Pan-Commonwealth Forum, 9-12 September 2019, Edinburgh, Scotland.

Learning science online: inquiry learning in formal and informal settings

Eileen Scanlon

Abstract: In the past 50 years we have conducted many of projects investigating science learning in formal and informal settings at the UK Open University (UKOU). We review the teaching of science at a distance with the UKOU and the development of methods to include practical work in distance and online learning. Our recent work on the development of an inquiry learning pedagogy offers the possibility of extending opportunities for learning science in informal settings. Currently our work is extending into exploring the perspective of citizen science as a setting in which learning about science can take place. Interest in citizen science is growing, and in particular those projects supported by technology. We have developed the concept of citizen science inquiry which is a combination of mass participation citizen science and learning to be a scientist through scientific inquiry (Herodotou et al, 2017). Finally, we report on the development of software to support citizen science inquiry and we will describe the evolution of the various platforms including nQuire and nQuire-it. We have recently developed a new web platform for the conduct of citizen inquiries in conjunction with the BBC Tomorrows World. This new platform allows for scientists, and members of the public to create and run online studies. Our aim is to increase the scale of the inquiry missions we can support, and further investigate informal opportunities to learn science. This paper will describe the development of our work in over the years in online practical work in science.

Introduction: Learning science at a distance

Teaching science at a distance has always been regarded as a difficult thing to do. The first Dean of the OU Science Faculty remembers the reaction of colleagues:

In 1969 I discussed the Open University with scientific and academic friends and colleagues. With very few exceptions, they were sceptical. It was clearly a preposterous idea, to try to teach university-level science at a distance to part-time students, many of whom would have had little or no secondary school qualifications and many, if not most, of whom would not have studied science before. λ Perhaps, one might be able to teach some arts subjects this way, but science....? What about laboratory work for a start?' It can't be done!', they said'

Mike Pentz, Ritchie Calder lecture

Several approaches have been taken by distance teaching universities to this dilemma, including the UKOU provision of home kits for students who appreciate that learning science requires practical activity (see Ross and Scanlon, 1996).

Learning science online and at scale

Contemporary approaches to learning science online have increased the range of possibilities for offering students an authentic activity. Using experiment kits both physical and virtual, and online simulations and case studies is one way of doing so. Such developments as online laboratories are providing access to simulations remote experiments and a virtual reality field trips. (See reports by de Jong et al, 2013, 2014; Furtak et al.,2002; de la Torre et al. 2016; and Zacharia et al. 2015.)

Support built into OU materials, together with support from tutors and assessment, has enabled 2 million people to complete university level courses without the need to meet initial entry requirements. The courses are constructed as follows. Modules are for 6- or 9-months duration and involve wither 300 or 600 hours of study an average of between (8-16 hours per week). Students study part-time from home (or work, bus, train, prison, submarine. Increasing numbers of student are starting to choose full-time study intensity for all or part of their studies. Students are arranged in groups of around 15-20 with an assigned tutor who may conduct face to face or online tutorials. Learning activities are delivered primarily through the module website using a weekly study planner, and these are sometimes augmented with books and other learning resources. The scale of the operation of online OU study is huge. The OU Virtual Learning Environment has 180,000 active users (students and staff) every year. There are around 450 live module websites, and more than5000 historical sites. There are over 1 million transactions per day and forum views per day average 170,000. The number of unique users per day averages 35,000 and peaks at 50,000. There are 700,000 quiz attempts per year and 6 million quiz questions

answered per year. (Steve Rycroft, personal communication). This is the scale of the online activity in UKOU courses. And an indication of the scale of interactive activities which need t be supported. Practical science is one of these activities.

Practical work at the Open University

From the beginning of the University there was an understanding of importance of locating experience of practical work for students studying at a distance. There was also an appreciation of the potential role for media in developing methods for teaching science at a distance. Home experiment kits, Radio or audiotapes, TV programmes illustrating experiments and Laboratory classes at day or residential schools and computer assisted learning. In terms of computer assisted learning even in the late seventies an evaluation of early attempts at use of CAL in science faculty reviewed remedial CAL tutorials delivered on terminals available (for limited access) at study centres, and simulation programmes available at residential or day schools (see Jones et al. 1982). In terms of multimedia, through its provision students can have vicarious experience of observing experiments. In addition, there is the possibility of controlling variables and drawing inferences. An introductory science course offered at the Open University in the 1990s offered students the possibility of interacting with a global warming simulation, taking a virtual desert field trip and conducting Galapagos field trips (see e.g. Taylor et al. 1996, Whitelock, 2001) sometimes with a problem-solving pedagogy applied (see e.g. Ross and Bolton., 2002). Virtual field trips where users explore a three-dimensional environment have also been used (see e.g. Whitelock,2001, Whitelock et al. 2005).

Early experiments at the UKOU of remote laboratories (see Cooper and Ferriera, 2002) has been effectively built into the latest development in online science. 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 to students anywhere anytime the internet is available. The lab has more than 100 experiments including online experiments, remote access to scientific instruments and real physical instruments and equipment through robotically controlled experiments, or experimental set ups. It also allows access to tools which can be used in citizen science experiments and networks such as iSpot. access to; interactive screen experiments; virtual instruments and labs; immersive 3D experiments and virtual field trips. (Garrow et al., 2013; Villasclaras- Fernandez et al., 2013; Muirhead et al., 2018).

This concept was further extended to form the Open STEM labs incorporating the Open Science Lab, the Open Science Observatories and the Open Engineering Lab (OEL). Thereby there is access to two 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.

Supporting inquiry

As impressive as these developments are, there is a need to properly connect science students to authentic activity. This requires involving students in the scientific methods of data collection, interpretation and analysis. Inquiry learning approaches to teaching signs are not new there. There is a considerable literature on this topic (see for example Chin and Malhotra, de Jong and others). One of the key aspects discussed in the literature is to the benefits and challenges of involving students in this teaching method. The main disadvantage is the overhead of developing appropriate support for students in the inquiry learning process to develop learning. This is the challenge that we have accepted over a period of 10 years, working to support science learning through the inquiry processes.

Personal inquiry was the first of our funded projects. We were funded to investigate personalisation of the inquiry process supported by technology (see Sharples et al. 2015). The role of technology in our project was to combine to provide support for students in all the settings where at site science activity were taking place. This meant providing software support for the enquiry learning process both in classrooms and beyond. By beyond the classroom, we mean that students working at home, students watching television, students on field trips students on museum visits. The software that we developed was first called an activity guide however in later versions we attach we used the term nQuire. We had considerable success with this project and details of work is to be found in our edited volume called Orchestrating Inquiry learning (Littleton et al.,2012) and in journal articles such as Sharples et al. (2014). During this project we discovered that the approach we had taken would also be applicable to more informal settings such as after-school clubs. This was because in such settings

students could frame their own inquiry questions and use their software to guide them through appropriate processes to result in an answer to their posed questions. This inspired us to develop the project further and to develop the software further. The work continued to two tracks, one stream funded by the Wolfson Foundation and another the Nominet trust.

The Wolfson Foundation co-funded with the University the development of the Open Science Lab online laboratory described above. In the context of this laboratory we developed an application combining the use of our inquiry software with other tools such as the virtual microscope (see Villasclaras-Fernandez et al. 2013).

The Nominet trust funding allowed us to develop the software further using participatory design methods with a 16 to 18-year-olds to increase the functionality of our software. This new version was to include the development of the sunset at delete which allowed students access to all the sensors available on their Smartphone. (See Herodotou et al. 2017). It also allowed us to develop individual missions so that students or members of the public could construct and conduct their own inquiries. The work of a PhD student Maria Aristeidou was to investigate what was necessary to provide a community of practice round personally driven missions (see Aristeidou et al., 2017). By this point we were ready to coin the term Citizen inquiry (Herodotou et a., 2017). Citizen inquiry combines the benefits of citizen science for extending an appreciation of science to members of the public while inquiry provides a set of processes which can support their participation or contribution or initiation of a mission. Aristeidou's thesis describes how the individual progress can be supported in these missions. Sharples et al. (2017) describes the results of use of the tool.

Citizen science support of software has been further developed thanks to funding and interest from the BBC (Sharples et al.,2019). The most recent version of the nQuire platform is supporting online science investigations. These allow the public to participate in science investigations linked to TV and radio broadcasts.

Conclusion

The challenge of developing practical experiences for students of science has been met in a number of ways over the last 50 years of the Open University. With the introduction of more possibilities due to the range of different ways in which ICT has been incorporated into practical work, we can extend the participation in science both in formal and informal settings. Our approach to remote and virtual experiments has been investigated in a variety of evaluation projects. The investigation of an inquiry learning pedagogy and its development into citizen science inquiry is offering us new and effective ways to engage both students and the public.

References

Aristeidou, M., Scanlon, E. and Sharples, M. (2017). Profiles of engagement in online communities of citizen science participation. *Computers in Human Behavior*, 74 pp. 246–256

Aristeidou, M. and Herodotou, C. (2018). Tomorrow's World nQuire: young people's requirements for engaging with inquiry-led, civic engagement technologies. In: *Proceedings of 17th World Conference on Mobile and Contextual Learning (mLearn 2018)* (Parsons, D; Power, R; Palalas, A; Hambrock, H and MacCallum, K eds.), LearnTechLib, pp. 51–53

Cooper, M & Ferreira, JMM (2009). Remote laboratories extending access to science and engineering curricula. *IEEE Transactions on Learning Technologies*, 2(4), 342-353

Chin, C. and Malhotra, B. (2002) Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks Science Education Vol 103

De Jong, T., Linn, M.C., and Zacharia, Z.C. (2013).Physical and virtual laboratories in science and engineering education, *Science*, 2013

De Jong, T. (2014). Innovations in STEM education: the Go-Lab federation of online labs

https://link.springer.com/content/pdf/10.1186%2Fs40561-014-0003-6.pdf

de la Torre, L., Sánchez, J.P. and Do, S. What remote labs can do for you, Article *in Physics Today* · April 2016

Furtak, E.M. and Penuel, W.R. (2002).Coming to terms: Addressing the persistence of "hands-on" and other reform terminology in the era of science as practice, *Science Education*, 103, 1, (167-186)

Garrow, K. , Braithwaite, N. , Richardson, B. and Swithenby, S. (2013).The OpenScience Laboratory: a globally available online lab at the cutting edge of practical science teaching. In: *ED-MEDIA 2013: Conference on Educational Multimedia, Hypermedia & Telecommunications*, AACE.

Herodotou, C., Aristeidou, M., Kelley, S. and Scanlon, E. (2017). Students' engagement with practical science online: Pedagogical implications of the use of virtual microscope in distance learning. In: *EARLI 2017*, 29th August - 2nd Sept 2017

Herodotou, C., Sharples, M., Scanlon, E. (eds) (2017). *Citizen Inquiry: synthesising science and inquiry learning*, Routledge

Herodotou, C, Aristeidou, M., Sharples, M. and Scanlon, E. (2018). Designing citizen science tools for learning: lessons learnt from the iterative development of nQuire. *Research and Practice in Technology Enhanced Learning*, 13(4)

Jones, A., O'Shea, T. and Scanlon, E. (1987). Evaluation of Computer Assisted Learning at the Open University. pp263-276 In Jones, A., Scanlon, E. and O'Shea, T. (eds) *The Computer Revolution in Education.* Harvester Press, l987.

Littleton, K., Scanlon, E., Sharples, M. (eds) *Orchestrating Inquiry Learning*, Routledge, 2012

Muirhead, D., Herodotou, C., Aristeidou, M., Hole, M. J., Kelley, S., Scanlon, E. and Duffy, M. (2017). A Comparative Study of Blended and Online Learning using the Virtual Microscope for Earth Sciences. In: *Horizons in STEM Higher Education Conference: Making Connections and Sharing Pedagogy*, 39 June - 30 June 2017, Heriot-Watt University, UK.

Ross, S. and Scanlon, E. *Open Science: the distance teaching and open learning of science subjects.* Paul Chapman Publishing, 1995

Ross, S.M. and Bolton, J.P.R. (2002). Physica: a computer environment for Physics problem-solving. *Interactive Learning Environments*, 10(2) pp. 157–175.

Scanlon, E. (2011) Technology enhanced science learning at a distance, *Open Learning The Journal of Open and Distance Learning, 24 (2)*

Sharples, M., Scanlon, E., Ainsworth, S., Anastopoulou, S., Collins, T., Crook, C., Jones, A., Kerawalla, L., Littleton, K., Mulholland, P., & O'Malley, C. (2014). Personal inquiry: Orchestrating science investigations within and beyond the classroom. *Journal of the Learning Sciences*, *24*(2), 308–341

Sharples, M., Aristeidou, M., Villasclaras-Fernández, E., Herodotou, C. and Scanlon, E. (2017). The Sense-it App: A Smartphone Toolkit for Citizen Inquiry Learning. *International Journal of Mobile and Blended Learning*, 9(2) pp. 16–38.

Sharples, M., Aristeidou, M., Herodotou, C., McLeod, K. and Scanlon, E. (2019). Inquiry learning at scale: pedagogy-informed design of a platform for citizen inquiry, *Proceedings of the Learning@Scale conference*, Chicago, June

Taylor, J., Scanlon, E. and Hodgson, B. (1996). Multimedia and Science Education, *Education Research and Perspectives* , 23 (2), 48-58

Villasclaras-Fernandez, E.; Sharples, M.; Kelley, S. and Scanlon, E. (2013). nQuire for the Open Science Lab: supporting communities of inquiry learning. In: *Scaling up Learning for Sustained Impact*, Lecture Notes in Computer Science, Springer, pp. 585–588

Whitelock, D. (2001). *Going Live to the Galapagos Islands and an Oak Wood: S103 Student Responses to some Biological Multimedia*, Programs IET internal report Program on Learner Use of Media report No 138

Whitelock, D. and Jelfs, A. (2005). 'Would you rather collect data in the rain or attend a virtual field trip?': Findings from a series of virtual science field studies. *International Journal of Continuing Engineering Education and Life-Long Learning*, 15(1-2), pp. 121–131

Zacharia, ZC, Manolis, C, Xenofontos, N, de Jong, Ton, Pedaste, M., van Reiser, S., Kamp, E., Maeots, M, Siiman, L, Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Education Technology Research and Development*, 63, 257-302

.