Discussion panel on education and training.

Geoff Baldwin – Chair – Imperial College

King L. Chow – HK UST

Elaine Shapland – Amyris

Jamey Whetmore – Arizona State University

Sven Panke – ETH

Maria Mercedes Roca – Zamorano University

The above panel members commented on a series of questions and responses were then invited from the audience. Below are the contemporaneous notes that were made both from the panel and audience comments. The initial questions are **bold** and the panel responses are bullet pointed, subsequent discussion is in red. All comments are unattributed.

At what level should SynBio be taught?

- Undergraduate Level- From 1st year ug to 5th year Masters,
- School level? – It is a good subject to engage kids with since it is so interdisciplinary.
- At every level- because people exit education at each level, so people from each level should be able to discuss or understand synbio.
- Science is too compartmentalized. High school students should be more open to newer, multi-disciplinary fields as this will enthuse students. It will also demonstrate to students why they should study the different disciplines because they will begin to see the connections between them.

Wouldn't students benefit from studying basic sciences first and only approaching synthetic biology when they have good knowledge of the foundations?

- Interdisciplinary studies are not for everyone, but the option should be open.
- Fundamental training is necessary. For SynBio, people should be exposed to Engineering tools. A new mix for the initial stages of the undergraduate training.
- We cannot all be experts in all fields so some degree of specialisation is inevitable. As stated above, exposing students to interdisciplinary studies earlier will make them realise why they need to e.g. keep up with maths.
- Problems today cannot be solved with individual disciplines.

Science (esp. Biology) at school is too boring. So, an exposure to more inspirational research would result in more students choosing science as a career choice.

How much biology does an engineer need to know to study synthetic biology? & How much engineering does a biologist need to know to study synthetic biology?

- Absolutely essential to expose biologists to engineering
- Important for communication in interdisciplinary workplaces
- Both engineers and biologists can focus on specific problems, but it is necessary to have a general knowledge over wider fields
- There are different languages, goals, reward systems between different disciplines. There is thus a need to find common ground.
- Expectations from engineers are more defined as compared to those from biologists. Biology is much broader.

It would be a mistake to force biology on engineers and vice versa.

You don't need an engineering background to do SynBio. Engineering students are pushing for synbio because they feel that they are missing out.

Is it harder for an engineer to become a synthetic biologist?

- Engineers deal more with principles, harder to deal with the degree of memorisation.
- Practical techniques difficult for engineers to adopt?

- Engineers are confounded by how unpredictable biology is.
- Biologists have a long way to go to learn systematic thinking.
- Biologists could adopt collaboration as a standard practice.

At Imperial- students from different backgrounds are brought together to study synbio and this helps to break down interdisciplinary barriers at a relatively early stage in peoples career.

Has iGEM changed the way that we engage with the educational process?

- It has been very successful in bringing problem based learning into biology and enabling students to be creative
- Involves students in defining objectives, finding new problems and solutions for projects.
- It's very impressive how iGEM has led to collaborations between different students, faculty, and universities.
- Learning by doing. Introduced students to new skills. The iGEM approach helps educators promote problem driven, student oriented teaching.

iGEM has brought fun into Genetic Engineering! It allows for a greater degree of creativity.

iGEM is an excellent way to teach problem-solving but it does not provide a solid foundation for study in the didactic sense. A synthetic biology course cannot be taught by iGEM alone, but needs to be supported by additional materials. E.g at Imperial the undergraduate course has a drylab, wetlab, and lectures before the students in groups do a 2 week mini-iGEM project, which has modelling but no wetwork.

Helps biology and engineering students interact.

It is good to give students ownership of a project as this encourages their engagement.

Are different training/skills required for industrial and academic careers? What skillsets do synthetic biologists possess?

- iGEM teaches project management. In academia you are responsible for everything while in industry you are still responsible but you also need

to communicate and collaborate with other people as projects are delivered by teams of people rather than individuals. Industry requires more interpersonal skills and the ability to let go.

- Project and People management is an essential part of corporate life
- Engineers tend to have well defined career paths, but synthetic biologists, more like life scientists have more a broader range of career options.
- Training required to prepare students for life in corporations/industry. To what extent can these skills be taught?
- An engineering label for synthetic biologists could be a good thing once people understand what it means in the same way that they know the skills an electrical or mechanical engineer will have.

Need to teach competencies not facts. 50% credits in the classroom and 50% in the field. Skills and facts change all the time. Principles and competencies remain the same.

Facts are terribly important in a knowledge based world.

We should appreciate the difference between education and training. Training teaches you how to do a specific task right now, but education provides skills and competencies that last a lifetime.

Education in the US has morphed into a reflection of what employers want to the detriment of the educational experience.

Other skills?-

How can we integrate social aspects of SynBio in the curriculum

- Faculty collaboration is very important. Develop skills to communicate with others about the social aspects.
- It should be taught to someone who's coming into industry, even though it is not an essential part of the 'job description'.
- Scientists definitely need to understand regulation.
- Courses in regulation, entrepreneurship will exist/already exist in engineering programs.
- You can't escape values, science is a social practice.

The question is not framed appropriately since it should already be integrated as part of the teaching

- The fact is that in many, if not most, sciences courses taught in the UK there is not ethical or social teaching incorporated into the curriculum

Several social scientists in the room shared their stories of how they have compulsory ethical or social science classes where the students are clearly disinterested in the topic (traffic school); it is scheduled in graveyard slots; it brings together people from different disciplines and attempts to ask common ethical questions when the practices are very different across disciplines.

- It is challenging to engage students who think it is not relevant. Collaborations between the educator and a scientist to help frame appropriate perspectives can be instructive. Use of humour always helps.
- Instead of having stand-alone, all-encompassing ethical or social science lessons these should be integrated with subject areas to provide relevance and context.
- Teaching these aspects within a synbio course is useful because context is provided.
- Use of the DEMOCS exercise for synbio is a good way of having student discussion led learning that is more effective that lectures. Additional reading material can be provided for follow on self-study.

How important is it to teach communication between disciplines and with external people/media etc.

- Essential. It is also a process whereby people realise that they have to learn each other's vocabulary and be patient.
- Realistic and frank communication is very important
- Everyone should have an elevator pitch
- Trying to involve everyone in all situations is not a good idea

What tools and mechanisms can we use to share resources/ ideas/ etc.

- Openwetware?
- Syllabus exchange programs – in many fields these are organised by professional bodies

- Massively Open Online Courses

There was some discussion about whether it would be a good idea for there to be an effort to coordinate sharing of resources for the facilitation of teaching, best practice and encouraging more places to teach synthetic biology. It was generally agree that this would be a good thing and that either the Biobricks foundation or iGEM could be good organisations to provide the professional coordination required.