Learning science at a distance: it can be done

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Abstract

At the UK Open University, approaches to learning science at a distance have been pioneered over the past 54 years. In 1969 when the University was founded, there was a great deal of scepticism about whether teaching science could be done at all (e.g. see the account in Pentz, 1982). However, over the period, learning experiences for students have been designed with some success. With the advent and spread of digital technologies and capabilities, more ways of supporting these learning experiences have been developed. This paper describes how the University dealt with the perceived importance of practical work, the accommodations arranged by over time, and the recent approaches to developing science capacities and capabilities for students. In the early days the approaches included home experiment kits, radio and TV programmes and laboratory classes at residential schools (see also Ross and Scanlon, 1995). In recent years the possibilities available to us as teachers have been extended by Technology Enhanced learning methods and these are described along with research projects on teaching science with learners of all ages (see also Scanlon, 2021). Several of these approaches designed to maximise inclusion of students studying science at a distance in practical work are reviewed.

Keywords: Science learning, technology enhanced learning, remote laboratories.

Introduction

One of the key issues faced by the Open University (OU) in 1969 was the unsolved problem of how to provide practical work at a distance. Since that time there have been many developments in technology which can be applied to help enhance the distance learning of science. As a result, there have been a number of experiments in establishing what works both in terms of providing appropriate learner experiences and investigating in more detail the role of practical work in science courses.

Throughout this period the University has been designing and delivering successful science courses. And in each decade since then by dint of innovations in pedagogy and technology approaches to learning science continue to be developed which allow students to develop appropriate skills and understanding.

Why is science hard to learn?

Several explanations are provided for why science is hard to learn for many students. For Open University students there were particular challenges. The OU's open entry policy allowed students with no previous qualifications to study science, so learners lacked mathematical skills, along with other prerequisites for study and with the need to build science content knowledge. Providing practical experiences is often cited as a particular problem for studying science at a distance.

Why is providing appropriate practical experiences important for science students?

A number of reasons are given for this. First, the development of appropriate skills which are said to be key in learning science. Secondly, that whether by illustration or the development of evidence, hard concepts become more understandable. Thirdly, that by engaging in experimental work learners will learn more about the nature of science.

The development of the OU's approach to practical work

From its inception in 1969, the Open University faced the problem of providing practical work for science learning. Several different approaches to providing students studying science with access to practical experiences were developed. Initially, this involved the incorporation of a variety of media in courses. For example, home experiment kits, radio or audiotapes, TV demonstrations of experiments and laboratory classes at 'in person' day schools were incorporated in the media mix of courses. This approach to teaching using a mix of different media

came from the wish to provide students with different ways of approaching the development of understanding Equally important was the intention to make learning objectives of any practical experience very clear.

Kuluska-Hulme (2023) notes the importance of media mix as

'*teacher trainers and professional learning developers have an ever-growing repertoire of available methods and technologies as well as multiple learning spaces (online and offline) that can be deployed to fulfil their aims. All this seems to represent what can be described as a trend towards "a multiplicity of technologies, methods and modalities" available for a learning experience (Kukulska, 2021) , meaning that several media and modes of communication and delivery can support teaching, learning and assessment across a range of contexts and spaces. It makes for a potentially complex teaching and learning environment where student activity needs to be 'orchestrated',[…]. It has, however, the advantage of offering more options to suit different circumstances and student needs and it can support combining formal teaching and independent or informal learning. Kukulska et al (2023), p 9.*

In the mid 1970's computers were added to the media mix, beginning with the advent of remedial tutorials provided at computer terminals available at local study centres and the use of simulations and modelling available at residential schools. Personal computing allowed multimedia experiences to be provided on CDs and DVDs and advances in communication and conferencing it became possible for students with internet access to work with others.

So at first the students were provided with home experiment kits, residential schools allowed students to work in the laboratories of conventional universities during the summer break, and broadcast TV programmes gave opportunities to observe and to some extent participate int experiments. The provision of multimedia allowed closed observation and the potential for manipulating variables and drawing conclusions.

By the mid-1990s these opportunities increased and for example one science course could offer a global warming simulation for students to interact with, virtual field trips to the Sonoma desert or the Galapagos were available and further work on virtual environments were developed (see e.g. Taylor et al. 1996, Whitelock, 2001, Whitelock and Jelfs, 2005). In 2013, the UKOU with support from the Wolfson Foundation launched the Open Science Laboratory a virtual lab which allows students to carry out experiments online and brings interactive practical science. Online experiments, remote access to scientific instruments and real physical instruments and equipment through robotically controlled experiments, were made available, and included access to tools which can be used in citizen science experiments and networks, access to interactive screen experiments; virtual instruments and labs; immersive 3D experiments and virtual field trips (Garrow et al., 2013; Hatherly et al., 2004; Villasclaras-Fernandez et al., 2013). By 2014, virtual labs were becoming more available in higher education for science and engineering (see e.g. deJong, 2014).

The use of technology tools to allow participation in practical work '*promote enthusiastic engagement with science and give opportunities for participation and learning. For example, the use of simulations allows for hands-on experimental work to take place at any time, in a playful manner and by learning through failure, exploration and experimentation. Simulations lower the barriers to participation and make it easy for people to engage with activities often viewed as determined by scientists'* (Scanlon et al., 2019, p 135).

Research into teaching and learning science online

As technology enhanced learning techniques and tools became more available, and proved appropriate to help provide practical experiences (see e.g., Scanlon, 2011 for a summary) a programme of research projects was designed to explore and evaluate these possibilities. Identifying the potential of technologies to support learning from practical work designed to be accessed by students at a distance were explored in a number of research projects investigating remote access to laboratories, remote access to instruments such as the virtual microscope, and augmented experiences.

Remote labs: the PEARL project

From 2000, with funding from the EU IST programme the Practical Experimentation for Access to Remote Learning project (PEARL) investigated the feasibility the potential of remote access to laboratory work (see Cooper and Ferriera, 2002; Scanlon, Colwell & di Paolo, 2004.). Colwell et al. (2003, p. 5) describes the approach as follows:

'The PEARL system involves a complex structure of network, server, and interface technologies, equipment control technology, video cameras, microphones and streaming media technology, and collaboration tools. These technologies work together to allow students to issue commands from their PC to the remote laboratory, which in turn will carry out the command and send feedback back to the student. The student will be able to see the laboratory equipment being controlled via a video stream, and to communicate with their peers about the experiment'.

This project investigated the potential of this, in conjunction with 4 European universities, the Universities of Porto, of Dundee, Trinity College Dublin and the Open University. The OU setting was the implementation of one of the experiments provided at an introductory residential school, a spectrometry experiment. This vignette allowed the exploration of how the introduction of technology influenced the design of the experiment to make it effective online. Of particular interest was how the provision of the experiment in this way could support students who for any reason found it difficult to access laboratory work in by conventional means whether due to disability or caring responsibilities. A key insight for us was how design for accessibility could improve the experience for all students.

Online tools: the Virtual microscope

Virtual Microscopes (VMs) that allow for viewing and manipulation of online images by multiple students were an early example of the potential of such opportunities (Whalley, Kelley & Tindle, 2010). A number of studies have examined waysof using a VM in online and distance learning including combining VM with inquiry learning (Villasclaras et al., 2013), and comparisons between the use of VM in conventional universities where the value of VM as a means to provide hands-on, interactive science experiences to students online as opposed to reading materials and lecturing were considered (Herodotou, Kelley & Scanlon, 2019). '*Teachers saw the VM as being easier to use by manipulating buttons on a website, whereas a physical microscope requires additional training about how the tool functions, for example, how to manipulate magnification and focus or change the field of view*.' p.6. Although students are found to be generally satisfied with the use of VMs, further experiments with teaching and learning approaches will establish how best to support their use and lead to enhanced learning outcomes. (Herodotou et al., 2019).

Enriched realties: Virtual Field trips and VR

Over a similar period, Universities were also exploring the pedagogical affordances of virtual worlds. One example at the Open University was the Virtual Skiddaw fieldtrip (Argeles et al., 2009; Minocha et al., 2017). Remote participation on field trips offers the possibility of exploring places that would be inaccessible to the learner. In their alternatives to field trips study Grand et al. (2021) interviews with students uncovered more about the complexity of replicating all the purposes of field trips on line.

'Fieldwork is seen as important for enabling hands-on experience, developing understanding of complexities and being able to 'think on your feet' but also for bonding students with each other and staff. The fluid, less formal ambience of fieldwork enhances relationships between students and facilitators, increasing their feelings of belonging to a group. p 17'

Informal learning: citizen science

Another development over this period there has been increasing interest in extending access to science experiences to the wider public. This coincided with the possibility of participation with such studies online. Platforms such as iSpot and nQuire (Scanlon, Woods & Clow, 2014; Herodotou, Scanlon & Sharples, 2017) were developed which have provided opportunities for involving students and members of the public in informal learning opportunities.

Conclusions

The Open University continues to develop its approach to practical work. This paper has only highlighted a few experiences in doing this, pointing both to some opportunities developed for all science students, as well as some more limited research projects exploring future possibilities.

In terms of facilities for students from the inception of the Open Science Lab in 2013, further development and investment extended to formation of the the Open STEM labs incorporating the Open Science Lab, the Open Science Observatories and the Open Engineering Lab (OEL) (see Kukulska-Hulme et al., 2020 for a summary). Access is available to remotely operated optical telescopes based in Tenerife, and a radio telescope based at the UKOU main campus in Milton Keynes. OEL provides practical lab-based teaching at a distance covering engineering, electronics, control, materials, and robotics. Contact with the on-campus labs also allows students to

acquire and practice lab-based skills. Lab and field casts provide an interactive experience by connecting students and lecturers via live web streaming (see also STEM 7th July - What practical skills you learn through the OpenSTEM Labs - YouTube.) A recent development is the funding of a new facility for the incorporation of extended reality in modules OU secures £5.8m to build extended reality studio | Faculty of Wellbeing, Education and Language Studies (open.ac.uk).

Experiments in performance augmentation (Performance Augmentation | Institute of Educational Technology, The Open University), together with research funded on exploring tools for extending design thinking (OU researchers help teachers to harness technology and co-design learning | The Open University) are among the activities being developed in the research space.

During the pandemic our description of some of these experiences have been useful to other Universities interested in development of their hybrid or blended approaches to teaching science at a distance. We know it can be done.

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