

# *Virtual Labs: An investigation in to the future of the teaching labs*

## **I. Objectives**

- As part of the investigation for the Collaborative Teaching Lab project,
- Define what a virtual lab is and its requirements;
- Review current technologies and development methodologies used in virtual labs in STEM subjects (STEM- science, technology, engineering and mathematics);
- Survey and compare other competitors' and our implementation of virtual lab;
- Feedback and discussion from the mini conference of the future of the teaching Labs

## **II. Virtual labs**

### **Demands**

The demand for virtual lab is growing with the development of online learning. Online lectures by video are fine for conveying facts, formulas and concepts, but they can't give students experience in planning an experiment and analysing data, or exercising any of the other practical and social skills essential for success in science. Researchers and lecturers are seeking new ways to teach the practical skills especially in the STEM subjects (STEM- science, technology, engineering and mathematics).

As part of the investigation for the Collaborative Teaching Lab project, virtual lab is not only a measure to enhance the teaching and student experience in learning practical skills but also provides a new means for remote students to participate in lab.

### **Definition**

The demand for virtual lab is growing with the development of online learning.

Online lectures by video are fine for conveying facts, formulas and concepts, but they can't give students experience in planning an experiment and analysing data, or exercising any of the other practical and social skills essential for success in science.

The virtual laboratory is an interactive environment for creating and conducting simulated experiments: a playground for experimentation. The Virtual Laboratory empowers students to create information on the internet by collecting it from the physical world. Remote computer access to laboratory instruments allows students to conduct actual experiments at any time and from any location. This technology greatly enhances the flexibility of laboratory education, and introduces students to the new paradigm of remote experimentation.

### **Main Features**

Depending on the purpose and functions of virtual lab, it may vary slightly different in layout and presentation. However there are a few key features in common:

- 1) It is usually based on an online platform offering accessible experiments to students.
- 2) It could be made available to students at anywhere and anytime.
- 3) It is normally designed for one specific subject or course; usually it is a virtual simulation of a science process or explanation of the topic.
- 4) It may or may not involve remotely controlled instruments, however the experiment data and process are collected from the real world experiments;

### **Benefits**

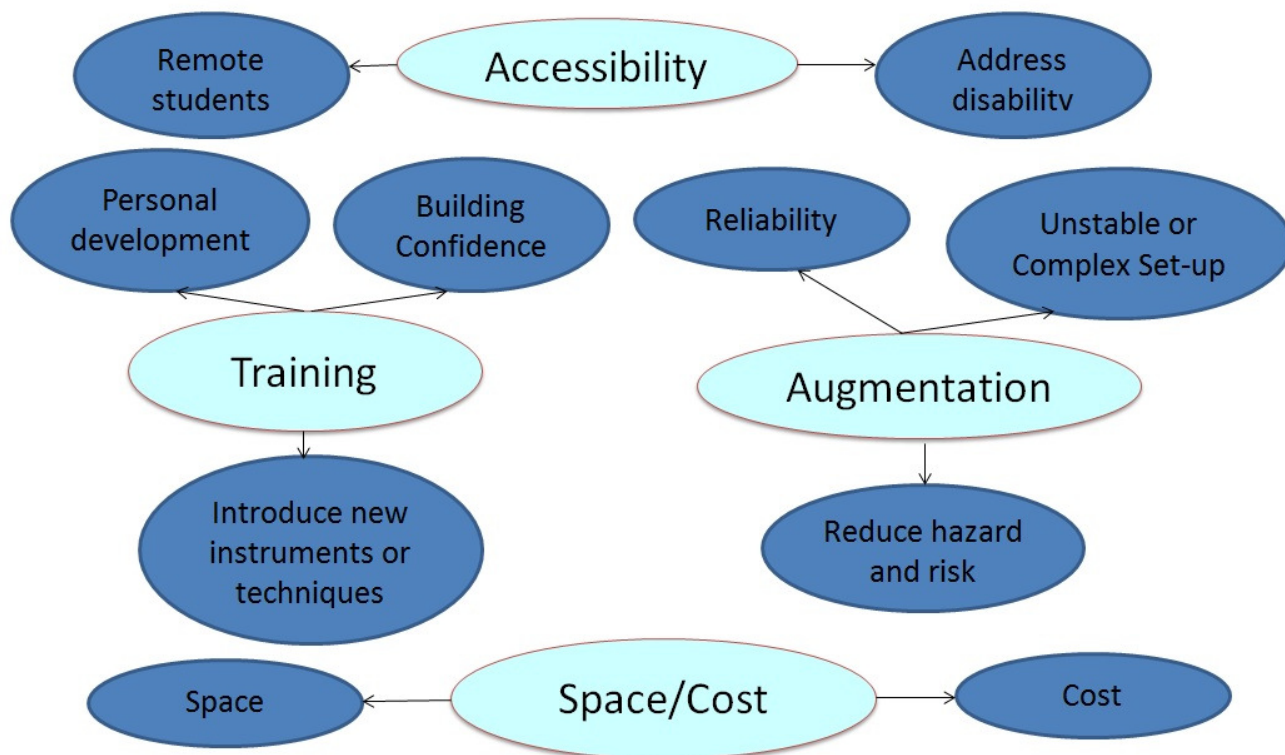


Figure 1 Benefits of the Virtual Lab

### III. Survey of Labs in UOB

#### Chemistry Lab

Pre-lab:

Current:

1. Lab material was uploaded to Canvas by lecturer: material includes lab instructions, some guided video of the specific lab equipment and a quiz to get students familiar with the lab;
2. Students will read the lab material on Canvas, and will be required to pass the quiz before go into the real lab;

Potential:

1. More interactive lab content, eg. Virtual lab, flash content....
2. Virtual lab material integrated within canvas;
3. Virtual lab material should be multiplatform supported.

In-lab:

Current:

1. Demonstrator (normally post graduate students) will give a short introduction of the lab, and any health and safety measures; demonstrator will also supervise and help during the lab;
2. Students wearing suitable lab gowns, glasses, gloves doing the lab;
3. Printed copy of lab instructions, student took notes of the lab result on the lab notebook;

Potential:

1. Interactive guide showing on monitor/screen;
2. Student can refer to the lab instructions on mobile tablet if needed;
3. Student taking notes on mobile tablet;
4. Lab note management application potentially (?)
5. Mobile/video of the lab process if necessary;

Post-lab:

Current:

1. Lab notes book submitting to the lecturer/demonstrator;

Potential:

1. Electronic lab notes submitted to the lecturer/demonstrator;
2. Integrated marking in Canvas

## Pharmacy – Virtual lab – Sam Butterworth

Back ground of Pharmacy lab: new pharmacy lab built from Sept 2012. The MPharm degree combines the study of the science underpinning the pharmacology, synthesis, development, formulation and production of medicines, together with the study of related law, ethics and health science in order to optimize medicines usage for patients. For the first year student, fundamentals in the pharmaceutical sciences, including cell biology, physiology, and pharmacology, along with the basic principles of pharmaceutical chemistry, which underpin the formulation and synthesis of drugs. A real lab of sub purpose will cost 3 million, so a virtual lab choice is made. Virtual lab is about 2 years old now.

A URL of Virtual lab is sent to all students, students are required to do the virtual lab in the Pharmacy lab building with Peer Collaboration. Lecturer will provide help/instructions if necessary. Currently the ratio of lecturer to students is 1:40. It would be much lower ratio in the real lab.

MPharm virtual lab is not integrated with Canvas. Canvas has issues with displaying flash items. And users login in are not authenticated through Canvas. Students access the virtual lab through URL sent by lecturers. The virtual lab results can be collected through the lab itself (provides statistics results etc.)

MPharm virtual lab is designed using Articulate Story Line 2. It is completely web based. Potentially could be devices independent, further testing needed (as the publishing method)

MPharm virtual lab is collaboration by lecturers (subject expert) and technology specialist. The design method is the subject expert produces the content by PowerPoint for instance, and the technology specialist transfers the content into moving objects, using quiz, select and drop etc. methods, converting the content into an experiment process. The correlation between these objects can create different experiments. From the subject expert's point of view, these objects are 80% re-useable in Pharmacy content, possible some content can be re-useable in a related subject – such as “Chemistry”. No real data is collected in this virtual lab.

MPharm lab URL

[http://mymds.bham.ac.uk/rainger\\_demos/MPharm/P1-Lab/story.html](http://mymds.bham.ac.uk/rainger_demos/MPharm/P1-Lab/story.html)

[http://mymds.bham.ac.uk/rainger\\_demos/MPharm/P2-Lab/story.html](http://mymds.bham.ac.uk/rainger_demos/MPharm/P2-Lab/story.html)

[http://mymds.bham.ac.uk/rainger\\_demos/MPharm/P5-Lab/story.html](http://mymds.bham.ac.uk/rainger_demos/MPharm/P5-Lab/story.html)

[http://mymds.bham.ac.uk/rainger\\_demos/MPharm/P6-Lab/story.html](http://mymds.bham.ac.uk/rainger_demos/MPharm/P6-Lab/story.html)

Findings & improvement for the future:

1. More mathematics involved – users will be able to change the parameter. There is no direct method in Articulate, need to create a flash object and embed in the web pages.
2. Using an open ended method: not only one concrete answer to one particular question. Provide potentially multi choices answers during experiment and the possible scenarios may grow exponentially during the whole experiment.
3. get technique specialist back ( his contract was not renewed ) : a new way of teaching, from online courses (MOOCs) to virtual labs ( teach practical skills in online environment) , those content delivery needs the collaboration of subject expert and technology specialist

Nomination for the Best learning game, simulation or virtual environment in Learning Age Awards 2014

(<http://www.elearningage.co.uk/shortlist/category1.aspx>)

The University of Birmingham (UoB) has successfully delivered the first year of a new 4 year MPharm program to 80 students. The highly innovative integrated curriculum design includes a module on chemistry for pharmacists in the first year. The module is delivered through lectures, small group teaching (SGT), online learning resource and five 3-hour “practicals”. The programme is jointly accredited by the University and the General Pharmaceutical Council (GPhC) who are the professional regulators that allow graduates to clinically practice.

## IV. Survey of Virtual Labs in Other Universities

### Case Studies in UK:

#### 1. Open University: OpenScience laboratory

The OpenScience Laboratory is an online laboratory for practical science teaching. It is funded through a £1m grant awarded by the Wolfson Foundation. The laboratory features investigations based on on-screen instruments, remote access experiments and virtual scenarios using real data.

Several activities are available to all, while others are available only to registered users.

OpenScience Laboratory experiences include:

- **remote access to laboratories and observatories:** students can operate real physical equipment controlled remotely – a method already established in astronomy
- **virtual laboratories and instruments, such as the virtual microscope:** interactive screen experiments will include photo-realistic recordings of physical experiments and replicate the behaviours of real specimens
- **online field investigations:** these can involve electronic access to a conventional field trip or offer a virtual experience using satellite-borne and remotely-operated sensors
- **citizen science:** a distributed way of gathering data, where non-professionals collect or process data as part of a scientific enquiry. This data can be combined to offer new insights.

More information is available on <http://www.open.ac.uk/researchprojects/open-science/> .

#### 2. University of Bristol: eBiolabs

eBiolabs is a set of integrated tools that support laboratory based learning. It aims to increase student achievement in laboratories by reducing the cognitive load. It supports many different subjects within the biosciences, including Biochemistry, Physiology, Pharmacology and Neuroscience, Cellular and Molecular Medicine. The initial concept for the Dynamic Laboratory Manual came from the School of Chemistry who developed the first DLM as part of the ChemLabS CETL.

In eBiolabs, for each practical there are three on-line activities:

- i) **Experimental information:** interactive animations or videos are used in this section to explain the background on the methods, techniques and equipment used in the practical;
- ii) **Pre-lab quiz:** ensure that the student has engaged with and understood the Experimental Information.
- iii) **Post-lab assignment:** experiments data are collected in the electronic form

Find out more at <http://www.bristol.ac.uk/ebiolabs/>

#### 3. Birmingham City University : Virtual Case Creator

Virtual Case Creator (VCC) is a web-based software training platform that presents health and social care professionals with highly interactive online practice simulations that can support any aspect of vocational education and training. VCC provides safe and flexible opportunities for learners to develop their clinical, observational, analytical, diagnostic, problem-solving and decision-making skills.

<http://www.bcu.ac.uk/nursing-midwifery-and-social-work/business-and-innovation/e-learning-education-and-training/virtual-case-creator>

### Case Studies outside UK:

#### 1. Howard Hughes Medical Institute – BioInteractive

BioInteractive supports quality science education by providing educators with free resources focused on current research, to clarify important scientific concepts and encourage students a passion for and an understanding of the scientific process. It provides free multimedia resources for science education, including apps, animations, videos, interactives, and virtual labs. Many of the resources are targeted to a high school and undergraduate audience but can be easily adapted to different levels of instruction.

<http://www.hhmi.org/biointeractive>

## 2. Nectar Virtual Laboratories

The NeCTAR project (National eResearch Collaboration Tools and Resources) is an Australian Government project conducted as part of the Super Science initiative and financed by the Education Investment Fund. It aims to enhance research collaboration by building information and communications technology infrastructure in Virtual Laboratories, eResearch Tools, A federated Research Cloud; a National Server. In virtual laboratories area, a list of virtual laboratories in

<https://www.nectar.org.au/sites/default/files/2013VirtualLaboratoriesbrochure.pdf>

<https://www.nectar.org.au/virtual-laboratories-1>

## Genetic Science Learning Centre – University of UTAH

Using interactive animated Flash (HTML5) to simulate and explain the process: DNA extraction, Gel Electrophoresis, PCR and DNA Microarray. <http://learn.genetics.utah.edu/content/labs/extraction/>

## V. Discussion and Feedback

As part of the consultations for the Collaborative Teaching Labs project, Feedback from Facilitated Discussion Session was collected as below:

1. To what extent is the Learning Science material future proof?
  - Not entirely: requires modification, technology changing all the time, building support into a development contract
  - Budgeting maintenance costs, requires longer term investment
  - (Other comments about the volume of work required being large, and about how beneficial it is in converting UCAS offers into firms)
2. What elements are unpopular with students
  - Work students harder than they used to, no hiding, completing much more work
  - Manual handling in becomes unpopular when required eg. For MOMD!
  - More realistic experiences - eg having to work harder to find answers rather than following recipe
  - Completing much more work
3. Where do students complete the virtual labs?
  - Bristol - start during freshers week, broadband in halls of residence
  - Mostly preparation for labs they're running anyway, changes what you can do with the lab
  - Learning different skills from practical, manual still in lab (feel and smell)
  - Analytical processes already run from a keyboard so not very different doing it virtually
4. Maintain practical time and improve experience, or is practical time reduced?
  - Making better use of time on the whole
  - Wasn't driven to reduce lab time in Bristol - purpose of preparing them before and assessing them afterwards
  - Employers want students with a generic set of skills, so they can learn again how to do it the way that the company does it - helpful to avoid the recipe following mentality
5. Virtual labs - do they replace or enhance practical sessions?
  - Depends what the skill is - know what you can't do (touch and smell)
  - 24/7 opening hours of online labs!
6. Question: From your perspective, what would be the main dos/don'ts for the teaching labs of the future?
  - Students need to be able to retrieve the dataset from actual/virtual experiment devices to their laptop/tablets etc
  - Bring your own device is the way to go not loan machines as they become out of date plus the update costs
  - Set entry requirements of tech for students' equipment
  - Will need local tech support & funding for virtual & physical labs. This means management need to release funds, instructional designers/technologists etc.

- It was good to see the futurist views of the presentations. However, in contrast IT Services chooses to show pictures of lockers from which students will loan laptops or other equipment to use in the “wet labs”. I’m sure that if we think really hard there’s a better way of doing this.
- On a cautious note, there was a perfect demonstration of how things fail to live up to claims. The big touch screen was difficult to use and people still continued to claim that it was the best and easy to use and intuitive. Really? I think it better to have good deliverable service rather than disappointing futurist equipment that doesn’t quite hit the mark. There’s a real sense of being short changed by getting it wrong.
- Do: Have a solution that is easy to use and works 100%. It really needs to be reliable.
- Sounds very useful to have access to other learning materials as well as videos, pre-lab training etc whilst in lab.
- Devices must be spill-proof for all possible solvents, not just water-based materials. Many materials are vulnerable to solvents (eg: acetone, chlorinated solvents, aromatic solvents) and strong acids/bases.
- I like the idea of recording results and processing in a seamless fashion (we have tried to encourage data analysis “as you go” for years) but any e-lab book must be cheat-proof and compatible with industry needs. Physical lab books are also needed because they are used elsewhere too – both skills should be learnt.
- Virtual labs would be beneficial, when used in the way they are at Bristol (as a supplements to lecture notes). They cannot be used to replace areal practical experience. They need that far research work in their future career.
- Virtual labs can work for situations where the outcomes are already known. When a student carries out research, he/she will need the practical skills as well as knowledge and other skills such as analysis.
- Don’t think that virtualisation can replace real lab skills, particular in accredited subject. They can provide a great pre-lab preparation & help in post-lab analysis.
- Do budget appropriately to develop & support activities such as a dynamic laboratory manual – Bristol has a superb system but at a seven-figure cost. We should aspire to a similar investment.

## VI. Ref:

Virtual and Remote labs in Physics Education <http://discoverlab.com/references/harms1.pdf>

Virtual Laboratory for Distance Learning: Conceptual Design and Technology Choices <http://ceur-ws.org/Vol-716/ICTERI-2011-CEUR-WS-paper-9-p-116-125.pdf>

Definition of Remote, Online, Virtual, Simulation and Distance Labs <http://seiler.it/remote-and-virtual-labs/>

Education online: The virtual lab <http://www.nature.com/news/education-online-the-virtual-lab-1.13383>

<http://onlinelabs.in/chemistry>

[http://www.vlab.co.in/ba\\_labs\\_all.php?id=1](http://www.vlab.co.in/ba_labs_all.php?id=1)

<https://web.phys.ksu.edu/icpe/Publications/teach2/Hatherly.pdf>

<http://users.ece.cmu.edu/~stancil/virtual-lab/virtual-lab.html>

[http://www.nature.com/polopoly\\_fs/1.13383!/menu/main/topColumns/topLeftColumn/pdf/499268a.pdf](http://www.nature.com/polopoly_fs/1.13383!/menu/main/topColumns/topLeftColumn/pdf/499268a.pdf)