SATW INFO

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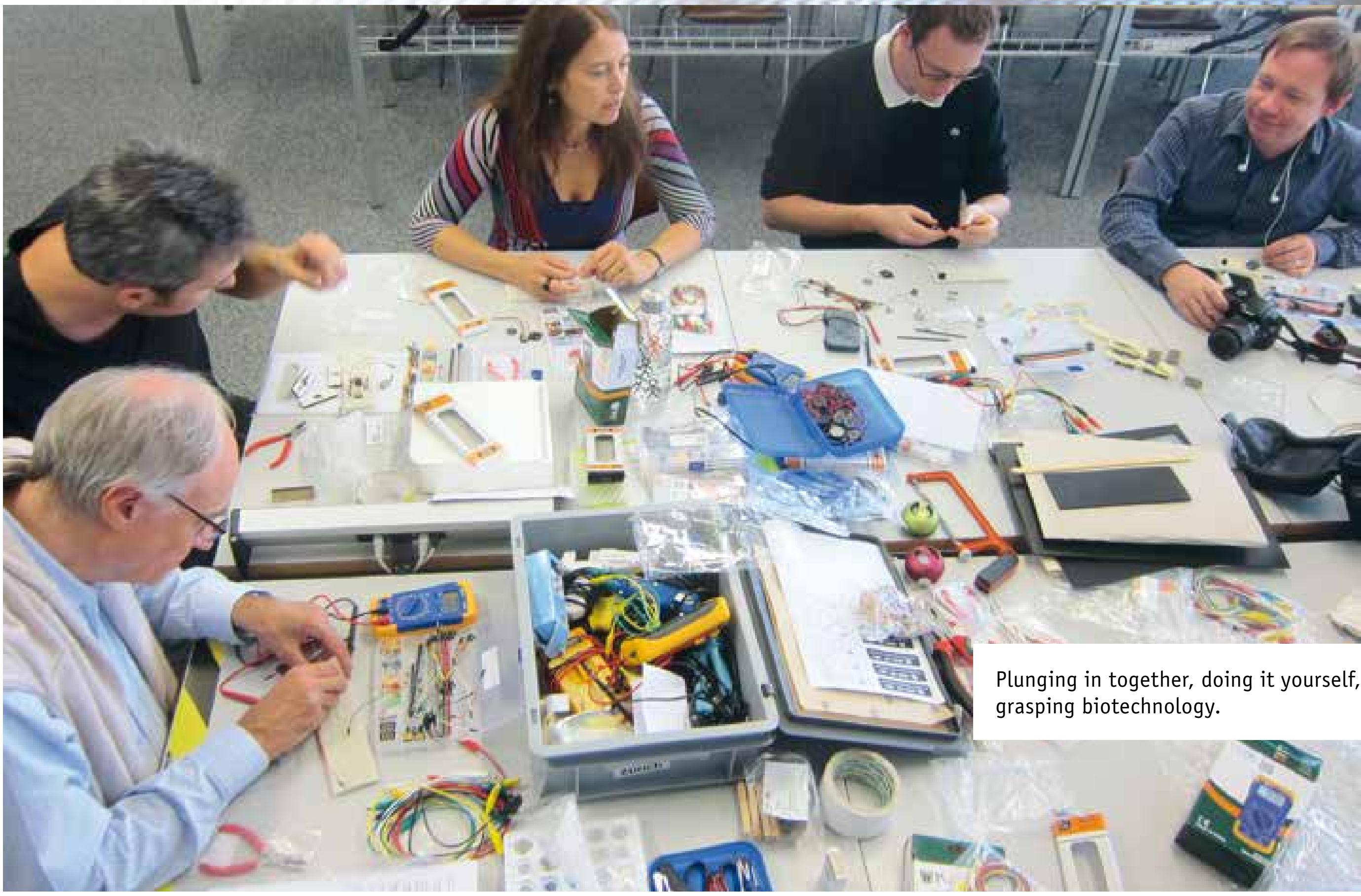


Plunging in together, doing it yourself, grasping biotechnology.

Biotechnology for all

Biotechnological research is no longer limited to specialist laboratories: a growing community of biologists, amateur enthusiasts and technophiles is experimenting in kitchens, workshops and DIY laboratories. Some people view the democratisation of biotechnology as a threat, others as an opportunity to gain a better understanding of complex scientific interrelationships within society.

A few years ago, something which occurred in software development in the early 1990s also began to emerge in the field of biotechnology: "open source" and "do-it-yourself" ("DIY") strategies are opening up a field of knowledge traditionally occupied by experts, universities and large companies to a broader community. In 2008, a handful of technology enthusiasts in Boston set out to drag biotechnological research out of established institutions into garages and kitchens in urban and rural settings. Since then, Europe, the USA and Asia have seen the emergence of dozens of garage laboratories with scales, mixers, refrigerators and incubators, all purchased cheaply from eBay. Some laboratories are also equipped with homemade bioanalytical devices. Inquisitive laymen and experienced researchers conduct experiments shoulder to shoulder, pursuing personal biotech research projects or simply indulging in the satisfaction of DIY.

Microscopes from cheap webcams

There are several parallel developments behind the boom in DIY biotechnology: the technical components for developing homemade bioanalysis equipment, including microchips and LEDs, have become so cheap that they are now affordable even to non-specialists. With great creativity, DIY biologists use individual components to construct laboratory materials such as spectrometers, microscopes or even DNA sequencing machinery.

Doing research with home-made laboratory equipment in the GaudiLabs. Interdisciplinary teams develop their projects further in short hack sprints.

The strategy of "hacking" is an integral part of this process: cheap, state-of-the-art devices produced for the mass market (such as smartphones) are modified for new functions with laboratory capabilities. For example, the Internet can provide anyone interested with instructions for how to build a computer-compatible microscope out of a webcam for just a few dollars (http://hackteria.org/wiki/DIY_microscopy): the webcam's electronics remain unchanged, with just the position of the lens being altered. A solid platform enables the small objects of study to be fixed in position and precisely focused upon, and the objects are illuminated by an LED.

DIY biology was also spurred on by the new interactive and collaborative opportunities of Web 2.0 and social media: newly founded laboratories soon became networked. DIY biologists share knowledge across the world via blogs. Scientific and technical findings are increasingly not being confined to specialist journals for a professional audience, but are accessible to anyone with an internet connection. In any case, things developed in garage laboratories generally appear online almost immediately, as it is an unwritten law of DIY biology that new discoveries and developments should be shared via the Internet. As in the open source community, copyleft is preferred to copyright. Biotechnological innovations are not to be protected as is the case within commercial companies, but should instead be democratised and disseminated. The online platform "Hackteria.org", for example, provides a wiki for interested readers, listing more than 80 projects including equipment blueprints, software programming code and project descriptions. Last but not least, DIY biology is also an expression of a new, contemporary desire for community DIY. Alongside new collaborative workshops, sewing studios and fab labs with 3D printers, collaborative DIY biolaboratories generally funded by member contributions are also part of this trend.

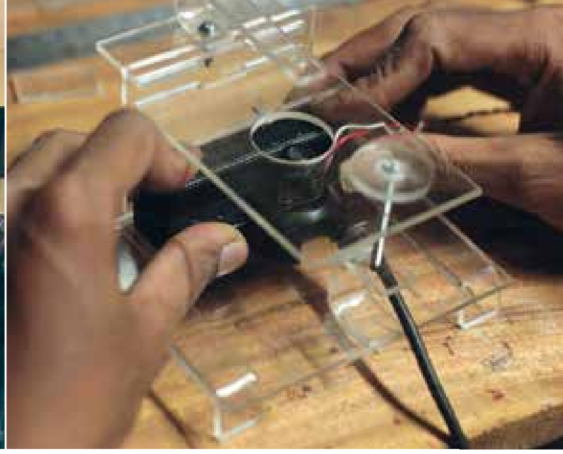
New dangers and limits

However, are there dangers lurking in this democratisation of a technology once only accessible to specialists? Recent years have seen public debate on this issue, particularly in the USA. Some people fear new hiding places for the development of biological warfare agents, or accidents with devastating consequences. Although this may be an exaggeration, it is important not to play down the danger of abuse. The USA has been pursuing a cooperation strategy to counter this: the FBI organises courses for garage laboratory directors and trains them to report suspect members at an early stage (http://ask.diybio.org/).

In many analytical activities, including in the service sector, laboratories are required to comply with national and international rules and standards defining areas such as the choice of methods and instruments. Laboratories also often have to be accredited. However, these are areas which will remain reserved for professional, specialist laboratories.

Potential for developing countries and teaching

Biotechnology and the biological sciences in general are becoming increasingly complex, and DIY biology should not prompt a return to "oversimplification". This means that even simpler approaches must be pursued in a way which is in line with scientific ethics and standards.



Workshops to build a computer-compatible microscope out of a webcam have already been carried out worldwide.

Exponents of DIY biology emphasise that their infrastructure and knowledge are never sufficient to produce dangerous organisms, and above all they have as little interest in doing so as society as a whole. In their view the positive potential of DIY approaches (for example for developing countries) clearly wins out – where the knowledge and money for expensive bioanalytical analysis is lacking, DIY can offer alternatives. For example, last year three inventors from the Netherlands hit the headlines for using a hairdryer, a shoe box and some electronics to develop a malaria detector which has since been refined into a prototype for field use in Africa (www.amplino.org). Despite this refinement, it still remains considerably less expensive than common machines used for quantitative real-time PCR, a duplication method for nucleic acids using a polymerase chain reaction (PCR) to quantify DNA.

Where the knowledge and money for expensive bioanalytical analysis is lacking, DIY can offer alternatives.

However, DIY biologists also see opportunities for teaching in developing countries. Where training budgets are insufficient and access to laboratories and specialist literature is extremely limited, garage laboratories can open up new avenues to learning.

We are also becoming increasingly aware of the opportunities of DIY for teaching. ETH professor Gerd Folkers recently wrote the following in an essay entitled "The meaning of grasp": "'Understanding' and 'grasp' are nowadays wrongly used as synonyms. Grasp means […] using the mind and body to interpret an object – and this is precisely what is required for us as physical beings to form a picture of the world around us." Unlike "understanding" which can be a purely mental process, "grasp" has a physical element relating to grasping with the hands. Garage laboratories can be a place for this "grasp", and the DIY approach its philosophy. They are not a place for knowledge to be unidirectionally conveyed from expert to learner, but rather a place where each person can bring their own particular knowledge to the table. New equipment, projects and products are therefore developed within a largely non-hierarchical space, enabling all involved to learn from each other. In a world increasingly imbued with (bio)technology, this form of "grasp" can result in better-informed debate within society on complex topics such as genetic engineering or stem cell research.

The workshop as a space for designing, discussing, exchanging, grasping, weighing and implementing.

DIY in bioanalytics: doing and grasping it yourself

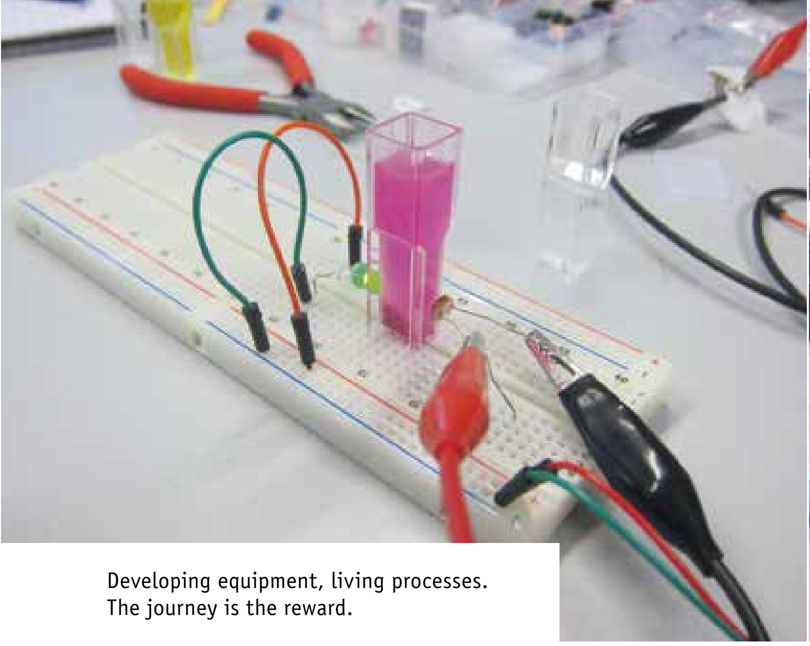
In collaboration with FHNW and the "Hackteria" network, SATW organised a two-day workshop on "DIY laboratory equipment for bioanalytics" in October 2014. The focus of this event was the question of how biohacking and DIY strategies could be used as meaningful teaching units.

On this Thursday afternoon, room 229 of the School of Life Sciences FHNW in Muttenz saw learning of a rather different style. Usually a place where students sit in rows and listen to a professor talking at the blackboard or by a PowerPoint presentation, it instead hosted seven workshop participants as they constructed a temporary biotechnology laboratory. It could have been Gyro Gearloose's workshop: strewn across numerous tables pushed together were screwdrivers, glue guns, multimeters, laptops, test tubes, forceps, tiny LEDs, wires and digital displays. A small wet area had been set up in one corner with pipettes, photometer lenses, PVC gloves and a sack of potatoes. The blackboard in front of the tables was adorned with chemical formulae and electrical circuit diagrams.

Learning from biohackers

The aim of the two-day workshop was to incorporate the strategies of DIY biology and globally popular garage laboratories into scientific teaching. Daniel Gygax (Professor at the Institute for Chemistry and Bioanalytics at FHNW), Marc Dusseiller (co-founder of the DIY biotechnology network "Hackteria") and Urs Gaudenz (Lecturer in Product Innovation at HSLU and a member of Hackteria) worked together with SATW to design a teaching unit for subsequent testing on a group of experienced biohackers, students and interested non-specialists.

> The aim of the workshop was to incorporate the strategies of DIY biology into scientific teaching.



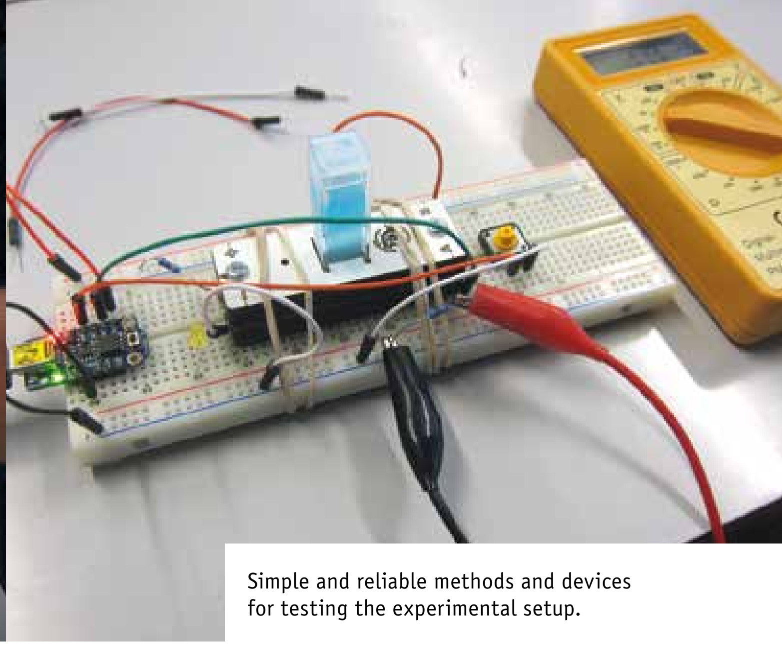
Developing equipment, living processes.
The journey is the reward.

The workshop consisted of several closely interlinked modules. The course organisers deliberately chose to include interaction between theory and practice as well as thematic introductions to electronics, biology and measurement techniques. The participants were thus constantly being asked to try new ideas and combine them with what they had just learned. Participants were also required to physically move about the area and continually form new groups. It was a conscious decision not to hold the course in one of FHNW Muttenz's many biotechnology laboratories, as constructing your own laboratory is a key element of the DIY philosophy. The aim was to increase participants' curiosity and make them aware that high-tech infrastructure is not required to perform bioanalytics.

Phosphatase activity text with potatoes

In the first thematic portion, the group received a crash course in electronics and were then asked to perform experiments using simple electronic components such as light-emitting diodes (LEDs), button cell batteries, resistors and multimeters. This was followed by initial work in the kitchen laboratory, where participants learned how natural enzymes are isolated and concentrated. They peeled and chopped potatoes, pressed them with a garlic press, and then separated the liquid from the solid elements using filter paper. Via pipetting, this potato extract was then used to create a dilution series which would enable a phosphate activity test to later be performed with para-nitrophenyl phosphate. The phosphatases catalyse this colourless substance's breakdown into para-nitrophenol, which is yellow and can therefore have its concentration spectroscopically measured (with a wavelength of 405 nm). Using the quantity of para-nitrophenyl phosphate added and the quantity of para-nitrophenol measured, it is then possible to determine phosphate activity.

> Constructing your own laboratory is a key element of the DIY philosophy.



Simple and reliable methods and devices for testing the experimental setup.

Next came a technical portion, known as rapid prototyping: using their introduction to electronic engineering, the participants constructed DIY measuring equipment to analyse the dilution series previously created. Possible designs were discussed, and each person was able to assemble a personal measuring instrument using the materials available. The aim of this "trial and error" experimentation was ultimately to successfully create a stable measurement setup consisting of a cuvette holder, stray light protection, power supply and measurement electronics. The DIY biologists were then able to use this simple setup to measure phosphate activity in the potato extract.

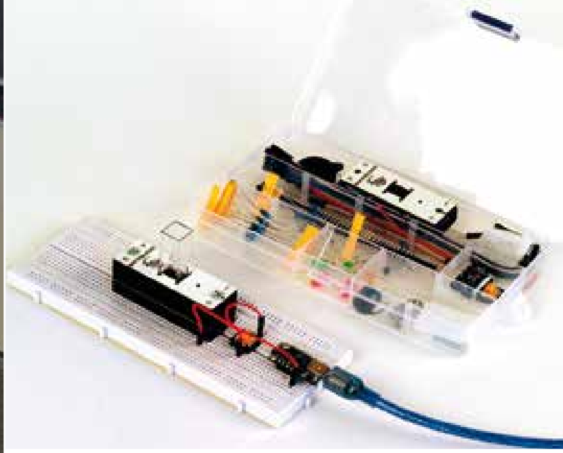
We were constantly exchanging ideas and comparing our findings. Everyone participated, regardless of how much they already knew about DIY biology.

To explain the principle of spectrometry and calibrations, the measurement setup was combined with a theoretical element where participants learned the essentials of how to translate measurement results. They also received an introduction to the Beer-Lambert law on the attenuation of light's radiation intensity according to the material which is absorbing it.

Experienced workshop participants went a step further and converted their setup to enable them to display and analyse measurement results from the homemade spectrometer on their laptop. This was made possible by easily programmable microcontrollers based on Arduino.cc's open hardware environment, as currently used by many engineers and amateur enthusiasts. The controller was linked directly with the laptop via a USB connection and operated using open source software from the internet.

Insight into the black box

At the end of the second workshop day, the group discussed its results together. The event organiser also asked for feedback on the process and difficulties of a DIY approach. It became clear that some participants had wanted a little more theory of electronics and biology, whilst others appreciated the "hands-on" approach with a particularly strong focus on DIY. A frequent comment was that the lack of clear instructions and the availability of various tools and components had helped to boost each person's creativity. For co-organiser Urs Gaudenz, the learning atmosphere during the workshop was particularly unique: "we were constantly exchanging ideas and comparing our findings. Everyone participated, regardless of how much they already knew about DIY biology." Gaudenz did not view himself as a workshop leader, but instead as a "facilitator", someone to facilitate the processing of a particular piece of knowledge. He and his colleagues suggest having three such facilitators per workshop, ideally complementing each other across disciplines: one with specific knowledge of bioanalytics or molecular biology,



A little tired, but with the certainty of having created and understood something.

another with electrical engineering or hardware-specific programming skills, and a third with experience in interdisciplinary projects and peer-to-peer learning methods.

Daniel Gygax has now incorporated a DIY bioanalytics course into the sixth semester of the Molecular Life Science programme at FHNW. He views this in particular as an opportunity to put the various forms of preparatory specialist training in chemistry, biology and engineering to use to benefit teaching. "The huge advantage of the DIY approach is that students gain a sense of what bioanalysis equipment contains and what components are required to perform bioanalysis measurements", says Gygax. "They view these instruments as more than just a black box." One student in the group was convinced that this practical, self-directed form of learning would go down well with his colleagues. This was confirmed by feedback from the first regular DIY bioanalytics course, which was overwhelmingly positive.

> The huge advantage of the DIY approach is that students gain a sense of what bioanalysis equipment contains.

However, this form of teaching also places enormous demands on organisers: "it is vital that the teachers engage in the process of joint research and learning", Marc Dusseiller emphasises, "as only this will ensure that participants' knowledge is incorporated into the course as much as possible, a prerequisite for successful learning".

DIY teaching handbook

The experiences gleaned from the "DIY laboratory equipment for bioanalytics" workshop were compiled into a handbook, containing potential learning sequences, schedules, materials lists, theory and software codes. The handbook and further information regarding other workshops are available free of charge to all teachers and interested individuals at **http://hackteria.org/education/satw/.**

For further information on the activities of the DIY biotechnology network Hackteria, visit
http://hackteria.org

DIY biology – further information

GaudiLabs, Luzern, DIY Labor-Instrumente
http://www.gaudi.ch/GaudiLabs/

wetPONG – Laborkurse mittels DIY Methoden zu Themen der Mikrofluidik und Nanotechnologie, FHNW
http://wetpong.net/

BioHack Academy – Open Wetlab @ Waag Society, Amsterdam
http://waag.org/biohackacademy

BIO-DESIGN for the REAL WORLD, hosted at School of Life Sciences at EPFL and Hackuarium, Renens:
http://biodesign.cc/
http://hackuarium.org/

MIT Media Lab (eg. Lifelong Kindergarten and others):
http://www.media.mit.edu/

Public Lab: a DIY environmental science community
http://www.publiclab.org/

J.M. Pearce, Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs, Elsevier 2014
http://www.appropedia.org/Open-source_Lab

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