Practical experience of delivering practical experiences online and at scale with an Internet of Laboratory Things

Nicholas Braithwaite, Tim Drysdale, Ulrich Kolb, Mark Hirst and the OpenSTEM Labs team

STEM Faculty, The Open University, Milton Keynes, MK7 6AA, UK.

Abstract The OpenSTEM Labs comprises a wide range of instruments and equipment for teaching practical science at a distance. The concept of an Internet of Laboratory Things describes our approach to creating a network of experimental activities unconstrained by distance. 17000 student-hours of use in the last academic year provides insight into use at scale. Ultralow latency protocols have proved an important component for rapid-real-time control experiments.

The OpenSTEM Labs 'Internet of Laboratory Things (IoLT)' aims to challenge the traditional university pedagogical model for lab teaching of students and teachers being co-located, during normal working hours[1]. Students are connected to state-of-the-art instrumentation and equipment for practical enquiries over the internet, where distance is no longer a barrier and where access to equipment can be available 24 hours a day. Students and teachers access the equipment via a web browser through which they can book an online session, undertake an experiment or activity, send real-time control commands, monitor real-time performance and download data for analysis. Our new paradigm is an important component of The Open University's distance learning environment and can be applied across the STEM education sector at all levels.

Primarily our IoLT is for our own students following higher education qualifications by distance-learning. There is provision for use by other educational institutions including high schools and by industrial trainers – equipment is maintained for use in our own curriculum, but it must earn its replacement value through enterprise activity. The operating model allows higher resource utilization than is normally the case for university teaching labs.

In March 2018 the real-time interactive 'hands-on' elements connected to our IoLT comprised: 80 workstations for electronics and control, 7 programmable collaborative robots, 7 analytical chemistry instruments, 2 scanning electron microscopes, 2 optical microscopes, 2 optical telescopes (at Instituto de Astrofisica de Canarias, Tenerife) and 1 radio telescope (OU Campus), 1 enclosed 'Mars landscape' and remote controlled, multi-user Mars rover, 1 flow-chemistry reactor, 2 particle detector cameras, 1 satellite ground station and a component of payload on board cube-sat Alsat N1, 1 studio lab for livestreaming of experiments and demonstrations.

1 Core values for the OpenSTEM Labs IoLT

The OpenSTEM Labs combines educational principles with the mission of the Open University to be open to people, places, methods and ideas.

1.1 Inclusivity and pedagogy

One of the main aims of the OpenSTEM Labs IoLT is to provide 'hands on' experiences without requiring physical presence or direct tactile interaction with scientific instruments. Experiments are designed to avoid the need for real-time supervision at the instrument location; use need not be restricted by availability of technical staff. Access to apparatus and equipment is booked via a Moodle-based system accessed through one of the common web browsers. Most IoLT activities function with a wide range of operating systems, but some are not yet compatible with tablet and

mobile platforms. Compatibility issues are pre-flagged or testing is built into the connection step. The remaining challenges for accessibility are from usability constraints of the interface.

Labs and observatories are natural environments for learning in STEM. Students need to be able to make decisions of real consequence and to make mistakes along the way – these can both incorporated well designed practical tasks. We aim to provide students with sufficient agency and sociability to achieve the full benefits of active learning, which can achieve significant gains over more passive approaches [2,3]. For example, our interfaces are designed so students feel as if co-located with their instruments; activities can be student-led or tutor-led; our booking system allows reservations for access to specific experimental equipment by single and multiple-users; the protocol is defined by the educator depending on the activity and the circumstances of the learner.

1.2 Veracity and authenticity

Observations and surveys from of our own students indicate there is a significant value attached to data being captured from real equipment in real-time[3]. This is one of the main drivers for our recent expansion of remotely controlled facilities. Though virtualization of some experiments can be achieved while still holding to this principle, where more than two experimental parameters are involved remote experiments offer a more truthful experience than a programmed simulation. The OpenSTEM Labs feature bespoke teaching tools, industrial grade equipment and research grade instruments. We have devised ultralow latency network protocols for rapid-real-time experiments.

2 Operating at scale

Figure 1 shows data from 4 activities scheduled in the first two months of 2018 from different modules. These illustrate some of the types of activity and the scale of use, imprinted by the pattern of study. We are now compiling richer statistics and gathering user feedback. In the last 12 months our IoLT connected ~7000 students to 17000 student-hours of practical work.

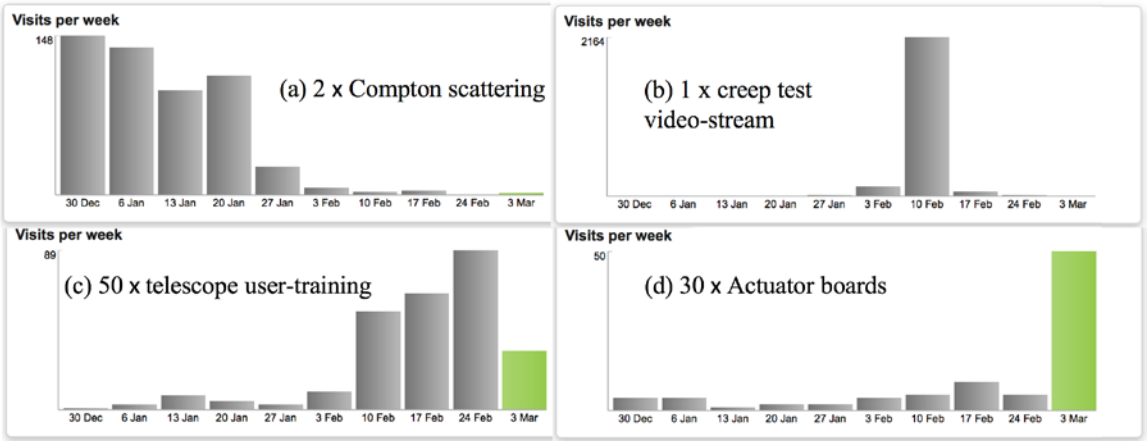

Fig. 1 Usage data: (a) Bench-top Compton Scattering experiment; (b) livestream video from a high temperature creep experiment in a research lab; (c) Virtual Training tool for students about to use the same interface for a robotic telescope; (d) Benchtop experiments on DC, stepper, brushless and servo motor configurations.

References

[1] https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=golc2
[2] R. Hake, R. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. (1998) *American Journal of Physics*, 66, 64-74.
[3] M. Brodeur, Design Priorities for Online Laboratories in Undergraduate Practical Science, (2016) PhD Thesis, The Open University.