support Pack

Cite | Download (1.14 MB) | Share | Embed | + Collect

Version 2 Educational Resource posted on 30.08.2021, 11:32 by Verena Ras, Sumir Panji, Nicola Mulder, Faisal M. Fadlelmola, Lyndon Zass, Shaun Aron

- Starting Bioinformatics from scratch
- Building infrastructure and training in LMICs

OPEN ACCESS

EDITORIAL

Ten simple rules for organizing a bioinformatics training course in low- and middle-income countries

Benjamin Moore, Patricia Carvajal-López, Paballo Abel Chauke, Marco Cristancho, Victoria Dominguez Del Angel, Selene L. Fernandez-Valverde, Amel Ghouila, Piraveen Gopalasingam, Fatma Zahra Guerfali, Alice Matimba, Sarah L. Morgan, Guilherme Oliveira, Verena Ras, [...], Nicola Mulder [view all]

Published: August 19, 2021 • https://doi.org/10.1371/journal.pcbi.1009218

Challenges and Considerations for Delivering Bioinformatics Training in LMICs: Perspectives From Pan-African and Latin American Bioinformatics Networks

Verena Ras[1], Patricia Carvajal-López[2], Piraveen Gopalasingam[2], Alice Matimba[2], Paballo Abel Chauke[1], Nicola Mulder[1], Fatma Guerfali[3], Victoria Dominguez Del Angel[4], Alejandro Reyes[5], Guilherme Oliveira[6], Javier De Las Rivas[7] and Marco Cristancho[8]*

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